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DETERMINATION OF THE ECONOMIC OPTIMAL CYCLE LENGTH FOR MAJOR SUGARCANE (*SACCHARUM* SPP.) VARIETIES IN LOUISIANA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
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in

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By

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ABSTRACT

The general objective of the study was to determine the economically optimal crop cycle length for major sugarcane varieties currently being produced in Louisiana. The specific objectives of the project included the specification of the mathematical acreage relationships which directly impact the production of a vegetatively propagated perennial crop in a whole farm context; the development of producer decision rules to be used to determine breakeven sugar levels on third stubble sugarcane crops for major varieties in the state; the evaluation of the impact of changes in production factors on developed crop replacement rules; and the optimal cycle length for current variety combinations in a whole farm context. Third stubble breakeven yield results indicate that on average, third stubble should be kept in production if its production exceeds 5,063 pounds of sugar per acre. If sugar per acre yields of plantcane, first stubble and second stubble were averaged, third stubble should be kept only if its production exceeds 74.3% of that average. Results of changes in production factors such as raw sugar price, diesel price, planting ratio and harvest costs indicated that this 74.3% was not significantly affected when the changes were analyzed in a whole farm context.

A maximum net return goal of $147,198 was achieved using variety HoCP 00-950 as the only variety planted in the whole operation, when there were no acre limitations on individual variety. Another scenario where no single variety should exceed 50% of the total planted area of the farm was developed and results showed that a maximum net returns goal of $145,154 was achieved by planting 500 acres of variety L 99-266 and 500 acres of variety HoCP 00-950. Finally, a third scenario where no single variety should exceed 30% of the total planted area was developed and results showed that a maximum net returns goal of $129,104 was achieved by planting 100, 300, 300 and 300 acres of varieties HoCP 96-541, L 99-226, L 99-233 and HoCP

00-950, respectively. For all scenarios, results showed that production should be kept until third stubble; therefore, the crop cycle length should be five years.

CHAPTER 1

INTRODUCTION

Sugarcane, a member of the grass family, is a perennial agricultural crop grown primarily for the juices expressed from its stalks that are later processed into raw sugar and finally refined into white sugar. As a perennial crop, one planting of sugarcane will allow from three to six or more annual harvests before replanting is necessary. Sugarcane in Louisiana is planted in the late summer to early fall, primarily in August and September, with the initial harvest of the crop coming in December of the following year. Sugarcane crops are generally classified based on its current year or stage of the crop cycle. The first crop harvested is generally referred to as the plant cane crop, with succeeding annual harvests referred to as ratoon or stubble crops (Salassi et al., 2002). In Louisiana, sugarcane is most commonly harvested through a second or third stubble crop, depending upon yield projections for older stubble.

The production of sugarcane in Louisiana is a major contributor to the agricultural economy of the state. In terms of market value of final product, sugarcane is the leading agricultural row crop commodity produced in Louisiana. The 2009 market value of raw sugar and molasses produced in Louisiana was $752.1 million. Of this amount, the gross farm value of sugarcane harvested was $447.0 million, with an additional $305.1 million value added from first stage processing (LSU Agricultural Center, 2009). In 2009, sugarcane was grown on 417,869 acres by 495 producers in 22 Louisiana parishes. An estimated 390,708 acres were available for harvest for sugar, assuming 6.5 percent of the total acres were used for seed cane purposes. The 11 operating factories in the state processed nearly 14 million tons of cane, producing 1.48 million short tons of raw sugar and 88.7 million gallons of feed-grade molasses. The total economic impact on the state’s economy attributable to sugarcane production, processing, and raw sugar refining is estimated to exceed $3.0 billion per year.

The Louisiana sugar industry is currently facing critical economic challenges from several sources, all of which will have a significant impact on what this industry will look like over the next decade (Salassi, 2008). Sugarcane production costs per acre have risen dramatically over the past several years, while raw sugar market prices, with the exception of the past two years, have historically varied within a rather narrow range and have actually trended downward slightly since 1990. Although increases in average sugarcane yield have generally kept pace with rising production costs over the years, the substantial rise in diesel fuel and nitrogen fertilizer costs since 2005 have squeezed much of profits out of sugarcane production. Total estimated sugarcane production costs for Louisiana have risen from $447 per acre in 2005 to a projected $605 per acre in 2010 (Salassi and Deliberto, 2010). Increased energy prices, as well as demand and supply conditions for nitrogen fertilizer, have caused fuel and fertilizer costs to rise substantially over the past several years, pushing sugarcane variable production costs to more than $400 per total farm acre. Projected total sugarcane production costs for the 2010 crop year in Louisiana range from 18 to 22 cents per pound of raw sugar produced, depending upon harvest yield and rental arrangement (Salassi and Deliberto, 2010).

In spite of the increase in per acre production costs, the Louisiana sugarcane industry has survived primarily due to the sugarcane variety development program which has the goal of releasing to the industry higher yielding sugarcane varieties developed for production in Louisiana. Although producing higher yielding sugarcane varieties does have a major impact on farm economic viability, the perennial crop nature of sugarcane production also requires acute attention to farm management production decisions in optimizing whole farm net returns. One of the most critical production decisions on sugarcane farms is determining the optimal crop cycle length, which involves the determination of the optimal number of stubble crops to keep in production, prior to plowing out the existing crop and replanting, with the goal of maximizing producers' net returns (Breaux and Salassi, 2001).

The long term variability of the sugar industry depends upon finding ways to produce sugar more economically through production management decisions which can increase returns. With a portion of farm acreage devoted to fallow each year for replanting purposes, maximizing net returns for a whole farm, rather than trying to produce the maximum amount of sugar per field, should be the primary goal of sugarcane producers (Salassi et al., 2002). Due to the fact that sugarcane is not an annual crop, it is important to determine when to plow out the existing stubble and replant to start a new crop cycle. At this point of the production cycle, the sugarcane grower is faced with a tradeoff between declining sugar yield and the cost of replacement of aging stubble (Crane and Spreen, 1980). With profit maximization as a primary goal of a farming operation, economic information relative to the expected net returns from sugarcane production over entire crop cycles is needed in making ratoon crop plow out decisions (Milligan and Salassi, 1997). An accurate analysis of the economics associated with keeping older sugarcane stubble crops in production will help producers make optimal crop cycle decision choices and maximize their net returns.

1.1 PROBLEM STATEMENT

Historically, sugarcane production in Louisiana has included a typical crop cycle length of harvest through a second stubble crop (three total crop harvests per planting). As yields decline with crop age, harvest of third stubble and older crops have generally not been economically viable decisions. In the 1990's, the release of the sugarcane variety LCP 85-384, with its higher yield potential, made the harvest of a third stubble crop prior to plowing out the field for replanting more economically profitable on much of the sugarcane acreage in the state. As acreage of this variety expanded, up to 91% of total state sugarcane acreage in 2004 (Table 1.1), the standard sugarcane crop cycle in Louisiana expanded out to harvest of a third stubble crop on a routine basis for most farms in the state.

Over the past five to six years, as the yields of LCP 85-384 started to decline, sugarcane growers began to transition farm acreage out of that variety and into newer released varieties of sugarcane. Recent data indicates that more and more sugarcane acreage in the state is being plowed out after harvest of the second stubble crop (Table 1.2). This plow out could be due to variety transition, but could also be a result of uncertainty of the optimal crop cycle length for these new varieties. Today, as production costs have increased and newly released sugarcane varieties are available, uncertainty exists as to the optimum level of sugar yields necessary to keep older stubble in production, the specification of decision rules for determining optimal cycle lengths for current varieties, and the impact of changes in factors such as raw sugar price, production and harvest costs, planting ratios and other factors on economically optimal sugarcane crop cycle length. In addition, given the three-year seed cane expansion process required to provide sufficient seed cane for planting on farms from original tissue-cultured seed cane, the impact of seed cane expansion on whole farm net returns must be included in the evaluation of optimal sugarcane crop cycle lengths.

1.2 OBJECTIVES

The general objective of this research project is to determine the economically optimal crop cycle length for major sugarcane varieties currently being produced in Louisiana. The specific objectives include:

Table 1.1 Sugarcane acreage distributions by variety, 2004-2009.

	Acreage planted to sugarcane by variety (% of total acreage)					
Variety	2004	2005	2006	2007	2008	2009
LCP 85-384	91	89	73	46	22	6
HoCP 85-845	3	2	1	2	1	<1
HoCP 91-555	3	4	5	3	2	<1
Ho 95-988	<1	<1	2	4	5	5
HoCp 96-540	1	3	14	31	44	50
L 97-128	<1	1	4	12	17	17
L 99-226	0	0	0	1	5	11
L 99-233	0	0	0	<1	2	6
HoCP 00-950	0	0	0	0	1	2
L 01-283	0	0	0	0	<1	<1

(Louisiana Sugarcane Variety Summary, LSU AgCenter.)

Table 1.2 Louisiana sugarcane acreage distributions by crop age, 2000-2009.

	Sugarcane crop age (% of total acreage)			
Crop Year	Plant Cane	First Stubble	Second Stubble	Third Stubble
2000	27.8	29.5	25.2	17.5
2001	23.6	28.8	28.5	19.1
2002	25.7	25.7	26.6	22.0
2003	23.7	24.6	24.8	26.9
2004	27.3	25.7	24.3	22.7
2005	29.6	27.5	22.9	20.0
2006	29.8	28.4	25.1	16.7
2007	31.3	30.3	27.3	11.1
2008	31.2	31.9	26.9	10.0
2009	27.8	31.9	29.5	10.8

(Louisiana Sugarcane Variety Summary, LSU AgCenter)

1. Specify the mathematical acreage relationships, which directly impact farm returns and costs, associated with producing a vegetatively propagated perennial crop such as sugarcane in a whole-farm context.
2. Develop producer decision rules which could be used to determine breakeven sugar levels on third stubble sugarcane crops for major varieties produced in the state.
3. Evaluate the impact of changes in factors such as raw sugar price, production and harvest costs, planting ratios and other factors on developed crop replacement decision rules.

4. Determine the optimal crop cycle length for current varieties combinations in a whole farm context.

1.3 GENERAL PROCEDURES

Economic evaluation of sugarcane crop cycle length is generally concerned with determining the optimal length of a crop cycle that would maximize economic returns. More specifically, it involves the determination of when to plow out the existing stubble crop and replant the field to start a new crop cycle. The objective is to determine the optimal number of sugarcane stubble crops to harvest that would maximize average net returns to the producer over the entire crop cycle. Therefore, planting costs, cultivation and harvest costs, as well as yields and raw sugar prices, must be considered over the entire crop cycle. To evaluate stubble decisions correctly, producers must consider the total cash flow from a sugarcane crop cycle, along with the appropriate adjustments for the time value of money.

The cash flow stream from a sugarcane crop cycle would include initial planting costs, representing the initial investment costs in the crop, as well as net returns from the harvest of the plant cane and stubble crops in future years. The net present value of the cash flow from one sugarcane crop cycle, at time $t=0$, with harvest through n-1 stubble crops can be stated as:

$$\mathrm{NPV_0} = -\mathrm{TPC_0} + \frac{\mathrm{R_1}}{(1+\mathrm{r})^1} + \frac{\mathrm{R_2}}{(1+\mathrm{r})^2} + \ldots + \frac{\mathrm{R_n}}{(1+\mathrm{r})^\mathrm{n}} \qquad \text{[Eq. 1]}$$

or

$$\mathrm{NPV_0} = \sum_{\mathrm{t=1}}^{\mathrm{n}} (1+\mathrm{r})^{-\mathrm{t}}\ \mathrm{R_t} - \mathrm{TPC_0} \qquad \text{[Eq. 2]}$$

where NPV_0 is the net present value of net returns over an entire crop cycle of n harvests, TPC_0 is the initial variable planting cost at time $t=0$ in dollars per acre, R_1 is the net return from production and harvest of the plant cane crop, R_2 is the net return from production and harvest of the first stubble crop, and R_n is the net return form production and harvest of the n-1 stubble crop.

To evaluate the impact of yield on optimal sugarcane crop cycle length on a year-in-year-out basis, the concept of a whole farm rotational acre will be utilized. Using this methodology, the analytical unit will be total farm acreage, with farm acreage allocated to planting and harvest operations based upon stated crop cycle length. The reasoning behind the use of this analytical tool is that producers generally have the goal of maintaining the acreage of the various phases of sugarcane production in relatively constant proportions from year to year. Being in a fixed acreage rotation allows the grower to plant and harvest the same amount of acreage each year, thereby facilitating farm planning decisions. Given the three-year seed cane expansion process, significant changes in required planted acreage from one year to the next causes major difficulties for the farm operation related to adequate seed cane availability and timeliness of planting operations. Advantages of this methodology include the incorporation of the impacts of changes in seed cane, planted and harvested farm acreage due to crop cycle length on whole farm net returns, the ability to evaluate alternative crop cycles in current dollars, as well as the ability to easily evaluate the impact of factors such as raw sugar price, production and harvest costs, planting ratios and other factors on optimal crop cycle length.

Historical sugarcane variety production data from the outfield variety trials conducted by the Sugar Research Station of the LSU Agricultural Center will be used as the basic secondary data for this research project. Sugar yield data for plant cane and stubble crops for currently produced sugarcane varieties in Louisiana will be evaluated to determine economically optimal crop cycle lengths by variety. Producer net returns above whole farm variable production costs will be estimated for comparable sugarcane crop cycle lengths. Using current production cost estimates and raw sugar market prices, breakeven levels of third stubble yield will be estimated for each major sugarcane variety. These breakeven yield estimates will be developed into producer level decision rules which can be used to make farm acreage planning decisions.

The third objective of this study is to evaluate the impact of changes in factors such as raw sugar price, production and harvest costs, planting ratios and other factors on the crop replacement decision rules developed in objective 2. This objective will be accomplished through the use of mathematical programming and budgeting procedures to evaluate the sensitivity of optimal crop replacement decision rules to changes in a variety of factors which impact net farm returns above variable production costs. The goal of this objective is to identify which factors have a greater impact on crop replacement decisions and to estimate the magnitude of those impacts.

The fourth and last objective of this study is to determine the optimal crop cycle length for current variety combinations in a whole farm context. Assuming that a farmer could have more than just one variety planted at his farm, the goal of this objective is to determine the economically optimal cycle length in a whole farm context by finding the best combinations of the currently most used varieties of sugarcane in Louisiana that would maximize the farm net returns.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKROUND INFORMATION

Perennial crop production has been studied across a wide variety of crops, with a broad array of optimization methodologies employed. In a study related to optimal replacement time of perennial crops, the authors argued that maximum sustainable yields (MSY), rather than more commonly utilized net present values, often need to be considered for policy (Tisdell and De Silva, 2008). While the NPV approach is valuable, it requires a considerable amount of information about prices and interest rates and more calculation than MSY. Despite these affirmations, economists have been critical of the MSY approach proposed by many foresters arguing that the optimal length of replacement cycle based upon the MSY usually will differ from that indicated by the NPV approach (Tisdell and De Silva, 2008).

According to Knapp (1987) perennial crop planting decisions must weight costs and returns over time spans from three to five years for alfalfa to more than forty years for some tree crops. In addition, annual yields and input requirements typically vary over the life of the crop. This implies that the optimal rotation (length of time the crop is left in the ground) and hence the age composition of the crop will vary over time depending on the price of output and prices of inputs including land and other factors (Knapp, 1987).

Knapp proposed an alternative approach to economic analysis of perennial crops, which utilized dynamic equilibrium conditions for a series of markets in future years. An equilibrium time path of prices, consumption, new plantings, and removals was computed given an initial stock and age consumption of the crop. The approach implicitly assumed that price expectations were formed according to the rational expectations hypothesis and allowed the optimal rotation to be determined endogenously in the model. Disadvantages of this model included the inability to incorporate all relevant decisions and constraints in the model and, depending on the problem, the assumption of rational expectations.

According to French and Matthews (1971), perennial crop production is distinguished from the production of annual crops by (1) the long gestation period between initial input and first output, (2) extended period of output flowing from the initial production or investment decision, and (3) eventually a gradual deterioration of the productive capacity of the plants. Thus, a perennial crop model must explain not only the planting process but the removal and replacement of plants and must explicitly consider the lags between input and output and the effects of populations of bearing plants on production.

French and Matthews introduced a model for asparagus supply response where two separate relationships were used to describe the total planting and removal. These relationships were subsequently combined to depict changes in bearing acreage. A third relationship was employed to explain variations in yields. Changes in yields and acreage were then combined to explain variations in output. Estimation of the structural system was not possible because of data limitations. Instead, a single-equation reduced from model which resulted from solving the structural system was estimated. However, structural parameters were under identified and could not be recovered from the estimated coefficients (Kalaitzandonakes and Shonkwiler, 1992).

According to Rae (1970) perhaps the simplest approach to capital budgeting problems is to determine the present value of future cash flows, the internal rate of return or the payback period for each of the alternative investment projects. However, such approaches are not applicable if (1) the investment projects are interdependent, complementary or competitive, (2) projects complement each other with respect to cash supplies or (3) projects have multiple uses.

In order to handle such problems, programming techniques have been employed by some authors. Loftsguard and Heady illustrated an objective of maximizing the present value of future income over some panning period, while Candler suggested that it would be equivalent but simpler to design a model which maximized income at the end of the planning period.

Arguing a lack of realism in optimal replacement analyses that assume constant prices and yield patterns over time, Etherington presented a stochastic model to determine the optimal replacement time of rubber trees in commercial plantations. This model dealt with the problem of replacing an asset which continues to produce by a new asset whose future income stream is uncertain. Etherington discussed key elements of the deterministic model and then proceeded to modify the basic model by the inclusion of stochastic elements appropriated to rubber production.

An early sugarcane study which determined a model of the stubble replacement decision for Florida sugarcane growers stated that the replacement decision depends on expected future values; therefore it is necessary to predict, in some manner, future yields for the current stubble crops as well as for the potential replacements (Crane and Spreen, 1980). A replacement analysis consists of two separate operations. The first is the selection of the “challenger”, that is to say, the best unit available for the replacement of the “defender”; the second is the determination whether the challenge is valid, in other words, whether the defender is presently replaceable (Crane and Spreen, 1980). The decision rule stated by this study is analogous of the replacement principle for the continuous case first proposed by Faris and later discussed by Perrin; the rule is to replace if the average net revenue from the “challenger” exceeds the net revenue realized if the “defender” is kept another year.

Another study determined the optimal number of sugarcane stubble crops to harvest which would maximize net returns for major sugarcane varieties in Louisiana. It was reported that for the three most cultivated sugarcane varieties in Louisiana in 2001, CP70-321, LCP 85-384 and HoCP 85-845, the net returns would be maximized for all three varieties by extending the crop cycle length through harvest of at least third stubble (Breaux and Salassi, 2001). It was stated that the economically optimal sugarcane crop cycle length is one which maximizes average net returns per acre over entire crop cycle. A decision rule which can be used to evaluate older stubble would state that a stubble crop should be kept for harvest only in the net returns for that crop would increase the average net returns over the crop cycle. The decision whether to keep current fields of older stubble in production include the impact of varying sugar prices, costs of production and sugarcane yields (Breaux and Salassi, 2001). This study, however, only evaluated optimization of net returns on a single tract of land, and did not evaluate the whole-farm implications of seed cane expansion requirements for crop cycles of different lengths.

CHAPTER 3

STUDY PROCEDURES

3.1 INTRODUCTION

Economic evaluation of sugarcane crop cycle length refers to the determination of when to plow out the existing stubble crop and replant the field to start a new crop cycle. In order to address this problem, many factors such as planting costs, cultivation and harvest costs, as well as yields and raw sugar prices, must be considered over the entire crop cycle. Given that development and release of new sugarcane varieties is a dynamic process in the Louisiana sugarcane industry, this study referred specifically to the economic evaluation of the five most planted varieties in the state of Louisiana in 2010. A whole farm rotational acre context was used in order to better understand the differences in land distribution in a single farm related to the numbers of stubbles kept in production. A mathematical programming was employed to address the problem of finding the economically optimal crop cycle length for each variety and the best variety combinations in a single farm context.

3.2 MATERIALS AND METHODS

3.2.1 Major Sugarcane Varieties in Louisiana

The constant release of new sugarcane varieties is a dynamic process and the main goal of sugarcane variety development programs in Louisiana. As a starting point, it was necessary to determine the currently most used varieties in Louisiana and its historical production yields for different stubbles. The top five most used sugarcane varieties in Louisiana where established and used in this study in order to develop an answer to the economical cycle length problem earlier cited. Sugar per acre yield data of five years of production for different crop stages was collected from sugarcane research annual reports from 2005 to 2009.

The five currently most used sugarcane varieties in Louisiana are listed in Table 3.1. The varieties are listed in order of importance in terms of percentage of total planted area in the state. In 2009, the variety HoCP 96-540 represented 50% of the total sugarcane planted in Louisiana, being the most important variety in terms of cultivated area. Varieties L 97-128, L 99-226, L 99-233 and HoCP 00-950 represented 17%, 11%, 6% and 2% of the total planted sugarcane area of the state, respectively. Sugar per acre yield data from 2005 to 2009 clearly shows the decreasing rate of production that every variety exhibits as the crop turns older. The average yield of sugar per acre drops after each year of production. First stubble sugar per acre yield represents on average 88.9% of the plant cane sugar per acre yield. Second and third stubble sugar per acre yields represent 80.7% and 80.9% of the plant cane sugar per acre yield, respectively.

Table 3.1 Sugar per acre yields from outfield trials.

	Sugarcane Crop Age			
Variety	Plant cane 2005 - 2009	First stubble 2005 - 2009	Second stubble 2005 - 2009	Third stubble 2005 - 2009
HoCP 96-540	9,784	8,671	7,365	7,045
L 97-128	9,043	8,197	7,611	7,687
L 99-226	10,235	9,438	8,095	8,124
L 99-233	9,862	8,511	8,018	8,392
HoCP 00-950	10,093	8,807	8,498	8,410
Average	9,803	8,724 (88.9%)	7,917 (80.7%)	7,931 (80.9%)

(Source: Sugarcane research annual progress report, 2010, LSU AgCenter.)

3.2.2 Single Land Tract Net Present Value Approach

Since sugarcane is a vegetatively propagated crop, with seed cane expanded over a three-year period, total variable planting cost (TPC_0) was stated as the future value of costs incurred in the current period as well as the previous two periods. In the first year of a sugarcane seed cane expansion period, an initial quantity of tissue-cultured seed cane is purchased to plant an initial acreage level. The following year, that initial cultured seed cane planting is harvested and immediately replanted into other tracts of land as propagated seed cane. Each harvested acre of cultured seed cane will plant 5-7 acres of propagated seed cane, depending upon replanting method (hand or mechanical). This ratio of propagated seed cane planted per harvested acre of cultured seed cane was referred to as the first seed cane planting ratio, $PR1$, in this first seed cane expansion.

The following year, each acre of propagated seed cane planted in this first seed cane expansion is harvested and immediately replanted into other tracts of land which will be harvested the following year as plant cane sugarcane sent to the mill for processing into raw sugar. Similar to the first seed cane expansion, each harvested acre of propagated seed cane will plant 5-7 acres of production sugarcane (plant cane) depending upon planting methods (hand or mechanical). The ratio of production sugarcane planted per harvested acre of propagated seed cane was referred to as the second seed cane planting ratio, $PR2$, in this second seed cane expansion. The total variable planting cost of sugarcane in year $t=0$ was stated as the future value of all seed cane purchased, fallow and seedbed preparation, field operation, and harvest expenses associated with the two-stage seed cane expansion process as:

$$\mathrm{TPC_0} = \mathrm{PC_{t-2}}(1+\mathrm{r})^2 + \mathrm{PC_{t-1}}(1+\mathrm{r})^1 + \mathrm{PC_t} \qquad [\mathrm{Eq.\,3}]$$

Due to the expansion of seed cane planted versus the quantity of seed cane harvested, only a portion of the planting costs in the first two years of the seed cane expansion period, PC_{t-2} and PC_{t-1}, were applicable to the final acre of production seed cane planted. As a result, these three planting cost variables in the above equation were replaced by the following values:

$$\mathrm{PC_{t-2}} = \frac{(\mathrm{FSP_{csc}} + \mathrm{CSCP_{csc}} + \mathrm{HP_{csc}})}{\mathrm{PR1} * \mathrm{PR2}} \qquad [\mathrm{Eq.\,4}]$$

$$\mathrm{PC_{t-1}} = \left(\left(\frac{\mathrm{SCFO_{csc}} + \mathrm{SCHV_{csc}}}{\mathrm{PR1} * \mathrm{PR2}}\right) + \left(\frac{\mathrm{FSP_{psc}} + \mathrm{HP_{psc}}}{\mathrm{PR2}}\right)\right) \qquad [\mathrm{Eq.}\,5]$$

$$\mathrm{PC_t} = \left(\left(\frac{\mathrm{SCFO_{psc}} + \mathrm{SCHV_{psc}}}{\mathrm{PR2}}\right) + \left(\mathrm{FSP_{pc}} + \mathrm{MP_{pc}}\right)\right) \qquad [\mathrm{Eq.}\,6]$$

where FSP_{csc}, $CSCP_{csc}$, HP_{csc}, $SCFO_{csc}$ and $SCHV_{csc}$ represent fallow/seedbed preparation costs, cultured seed cane purchase costs, hand planting costs, seed cane field operations costs and seed cane harvest costs for cultured seed cane, respectively; FSP_{psc}, HP_{psc}, $SCFO_{psc}$ and $SCHV_{psc}$ represents fallow/seedbed preparation costs, hand planting costs, seed cane field operations costs and seed cane harvest costs for propagated seed cane, respectively; and FSP_{pc} and MP_{pc} represents fallow/seedbed preparation costs and mechanical planting costs for production seed cane planted.

To compare the relative profitability of sugarcane crop cycles of different lengths, the net present value of the income stream (Equation 2) were annualized or converted to an annuity equivalent value. The present value of an annuity was stated as:

$$\mathrm{PVA} = \mathrm{PMT}\left(\frac{1-(1+\mathrm{r})^{-\mathrm{n}}}{\mathrm{r}}\right) \qquad [\mathrm{Eq.}\,7]$$

where *PVA* is the presented value of the annuity, *PMT* is the annual annuity payment, *r* is the discount rate and *n* is the number of periods over which the annuity is received. Substituting the net present value of net returns from a sugarcane crop cycle (NPV_0) for *PVA* and solving for *PMT*, which represented the annuity equivalent or the annualized value of NPV_0 for the particular crop cycle, *ANPV* yielded the following relationship:

$$ANPV = NPV_0\left(\frac{r}{1-(1+r)^{-n}}\right) \qquad [Eq.\,8]$$

As a result, the annualized value of net returns from a sugarcane crop cycle of a specific length was obtained by multiplying the net present value estimate by a capital recovery factor.

This annualized net present value (*ANPV*) of a sugarcane crop cycle income stream was interpreted as the average net return per year over a particular crop cycle adjusted for the time value of money and can be used to compare returns from sugarcane crop cycles of varying lengths.

One of the implicit assumptions in utilizing the net present value or equivalent annuity value method discussed above to compare crop cycles of different lengths and estimated breakeven yield values for keeping older stubble in production was that the total initial planting cost, TPC_0, was assumed to be the same for each alternative crop cycle length evaluated. Although this assumption would be true for evaluation of a single tract of land in production, this assumption would not hold true over the whole farming operation or a subset of total farm acres in production on a year-in-year-out basis. A sugarcane farming operation with crop cycles ending after harvest of a third stubble crop would have a different percentage of total farm acreage devoted to planting and harvest operations than would a similar farming operation with equal total farm acres but with crop cycles ending after harvest of the second stubble crop.

3.2.3 Whole Farm Rotational Acre Context

For a crop cycle length through harvest of a second stubble crop (total of three harvests before replanting) on a farm with a specified total farm acreage (*TFA* = x), total farm acres devoted to fallow and planting operations each year was determined as follows:

$$\mathrm{FLW} = \mathrm{TFA} * 0.25 \qquad [\mathrm{Eq.}\,9]$$

$$\mathrm{CSCPLT} = \mathrm{FLW}/(1 + (2 * \mathrm{PR1}) + (2 * \mathrm{PR1} * \mathrm{PR2})) \qquad [\mathrm{Eq.}\,10]$$

$$\mathrm{TAHPLT} = \mathrm{CSCPL}\ (1 + 2 * \mathrm{PR1}) \qquad [\mathrm{Eq.}\,11]$$

$$\mathrm{TAMPLT} = 2 * \mathrm{CSCPL} * \mathrm{PR1} * \mathrm{PR2} \qquad [\mathrm{Eq.}\,12]$$

$$\mathrm{TAPLT} = \mathrm{TAHP} + \mathrm{TAMP} \qquad [\mathrm{Eq.}\,13]$$

where *FLW* is total farm acres in fallow, *TFA* is total farm acres, *CSCPLT* is total acres of cultured seed cane planted, *PR1* is the planting ratio for the first seed cane expansion, *PR2* is the planting ratio for the second seed cane expansion, *TAHPLT* is the total acres hand planted, *TAMPLT* is the total acres machine planted, and *TAPLT* is total acres planted. Farm acres harvested under this crop cycle was defined as follows:

$$\mathrm{PCHVSD} = \ \mathrm{CSCPLT}\,(1 + 2 * \mathrm{PR1}) \qquad [\mathrm{Eq.\,14}]$$

$$\mathrm{PCHVSG} = 2 * \mathrm{CSCPLT} * \mathrm{PR1} * \mathrm{PR2} \qquad [\mathrm{Eq.\,15}]$$

$$\mathrm{PCHV} = \mathrm{PCHVSD} + \mathrm{PCHVSG} \qquad [\mathrm{Eq.\,16}]$$

$$\mathrm{ST1HVSD} = \mathrm{CSCPLT} \qquad [\mathrm{Eq.\,17}]$$

$$\mathrm{ST1HVSG} = 2\big((\mathrm{CSCPLT} * \mathrm{PR1}) + \ (\mathrm{CSCPLT} * \mathrm{PR1} * \mathrm{PR2})\big) \qquad [\mathrm{Eq.\,18}]$$

$$\mathrm{ST1HV} = \mathrm{ST1HVSD} + \mathrm{ST1HVSG} \qquad [\mathrm{Eq.\,19}]$$

$$\mathrm{ST2HVSG} = \mathrm{ST1HVSD} + \mathrm{ST1HVSG} \qquad [\mathrm{Eq.\,20}]$$

$$\mathrm{ST3HVSG} = 0 \qquad [\mathrm{Eq.\,21}]$$

$$\mathrm{TFA} = \mathrm{TAPLT} + \mathrm{PCHV} + \mathrm{ST1HV} + \mathrm{ST2HVSG} \qquad [\mathrm{Eq.\,22}]$$

where *PCHVSD* is the plant cane acres harvested for seed cane, *PSCHVSG* is the plant cane acres harvested for sugar, *PCHV* is total plant cane acres harvested, *ST1HVSD* is the first stubble acres harvested for seed cane, *ST1HVSG* is the first stubble acres harvested for sugar, *ST1HV* is total first stubble acres harvested, *ST2HVSG* is the second stubble acres harvested for sugar and *ST3HVSG* is the third stubble acres harvested for sugar.

With a change in crop cycle length to harvest through a third stubble crop (four harvests prior to replanting), equations in the above total farm acreage model changed to:

$$\mathrm{FLW} = \mathrm{TFA} * 0.20 \qquad [\mathrm{Eq.\,9a}]$$

$$\mathrm{ST3HVSG} = \mathrm{ST2HVSG} \qquad [\mathrm{Eq.\,21a}]$$

$$\mathrm{TFA} = \mathrm{TAPLT} + \mathrm{PCHV} + \mathrm{ST1HV} + \mathrm{ST2HVSG} + \mathrm{ST3HVSG} \qquad [\mathrm{Eq.\,22a}]$$

The farm acreage model outlined above adjusted the required acreages devoted to seed cane expansion to the revised value, in this case 20% of total farm acreage. Using the above model, economically optimal crop cycles through harvest of second and third stubble crops was evaluated by determining breakeven third stubble yields to keep acreage in production while incorporating the impacts of changes in whole farm planted and harvested acreage on net returns.

Table 3.2 shows two possible land acreage distributions of a 1000- acre sugarcane farm operation harvesting through second stubble and through third stubble. As was previously mentioned, total farm acres in fallow represents 25% of the total farm acreage for a crop cycle length through harvest of a second stubble crop; however it represents 20% of the total farm acreage for a crop cycle length through harvest of third stubble. In general, land distribution among different crop stages in a whole farm depend on how many stubble crops are kept in production.

Table 3.2 Total farm acreage distribution for harvest through 2nd and 3rd stubble.

	Farm Acreage Distribution	
Farm acreage	Harvest through 2nd stubble crop	Harvest through 3rd stubble crop
Cultured seed cane	0.41%	0.33%
1st seed cane expansion planted	4.10%	3.28%
2nd seed cane expansion planted	20.50%	16.40%
Plant cane harvested for seed	4.50%	3.61%
Plant cane harvested for sugar	20.50%	16.4%
1st stubble harvested for seed	0.41%	0.33%
1st stubble harvested for sugar	24.59%	19.67%
2nd stubble harvested for sugar	25.00%	20.00%
3rd stubble harvested for sugar	-	20.00%
Fallow/plant	25.00%	20.00%
Harvest for seed	4.91%	3.94%
Harvest for sugar	70.09%	76.07%
Total farm acres	100.00%	100.00%

(Source: LSU AgCenter, 2010)

3.2.4 Third Stubble Breakeven Yield

To determine the breakeven third stubble sugar yield per acre in evaluating the optimal crop cycle length, whole farm net returns above variable costs for a crop cycle through harvest of second stubble ($NRAVC_{Hv2}$) were set equal to whole farm net returns above variable costs through harvest of third stubble as shown below:

$$NRAVC_{Hv2} = \left(\left(Y_{pc}AH_{pc}\right) + \left(Y_{1st}AH_{1st}\right) + \left(Y_{2st}AH_{2st}\right) + \left(Y_{3st}AH_{3st}\right)\right) * MP_{sug} * GS_{sug}$$

$$- \left(\begin{matrix} \left(A_{fl}VC_{fl}\right) + \left(A_{cscp}VC_{cscp}\right) + \left(A_{hplt}VC_{hplt}\right) + \left(A_{mplt}VC_{mplt}\right) + \left(A_{pc}VC_{pcfo}\right) \\ \left(A_{1st}VC_{1sfo}\right) + \left(A_{2st}VC_{2sfo}\right) + \left(A_{3st}VC_{3sfo}\right) + \left(A_{hv}VC_{hv}\right) \end{matrix}\right) \qquad [Eq. 22]$$

where Y_{pc}, Y_{1st}, Y_{2st}, and Y_{3st} represents the sugar yield per harvested acre on production cane sent to the mill (plant cane through third stubble), AH_{pc}, AH_{1st}, AH_{2st}, and AH_{3st} represents the respective acres of production cane harvests, MP_{sug} represents the market price of raw sugar, GS_{sug} represents the grower share to total sugar production, A_{fl}, A_{cscp}, A_{hplt}, A_{mplt}, A_{pc}, A_{1st}, A_{2st}, A_{3st}, and A_{hv}, represents the farm acreage devoted to fallow, cultured seed cane planting, hand planting, machine planting, plant cane, first stubble, second stubble, third stubble and harvest, respectively, and VC_{fl}, VC_{cscp}, VC_{hplt}, VC_{mplt}, VC_{pc}, VC_{1st}, VC_{2st}, VC_{3st}, and VC_{hv} represent the variable production costs on those respective acreage tracts. After simplifying the latter portion of the equation to whole farm variable costs for harvest through third stubble (VC_{Hv3}), the relationship was solved for the breakeven sugar yield per acre for the third stubble crop (Y_{3st}), obtaining a final relationship as follows:

$$Y_{3st} =$$

$$\frac{NRAVC_{Hv2} - \left(\left(\left(Y_{pc}AH_{pc}\right) + \left(Y_{1st}AH_{1st}\right) + \left(Y_{2st}AH_{2st}\right)\right) * MP_{sug} * GS_{sug}\right) + VC_{Hv3}}{\left(MP_{sug} * GS_{sug} * AH_{3st}\right)} \qquad [Eq. 23]$$

This breakeven equation was the basis of this analysis, providing the ability to estimate breakeven yields for third stubble sugarcane crops in determining optimal crop cycle lengths and the ability to evaluate the impact of factors such as yield level, raw sugar market price, diesel price, planting ratio and other factors on this decision rule. It was stated as a decision rule that third stubble breakeven yields necessary to keep third stubble in production are a function of plantcane, first stubble and second stubble yields.

3.2.5 Impact of Changes in Production Factors

The impact of changes in factors such as market prices and production costs was also evaluated using the third stubble breakeven yield approach. Normal scenarios of production and its respectively third stubble breakeven yields were compared to different scenarios were prices and costs were changed in order to determine the impact of these changes in the final decision of keeping a third stubble in production. The factor changes that were evaluated were specifically: changes in mechanical planting ratio, changes in raw sugar price, changes in diesel price, changes in harvest costs and changes in projected sugar yields.

3.2.6 Linear Programming Models Specifications

A mathematical relationship was developed in order to better understand the dynamic behavior of the production of a vegetatively propagated crop. The production of a vegetatively propagated crop, such as sugarcane, not only involves costs of production and returns from final products, it also involves the problematic buying and propagating of the seed and the total farm acres distribution depending of the amount of stubble to be kept for each sugarcane variety in a single farm. These relationships were used later to specify a linear programming model and its constraints. Risk analysis using MOTAD and Target MOTAD models were also developed based on these relationships.

Linear programming was used as a method to determine the way to achieve maximum possible returns from a sugarcane operation in a whole farm context, when the five earlier cited varieties are available as optional crops. This part of the study was made based on an example farm size of one thousand acres. The sugarcane rotational acre linear programming model for farm net returns maximization that was used in this research can be specified as follows:

$$\begin{aligned} \text{MAX } Z = \sum_{i=1}^{5} \quad & r_{1\text{-}i}\,\text{PCHVMILL}_i + r_{2\text{-}i}\,\text{1SHVMILL}_i + r_{3\text{-}i}\,\text{2SHVMILL}_i + r_{4\text{-}i}\,\text{3SHVMILL}_i \\ & + c_{1\text{-}i}\,\text{TACPLOW}_i - c_{2\text{-}i}\,\text{KLSCPR}_i - c_{3\text{-}i}\,\text{TACHDPL}_i - c_{4\text{-}i}\,\text{TACHVSD}_i \\ & - c_{5\text{-}i}\,\text{TACMCPL}_i - c_{6\text{-}i}\,\text{PCACCULT}_i - c_{7\text{-}i}\,\text{1SACCULT}_i - c_{8\text{-}i}\,\text{2SACCULT}_i \\ & - c_{9\text{-}i}\,\text{3SACCULT}_i - c_{10\text{-}i}\,\text{TACHVSG}_i \end{aligned} \qquad \text{[Eq. 25]}$$

s.t.

[Eq. 25-1] $\text{KLSCPL}_i = \text{KLSCPR}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-2] $\text{KLPCHV}_i = \text{KLSCPL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-3] $\text{KL1SHV}_i = \text{KLPCHV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-4] $\text{SCX1PL}_i = 7\ \text{KLPCHV}_i + 7\ \text{KL1SHV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-5] $\text{SCX1HV}_i = \text{SCX1PL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-6] $\text{SCX2PL}_i = 5\ \text{SX1HV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-7] $\text{PCACCULT}_i = \text{KLSCPL}_i + \text{SCX1PL}_i + \text{SCX2PL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-8] $\text{1SACCULT}_i = \text{KLPCHV}_i + \text{PCHVMILL}_i + \text{SX1HV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-9] $\text{2SACCULT}_i = \text{1SHVSEED}_i + \text{1SHVMILL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-9] $\text{3SACCULT}_i \leq \text{2SHVMILL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-10] $\text{TACCULT}_i = \text{PCACCULT}_i + \text{1SACCULT}_i + \text{2SACCULT}_i + \text{3SACCULT}_i$

for $i = 1, 2, \ldots, 5$

[Eq. 25-11] $\text{PCHVSEED}_i = \text{KLPCHV}_i + \text{SCX1HV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-12] $\text{PCHVMILL}_i = \text{SCX2PL}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-13] $\text{1SHVSEED}_i = \text{KL1SHV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-14] $\text{1SHVMILL}_i = \text{PCHVMILL}_i + \text{SCX1HV}_i$ *for* $i = 1, 2, \ldots, 5$

[Eq. 25-15] $2SHVMILL_i = 1SHVSEED_i + 1SHVMILL_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-16] $3SHVMILL_i = 3SACCULT_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-17] $TACPLOW_i = 2SHVMILL_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-18] $TACHDPL_i = KLSCPL_i + SCX1PL_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-19] $TACMCPL_i = SCX2PL_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-20] $TACPL_i = KLSCPL_i + SCX1PL_i + SCX2PL_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-21] $TACHVSD_i = PCHVSEED_i + 1SHVSEED_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-22] $TACHVSG_i = PCHVMILL_i + 1SHVMILL_i + 2SHVMILL_i + 3SHVMILL_i$

for i = 1, 2, . . ., 5

[Eq. 25-23] $TFARMAC_i = TACPL_i + TACHVSD_i + TACHVSG_i$ *for i = 1, 2, . . ., 5*

[Eq. 25-24] $TFARMAC_i \leq 1000$ *for i = 1, 2, . . ., 5*

[Eq. 25-25] $\sum_{i=1}^{5} TFARMAC_i \leq 1000$

where r_{1-i}, r_{2-i}, r_{3-i} and r_{4-i} represent producer gross returns from plantcane, first stubble, second stubble and third stubble production, respectively, for each of the five possible varieties and c_{1-i}, c_{2-i}, c_{3-i}, c_{4-i}, c_{5-i}, c_{6-i}, c_{7-i}, c_{8-i}, c_{9-i} and c_{10-i} represent the following variable costs per acre coefficients associated with producing the same variety through harvest of a third stubble crop : (1) fallow and seedbed preparation (i.e., plowout cost), (2) cultured seedcane purchase, (3) hand planting, (4) seedcane harvest, (5) mechanical planting, (6) plant cane crop cultivation, (7) first stubble crop cultivation, (8) second stubble crop cultivation, (9) third stubble crop cultivation, and (10) harvest. Variables included in the linear programming model consisted of the following:

$KLSCPR_i$ = acre equivalents of cultured seedcane of variety *i* purchased,

$KLSCPL_i$ = acres of cultured seedcane of variety *i* planted,

$KLPCHV_i$ = acres of cultured seedcane of variety *i* plantcane harvested for seed,

$KL1SHV_i$ = acres of cultured seedcane of variety *i* first stubble harvested for seed,

$SCX1PL_i$ = acres of first seedcane expansion of variety *i* planted,

$SCX1HV_i$ = acres of first seedcane expansion of variety *i* harvested,

$SCX2PL_i$ = acres of second seedcane expansion of variety *i* planted

$TACCULT_i$ = total acres of variety *i* under cultivation,

$PCHVSEED_i$ = acres of plantcane of variety *i* harvested for seedcane,

$PCHVMILL_i$ = acres of plantcane of variety *i* harvested for mill processing,

$1SHVSEED_i$ = acres of first stubble of variety *i* harvested for seedcane,

$1SHVMILL_i$ = acres of first stubble of variety *i* harvested for mill processing,

$2SHVMILL_i$ = acres of second stubble of variety *i* harvested for mill processing,

$3SHVMILL_i$ = acres of third stubble of variety *i* harvested for mill processing,

$TACPLOW_i$ = total acres of older stubble of variety *i* plowed out,

$TACHDPL_i$ = total acres of variety *i* hand planted,

$TACMCPL_i$ = total acres of variety *i* machine planted,

$TACPL_i$ = total acres of variety *i* planted,

$TACHVSD_i$ = total acres of variety *i* harvested for seedcane,

$TACHVSG_i$ = total acres of variety *i* harvested for sugar,

$TFARMAC_i$ = total farm acres of variety *i*

Constraint [24-1] ensures that cultured seedcane planted, in acres, equals cultured seedcane acre equivalents purchased. Constraint [24-2] sets cultured seedcane acres harvested for seed equal to cultured seedcane plant cane acres planted. Constraint [24-3] sets cultured first stubble seedcane acres harvested equal to cultured plant cane acres harvested.

Seedcane expansion relationships are defined by constraints [24-4], [24-5], and [24-6]. Constraint [24-4] defines first expansion seedcane acres hand planted. Constraint [24-5] defines first expansion seedcane acres harvested. Constraint [24-6] defines second expansion seedcane acres machine planted.

Sugarcane acres under cultivation at any point in time are specified in the next five constraints. Constraints [24-7], [24-8], [24-9], [24-10], and [24-11] specify acres under cultivation of plant cane, first stubble, second stubble, third stubble, and total cultivated acres, respectively.

Constraint [24-12] defines plant cane acres harvested for seedcane, while constraint [24-13] defines plant cane acres harvested for mill processing. Constraint [24-14] defines first stubble acres harvested for seedcane, while constraint [24-15] defines first stubble acres harvested for mill processing. Acreage of second stubble and third stubble harvested for mill processing is defined in constraints [24-16] and [24-17].

Total older stubble acreage plowed out each year is defined in constraint [24-18]. Constraints [24-19], [24-20], and [24-21] specify total acreage hand planted, total acreage machine planted, and total acreage planted. Total acreage harvested for seedcane is defined in constraint [24-22] and total acreage harvested for sugar is defined in constraint [24-23]. Total farm acreage of variety *i* is defined in constraint [24-24].

Every linear programming model developed contained returns and costs for each of five varieties. Three different linear programming models were developed to analyze maximization of net returns when amount of land designated for a single variety was constrained to different amounts of acres. The first linear programming model had no acre limitations on an individual variety, meaning that the farm could be entirely planted with one single variety if this would be the case that maximized net returns. Second and third linear programming models had acre limitations of 50% and 30% of total acres respectively, meaning that no single variety could exceed 50% of the total farm acreage in the second model and 30% of the total farm acreage in the third model.

Economic returns for each crop stage included in the linear programming models were calculated by multiplying the sugar per acre yield of each crop stage by the farmer's share by the current price of a pound of raw sugar. Sugar per acre yields were obtained from outfield trials and adjusted to commercial sugarcane farm yields. This adjustment was realized using the CRS (commercially recoverable sugar) concept. CRS refers to the amount of sugar contained in a ton of sugarcane, which tends to be higher in outfield trials than in commercial operations. Amount of sugar per ton of sugarcane obtained from outfield trials were adjusted to average amount of sugar per ton of sugarcane obtained in commercial farms generating new adjusted data for yield of sugarcane per acre that were used to calculate farmer's returns in the linear programming models. The adjustment in sugar yields from research plot data to estimated commercial farm level yields were determined by the following relationship:

$$FY_{i,j} = (RY_{i,j} / ARCRS_j) \text{ x } (CRS_j + (RCRS_{i,j} - ARCRS_j)) \qquad \text{[Eq. 26]}$$

where $FY_{i,j}$ = adjusted farm level sugar yield in pounds per acre for variety *i* in year *j*, $RY_{i,j}$ = research plot sugar yield in pounds per acre for variety *i* in year *j*, $ARCRS_j$ = average research plot sugar recovery in pounds per ton of cane for year *j*, CRS_j = industry average sugar recovery in pounds per ton of cane for year *j*, $RCRS_{i,j}$ = research plot sugar recovery in pounds per ton of cane for variety *i* in year *j*, and $ARCRS_j$ = average research plot sugar recovery in pounds per ton of cane in year $_j$. Average research plot sugar recoveries, in pounds of raw sugar per ton of cane, were estimated to be 282, 277, 273, 292, and 277 for the years 2005-2009. Average industry sugar recoveries on commercial sugarcane farms over the same period were 219, 206, 222, 229, and 208 pounds of raw sugar per ton of cane. Research plot sugar yields per acre, research plot sugar recoveries, and adjusted (estimated) farm level sugar yields per acre, used in this analysis, are shown in Tables 3.3, 3.4 and 3.5.

Grower's share of the harvested sugarcane was determined after subtracting the land owner's share and the mill's share. The grower's crop share used in this study was 50.8%. This value is based on a 39% mill share and a one-sixth (16.7%) landlord share. The price of a pound of raw sugar used in the linear programming model was the average price received over the past five years (2005-2009) of $0.21 per pound of raw sugar.

Table 3.3 Research plot sugar yields for major sugarcane varieties, 2005-2009.

	Crop Age			
Variety (Year)	PC	1st	2nd	3rd
	(pounds of raw sugar per acre)			
HoCP 96-540 (2005)	9,054	8,292	6,614	6,439
L 97-128 (2005)	7,718	7,681	6,893	6,267
L 99-226 (2005)	9,750	8,929	7,976	8,124
L 99-233 (2005)	8,709	7,807	7,441	8,392
HoCP 00-950 (2005)	8,694	8,474	8,498	8,410
HoCP 96-540 (2006)	10,559	8,721	9,074	8,464
L 97-128 (2006)	10,009	8,249	9,151	9,654
L 99-226 (2006)	11,148	10,378	9,417	8,741
L 99-233 (2006)	10,340	8,754	9,041	9,634
HoCP 00-950 (2006)	10,767	8,746	9,959	8,410
HoCP 96-540 (2007)	10,489	9,539	6,617	7,774
L 97-128 (2007)	10,180	9,271	6,966	7,541
L 99-226 (2007)	10,728	10,462	7,957	8,002
L 99-233 (2007)	9,781	9,417	7,616	7,878
HoCP 00-950 (2007)	11,015	9,642	8,688	8,964
HoCP 96-540 (2008)	9,081	8,422	7,660	5,243
L 97-128 (2008)	8,265	7,433	7,559	7,439
L 99-226 (2008)	9,222	8,592	7,933	8,186
L 99-233 (2008)	8,645	7,864	8,413	8,191

Table 3.3. Continued

HoCP 00-950 (2008)	8,738	8,061	7,861	8,014
HoCP 96-540 (2009)	9,735	8,379	6,860	7,303
L 97-128 (2009)	9,043	8,349	7,488	7,532
L 99-226 (2009)	10,325	8,829	7,194	7,565
L 99-233 (2009)	11,833	8,715	7,578	7,865
HoCP 00-950 (2009)	11,250	9,112	7,485	8,252

Source: Sugar Station Annual Reports, 2005-2009, LSU Agricultural Center.

Table 3.4 Research plot sugar recovery for major sugarcane varieties, 2005-2009.

	Crop Age			
Variety (Year)	PC	1st	2nd	3rd
	(pounds of raw sugar per ton of cane)			
HoCP 96-540 (2005)	270	255	244	275
L 97-128 (2005)	270	270	274	281
L 99-226 (2005)	290	282	271	306
L 99-233 (2005)	281	263	258	269
HoCP 00-950 (2005)	299	297	287	296
HoCP 96-540 (2006)	285	291	285	288
L 97-128 (2006)	280	289	284	300
L 99-226 (2006)	296	303	301	308
L 99-233 (2006)	270	283	277	281
HoCP 00-950 (2006)	300	306	300	317
HoCP 96-540 (2007)	266	284	238	252
L 97-128 (2007)	270	286	258	272
L 99-226 (2007)	284	305	272	275
L 99-233 (2007)	249	281	239	245
HoCP 00-950 (2007)	290	311	286	296
HoCP 96-540 (2008)	273	276	273	247
L 97-128 (2008)	260	272	284	256
L 99-226 (2008)	286	300	297	277
L 99-233 (2008)	264	271	276	253
HoCP 00-950 (2008)	291	291	294	303
HoCP 96-540 (2009)	286	286	271	278
L 97-128 (2009)	268	273	271	273
L 99-226 (2009)	299	294	301	292
L 99-233 (2009)	268	271	265	262
HoCP 00-950 (2009)	295	301	292	303

Source: Sugar Station Annual Reports, 2005-2009, LSU Agricultural Center.

Table 3.5 Estimated farm level sugar yields for major sugarcane varieties, 2005-2009.

	Crop Age			
Variety (Year)	PC	1st	2nd	3rd
	(pounds of raw sugar per acre)			
HoCP 96-540 (2005)	7,047	6,453	5,066	4,970
L 97-128 (2005)	5,892	5,897	5,280	4,811
L 99-226 (2005)	7,682	7,003	6,296	6,356
L 99-233 (2005)	6,648	5,980	5,660	6,361
HoCP 00-950 (2005)	6,825	6,689	6,651	6,650
HoCP 96-540 (2006)	7,805	6,471	6,707	6,024
L 97-128 (2006)	7,268	6,090	6,857	6,969
L 99-226 (2006)	8,373	7,915	7,159	6,494
L 99-233 (2006)	7,551	6,454	6,709	6,923
HoCP 00-950 (2006)	8,133	6,606	7,547	6,434
HoCP 96-540 (2007)	8,480	7,828	5,200	6,202
L 97-128 (2007)	8,259	7,619	5,590	6,128
L 99-226 (2007)	8,803	8,714	6,467	6,519
L 99-233 (2007)	7,780	7,710	5,992	6,240
HoCP 00-950 (2007)	9,080	8,062	7,140	7,421
HoCP 96-540 (2008)	7,067	6,593	5,931	4,092
L 97-128 (2008)	6,399	5,808	5,877	5,872
L 99-226 (2008)	7,253	6,800	6,267	6,506
L 99-233 (2008)	6,621	6,108	6,493	6,349
HoCP 00-950 (2008)	6,897	6,396	6,205	6,416
HoCP 96-540 (2009)	7,252	6,116	4,924	5,474
L 97-128 (2009)	6,732	6,219	5,606	5,686
L 99-226 (2009)	7,873	6,673	5,366	5,862
L 99-233 (2009)	8,933	6,433	5,555	5,851
HoCP 00-950 (2009)	8,659	6,999	5,689	6,332

Variable production costs per acre included in the linear programming models were calculated as an average of variable production costs per acre data obtained from five years of production, from 2005 to 2009. Since the variety selection is not a factor that affects the production variable costs, the same production variable costs were used for all five varieties.

The specific mathematical objective function used in the linear programming model to maximize net returns over the production of the five major sugarcane varieties was specified as follows:

[Eq. 27]

$$\begin{aligned}
\mathrm{MAX}\ Z = {} & \$804\ \mathrm{PCHVMILL}_1 + \$714\ \mathrm{1SHVMILL}_1 + \$592\ \mathrm{2SHVMILL}_1 \\
& + \$573\ \mathrm{3SHVMILL}_1 - \$149\ \mathrm{TACPLOW}_1 - \$536\ \mathrm{KLSCPR}_1 \\
& - \$247\ \mathrm{TACHDPL}_1 - \$66\ \mathrm{TACHVSD}_1 - \$222\ \mathrm{TACMCPL}_1 \\
& - \$234\ \mathrm{PCACCULT}_1 - \$329\ \mathrm{1SACCULT}_1 - \$334\ \mathrm{2SACCULT}_1 \\
& - \$334\ \mathrm{3SACCULT}_1 - \$129\ \mathrm{TACHVSG}_1 \\
& + \$739\ \mathrm{PCHVMILL}_2 + \$677\ \mathrm{1SHVMILL}_2 + \$622\ \mathrm{2SHVMILL}_2 \\
& + \$628\ \mathrm{3SHVMILL}_2 - \$149\ \mathrm{TACPLOW}_2 - \$536\ \mathrm{KLSCPR}_2 \\
& - \$247\ \mathrm{TACHDPL}_2 - \$66\ \mathrm{TACHVSD}_2 - \$222\ \mathrm{TACMCPL}_2 \\
& - \$234\ \mathrm{PCACCULT}_2 - \$329\ \mathrm{1SACCULT}_2 - \$334\ \mathrm{2SACCULT}_2 \\
& - \$334\ \mathrm{3SACCULT}_2 - \$129\ \mathrm{TACHVSG}_2 \\
& + \$854\ \mathrm{PCHVMILL}_3 + \$791\ \mathrm{1SHVMILL}_3 + \$670\ \mathrm{2SHVMILL}_3 \\
& + \$676\ \mathrm{3SHVMILL}_3 - \$149\ \mathrm{TACPLOW}_3 - \$536\ \mathrm{KLSCPR}_3 \\
& - \$247\ \mathrm{TACHDPL}_3 - \$66\ \mathrm{TACHVSD}_3 - \$222\ \mathrm{TACMCPL}_3 \\
& - \$234\ \mathrm{PCACCULT}_3 - \$329\ \mathrm{1SACCULT}_3 - \$334\ \mathrm{2SACCULT}_3 \\
& - \$334\ \mathrm{3SACCULT}_3 - \$129\ \mathrm{TACHVSG}_3 \\
& + \$806\ \mathrm{PCHVMILL}_4 + \$699\ \mathrm{1SHVMILL}_4 + \$647\ \mathrm{2SHVMILL}_4 \\
& + \$675\ \mathrm{3SHVMILL}_4 - \$149\ \mathrm{TACPLOW}_4 - \$536\ \mathrm{KLSCPR}_4 \\
& - \$247\ \mathrm{TACHDPL}_4 - \$66\ \mathrm{TACHVSD}_4 - \$222\ \mathrm{TACMCPL}_4 \\
& - \$234\ \mathrm{PCACCULT}_4 - \$329\ \mathrm{1SACCULT}_4 - \$334\ \mathrm{2SACCULT}_4 \\
& - \$334\ \mathrm{3SACCULT}_4 - \$129\ \mathrm{TACHVSG}_4 \\
& + \$849\ \mathrm{PCHVMILL}_5 + \$744\ \mathrm{1SHVMILL}_5 + \$707\ \mathrm{2SHVMILL}_5 \\
& + \$710\ \mathrm{3SHVMILL}_5 - \$149\ \mathrm{TACPLOW}_5 - \$536\ \mathrm{KLSCPR}_5 \\
& - \$247\ \mathrm{TACHDPL}_5 - \$66\ \mathrm{TACHVSD}_5 - \$222\ \mathrm{TACMCPL}_5 \\
& - \$234\ \mathrm{PCACCULT}_5 - \$329\ \mathrm{1SACCULT}_5 - \$334\ \mathrm{2SACCULT}_5 \\
& - \$334\ \mathrm{3SACCULT}_5 - \$129\ \mathrm{TACHVSG}_5
\end{aligned}$$

The MOTAD (minimization of mean absolute deviation) model was used in this study as a method of incorporating risk into the decision analysis. This linear decision criterion using the expected return and the mean absolute income deviation was proposed by Hazell (1971) as an alternative to the *E*-*V* and *E*-semivariance criteria for farm planning under gross margin uncertainty. MOTAD model utilizes similar data on possible activity gross margin outcomes and has desirable properties as a decision criterion for farm management research and extension purposes (Hazell, 1971).

According to Anderson et al. (1977), the MOTAD programming model can be formulated as the minimization of the sum of the negative deviations subject to the usual technical constraints and parametric constraint on expected total net revenue. Alternatively, the expected farm net return can be maximized with a parametric constraint on the sum of negative deviations. MOTAD model can be formulated as follows:

$$MAX\ E(Z) = \sum_{j=1}^{n} \bar{c}_j\ x_j \qquad [Eq. 28]$$

s.t.

$$\sum_{j=1}^{n} a_{hj}\ x_j\ \{\geq = \leq\}\ b_h \qquad [Eq. 29]$$

$$\sum_{j=1}^{n} \left(c_{rj} - \bar{c}_j\right) x_j + y_r \geq 0 \qquad [Eq. 30]$$

$$\sum_{r=1}^{s} y_r \leq \lambda \qquad => \lambda\ varied\ from\ 0\ to\ max.value \qquad [Eq. 31]$$

In this formulation [Eq. 28] maximizes expected net return of the solution set. Technical constraints are represented by equation [Eq. 29]. In expression [Eq. 30] there is one variable y_r that represents the negative deviation of the total net revenue for each state r. The total deviation for each state is represented in the summation term of [Eq. 30]. If this sum is positive the value of y_r will be zero obeying the non-negativity restriction of [Eq. 30], in contrast, if the sum of the net return deviation for any state is negative in [Eq. 30] the corresponding variable y_r will be forced to adopt an equivalent positive value. Thus, λ in [Eq. 31] will measure the sum of the total negative deviations over all the states evaluated.

Farmer's economic returns and production variable costs used in the MOTAD model were the same as those used in the linear programming model. The MOTAD model included deviations from the mean of returns and production variable costs for all five varieties studied and for five years of production. Three different MOTAD models were developed to analyze risk related to net returns maximization. As well as in the linear programming model section, each MOTAD model had different constraints in terms of amount of land cultivated of one single variety. The first MOTAD model had no acre limitations on an individual variety, while the second and third MOTAD models had acre limitations of 50% and 30% respectively.

In the MOTAD model, risk constraints were added to incorporate net return risk based on the previous five years of historical price, yield and production cost data. The general form of the risk constraints in the MOTAD model can be stated as follows:

$$\begin{aligned}\sum_{i=1}^{5} \quad & d_{j1\text{-}i}\,\text{PCHVMILL}_i + d_{j2\text{-}i}\,\text{1SHVMILL}_i + d_{j3\text{-}i}\,\text{2SHVMILL}_i + dj_{4\text{-}i}\,\text{3SHVMILL}_i \\ & + d_{j5\text{-}i}\,\text{TACPLOW}_i + d_{j6\text{-}i}\,\text{KLSCPR}_i + d_{j7\text{-}i}\,\text{TACHDPL}_i + d_{j8\text{-}i}\,\text{TACHVSD}_i \\ & + d_{j9\text{-}i}\,\text{TACMCPL}_i + d_{j10\text{-}i}\,\text{PCACCULT}_i + d_{j11\text{-}i}\,\text{1SACCULT}_i + d_{j12\text{-}i}\,\text{2SACCULT}_i \\ & + d_{j13\text{-}i}\,\text{3SACCULT}_i + d_{j14\text{-}i}\,\text{TACHVSG}_i + Y_1 > 0 \qquad \text{for } j = 1, 2, \ldots, 5 \qquad \text{[Eq. 32]}\end{aligned}$$

$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 \leq \lambda \qquad \text{[Eq. 33]}$$

where λ is varied from zero to its maximum value.

Target MOTAD, a variation of MOTAD, was also used as a method for evaluating risk in the decision analysis. According to Tauer (1983), a Target MOTAD evaluation is useful because decision makers often wish to maximize expected returns but are concerned about returns falling below a critical target. In contrast to MOTAD, in Target MOTAD model deviations of returns and variable production costs are not measured from the mean. This means that Target MOTAD maximizes mean returns subject to a limit on the total negative deviations measured from a fixed target rather than from the mean. Target MOTAD model can be stated as follows:

$$MAX\ E(Z) = \sum_{j=1}^{n} \bar{c}_j\ x_j \qquad [Eq. 34]$$

s.t.

$$\sum_{j=1}^{n} a_{hj}\ x_j\ \{\geq = \leq\}\ b_h \qquad [Eq. 35]$$

$$\sum_{j=1}^{n} c_{rj}\ x_j + y_r\ \geq T \qquad => where\ T = target\ level\ of\ net\ returns \qquad [Eq. 36]$$

$$\sum_{r=1}^{s} p_r\, y_r = \lambda \qquad => \lambda\ varied\ from\ max. value\ toward\ zero \qquad [Eq. 37]$$

In this formulation [Eq. 34] maximizes expected net return of the solution set. Technical constraints are fulfilled by equation [Eq. 35]. Expression [Eq. 36] measures the revenue of a solution for a given state r. If this sum is less than the target T, the corresponding variable y_r will adopt an equivalent positive value. Expression [Eq. 37] represents the sum of the total negative deviations over all the states evaluated.

Three different Target MOTAD models were developed to analyze risk related to net returns maximization when a target net return is set. As well as in the linear programming model section, each Target MOTAD model had different constraints in terms of amount of land cultivated of one single variety. The first Target MOTAD model had no acre limitations on an individual variety, while second and third Target MOTAD models had acre limitations of 50% and 30%, respectively.

In the Target MOTAD model, risk constraints were added to incorporate net return risk based on the deviations from the target level of income specified using the previous five years of historical price, yield and production cost data. The general form of the risk constraints in the Target MOTAD model can be stated as follows:

$$\begin{aligned}\sum_{i=1}^{5} \quad & r_{1,j,i}\,\mathrm{PCHVMILL}_i + r_{2,j,i}\,\mathrm{1SHVMILL}_i + r_{3,j,i}\,\mathrm{2SHVMILL}_i + r_{4,j,i}\,\mathrm{3SHVMILL}_i \\ & - c_{1,j,i}\,\mathrm{TACPLOW}_i - c_{2,j,i}\,\mathrm{KLSCPR}_i - c_{3,j,i}\,\mathrm{TACHDPL}_i - c_{4,j,i}\,\mathrm{TACHVSD}_i \\ & - c_{5,j,i}\,\mathrm{TACMCPL}_i - c_{6,j,i}\,\mathrm{PCACCULT}_i - c_{7,j,i}\,\mathrm{1SACCULT}_i - c_{8,j,i}\,\mathrm{2SACCULT}_i \\ & - c_{9,j,i}\,\mathrm{3SACCULT}_i - c_{10,j,i}\,\mathrm{TACHVSG}_i \quad + Y_j \;\geq\; T \qquad \textit{for } j = 1, 2, \ldots, 5 \qquad \text{[Eq. 38]}\end{aligned}$$

$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 \quad \leq \quad M \qquad \text{[Eq. 39]}$$

where *T* is a specified level of whole farm target net income and *M* is varied from a large value toward zero.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DECISION RULES TO DETERMINE BREAKEVEN SUGAR LEVELS

Third stubble breakeven yields for the five most important varieties in Louisiana were determined using the whole farm context approach and results are presented in Table 4.1. These breakeven yields were obtained using actual research plot yields. Results indicated that, on average, third stubble should be kept in production if its expected raw sugar yield per harvested acre exceeds 6,459 pounds of raw sugar per acre. If sugar per acre yields of plantcane, first stubble and second stubble were averaged, third stubble should be kept only if its expected raw sugar yield acre exceeds 73.3% of that average. The variety L 97-128 presented the highest percentage of prior stages production average needed in order to keep a third stubble in production, while L 99-226 presented the lowest percentage of prior stages production average needed in order to keep a third stubble. However, differences in percentage among the five varieties were minimal, stating that 73.3% of the simple average of plantcane, first stubble and second stubble yields could be used as a basic decision rule in deciding whether to keep a third stubble crop in production for later harvest for sugar.

Table 4.2 shows third stubble breakeven yields for the five most important varieties in Louisiana using adjusted farm level yields. These results were determined using the whole farm context approach and results indicated that, on average, third stubble should be kept in production if its expected raw sugar yield exceeds 5,063 pounds of sugar per acre. After adjusting data to farm level yields, if raw sugar per acre yields of plantcane, first stubble and second stubble were averaged, third stubble should be kept only if its expected sugar yield per harvested acre exceeded 74.3% of that average. Differences in percentage among the five

Table 4.1 Third stubble breakeven sugar per acre yield using actual research plot yields.

Variety	Plantcane 2005-2009	First stubble 2005-2009	Second stubble 2005-2009	Third stubble 2005-2009	Third stubble Breakeven yield[2]
HoCP 96-540	9,784	8,671	7,365	7,045	6,303 (73.2%)
L 97-128	9,043	8,197	7,611	7,687	6,095 (73.6%)
L 99-226	10,235	9,438	8,095	8,124	6,768 (73.1%)
L 99-233	9,862	8,511	8,018	8,392	6,443 (73.2%)
HoCP 00-950	10,093	8,807	8,498	8,410	6,684 (73.2%)
Average	9,803	8,724 (88.9%)[1]	7,917 (80.7%)[1]	7,931 (80.9%)[1]	6,459 (73.3%)

[1] Stubble crop yield as a percent of plantcane yield.

[2] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

Table 4.2 Third stubble breakeven sugar per acre yields using adjusted farm level yields.

Variety	Plantcane 2005-2009	First stubble 2005-2009	Second stubble 2005-2009	Third stubble 2005-2009	Third stubble Breakeven yield[2]
HoCP 96-540	7,530	6,692	5,572	5,353	4,902 (74.3%)
L 97-128	6,910	6,327	5,842	5,893	4,752 (74.7%)
L 99-226	7,997	7,421	6,311	6,348	5,363 (74.0%)
L 99-233	7,507	6,537	6,082	6,345	4,986 (74.3%)
HoCP 00-950	7,919	6,950	6,646	6,651	5,314 (74.1%)
Average	7,573	6,785 (89.6%)[1]	6,091 (80.4%)[1]	6,118 (80.8%)[1]	5,063 (74.3%)

[1] Stubble crop yield as a percent of plantcane yield.

[2] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

varieties were minimal, stating that 74.3% of the simple average of plantcane, first stubble and second stubble yields could be used as a basic decision guideline in the decision of keeping a third stubble crop in production for later harvest for sugar. It was found that breakeven yields, as a percent of prior crop year average yields, using actual research plot yields and adjusted farm level yields were very similar.

In order to compare results from two different approaches (rotational acre approach versus single land tract net present value approach), third stubble breakeven yields for the same varieties were determined using adjusted farm level utilizing the single tract of land net present value approach. In this estimation approach, the breakeven sugar yield for a third stubble crop was determined that would equate the net present value of net returns above variable costs over the entire crop cycle through harvest of a third stubble crop with the net present value of a crop cycle through harvest of a second stubble crop. As shown in table 4.3, results for all varieties indicated that on average, third stubble should be kept in production if its expected yield per harvested acre exceeds 4,330 pounds of sugar per acre, representing very different percentages of the simple average yield of prior crop stages. This breakeven yield level for third stubble production is the yield for which net returns above variable production costs for a third stubble crop would be equal to zero. As a result, estimation of third stubble breakeven yields using this approach does not take into account prior crop yields on the land tract nor does it account for required seed cane and production cane acreage changes required when the crop cycle length is altered. Results showed that single land tract net present value approach is not reliable when predicting third stubble breakeven yields, since it underestimates the true breakeven yield.

Table 4.3 Third stubble breakeven sugar per acre yields using net present value approach.

Variety	Plantcane 2005-2009	First stubble 2005-2009	Second stubble 2005-2009	NPV Returns through 2nd st.	Third stubble Breakeven yield[1]
HoCP 96-540	7,530	6,692	5,572	$128.00	4,330 (65.6%)
L 97-128	6,910	6,327	5,842	$56.00	4,330 (68.1%)
L 99-226	7,997	7,421	6,311	$319.00	4,330 (59.8%)
L 99-233	7,507	6,537	6,082	$165.00	4,330 (64.5%)
HoCP 00-950	7,919	6,950	6,646	$304.00	4,330 (60.4%)
Average	7,573	6,785	6,091	$194.40	4,330 (63.7%)

[1] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

4.2 IMPACT OF CHANGES IN PRODUCTION FACTORS

As shown in Table 4.2, average yield of sugar per acre declines after each year of production and harvest. First stubble sugar per acre yield represented on average 89.6% of the plant cane crop sugar per acre yield. Second and third stubble sugar per acre yields represented 80.4% and 80.8% of the plant cane crop sugar per acre yield, respectively.

As shown in Table 4.4, different first and second stubble crop yield decrease scenarios were evaluated in order to analyze the resulting impacts on third stubble breakeven sugar yields. The percentage values in the table define third stubble breakeven yields as a percent of the simple average of prior plant cane, first stubble and second stubble crop sugar yields. The alternative first and second crop yield evaluated in this study did not have a significant effect on the third stubble breakeven yield for any of the five varieties. For example, if the first and second stubble crop yields for HoCP 96-540 were 85% and 80% of the plant cane yield, rather than 89.6% and 80.4%, the breakeven third stubble yield would increase to 4,943 pounds per acre, but that yield as a percentage of the prior three years crop yields would not change from 74.3%.

Table 4.4 Breakeven 3^{rd} stubble results - impact of alternative stubble crop yields.

	Breakeven third stubble yield[1]				
	Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Variety	89.6%, 80.4%	85%, 80%	85%, 75%	85%, 70%	80%, 70%
HoCP 96-540	4,902 (74.3%)	4,943 (74.3%)	4,849 (74.3%)	4,755 (74.3%)	4,662 (74.3%)
L 97-128	4,752 (74.7%)	4,561 (74.7%)	4,475 (74.7%)	4,388 (74.7%)	4,303 (74.7%)
L 99-226	5,363 (74.0%)	5,231 (74.0%)	5,131 (74.0%)	5,031 (74.0%)	4,932 (74.0%)
L 99-233	4,986 (74.3%)	4,929 (74.3%)	4,835 (74.3%)	4,741 (74.3%)	4,649 (74.3%)
HoCP 00-950	5,314 (74.1%)	5,183 (74.1%)	5,084 (74.1%)	4,985 (74.1%)	4,887 (74.1%)
Average	5,063 (74.3%)	4,969 (74.3%)	4,875 (74.3%)	4,780 (74.3%)	4,687 (74.3%)
		- 94	- 188	- 283	-376

[1] Percentage value equals 3^{rd} stubble breakeven yield as a percent of the simple average yield of plantcane, 1^{st} and 2^{nd} stubble yields.

Although the specific sugar per acre breakeven yield varied with changes in first and second stubble crop yields, the third stubble breakeven yield as a percent of the average of the three prior crop yields did not change.

Planting ratio refers to the ratio of how many acres of sugarcane can be planted from one harvested acre of seedcane. For this study, a planting ratio of 7:1 for the first seedcane expansion and 5:1 for the second seedcane expansion was used as a base scenario, meaning that one acre of seedcane harvested after the second expansion cycle turns into five acres of plantcane. As shown in Table 4.5, it was found that as the second expansion planting ratio increases, the third stubble breakeven yield also increases. A change from a 5:1 ratio to an 8:1 ratio lead to an increase from 74.3% to 76.0% of the simple average yield of plantcane, first stubble and second stubble in order to keep a third stubble in production. Although breakeven yield at an 8:1 second seedcane expansion planting ratio increased by 114 pounds of raw sugar per harvested acre, the breakeven decision rule, expressed as a percentage of the three prior crop yields, only exhibited a minor change in magnitude. This result indicates that a third stubble breakeven yield decision rule expressed as a percentage of prior yields is relatively stable over changes in planting ratios.

The impact of a change in raw sugar market price on third stubble breakeven yields was also studied for the five varieties. The approximate current market price in 2009 of $0.23 per pound of raw sugar was used as a base line market price for this study. The impact of decreases and increases of this price were evaluated and results are shown in Table 4.6. As the price of raw sugar increased, third stubble breakeven yield decreased. Alternative raw sugar market prices of $0.20, $0.23, $0.25 and $0.30 per pound of raw sugar were evaluated as possible raw sugar price scenarios, showing a decreasing tendency in third stubble breakeven yield. An increase of $0.10 per pound of raw sugar led to a decrease of 1.7% in the third stubble breakeven sugar yield.

Changes in the price of diesel fuel can have a significant impact on total farm expenses are a main concern among farmers. The impact of an increase of the current diesel fuel price in a whole farm context refers to the comparison of a whole farm producing all different stages of

Table 4.5 Breakeven 3rd stubble results - impact of alternative mechanical planting ratios.

Variety	Breakeven third stubble yield[1] Planting Ratio 5:1	Planting Ratio 6:1	Planting Ratio 7:1	Planting Ratio 8:1
HoCP 96-540	4,902 (74.3%)	4,951 (75.0%)	4,988 (75.6%)	5,016 (76.0%)
L 97-128	4,752 (74.7%)	4,797 (75.4%)	4,830 (76.0%)	4,857 (76.4%)
L 99-226	5,363 (74.0%)	5,415 (74.8%)	5,454 (75.3%)	5,485 (75.7%)
L 99-233	4,986 (74.3%)	5,035 (75.1%)	5,072 (75.6%)	5,100 (76.0%)
HoCP 00-950	5,314 (74.1%)	5,366 (74.8%)	5,404 (75.4%)	5,435 (75.8%)
Average	5,063 (74.3%)	5,113 (75.0%)	5,150 (75.6%)	5,179 (76.0%)
		+50	+87	+116

[1] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

Table 4.6 Breakeven 3rd stubble results - impact of change in projected 3rd stubble sugar price.

Variety	Breakeven third stubble yield[1] Base Case $0.23/lb.	- $0.03/lb. $0.20/lb.	+ $0.02/lb. $0.25/lb.	+ $0.07/lb. $0.30/lb.
HoCP 96-540	4,902 (74.3%)	4,948 (75.0%)	4,878 (73.9%)	4,831 (73.2%)
L 97-128	4,752 (74.7%)	4,798 (75.4%)	4,727 (74.3%)	4,680 (73.6%)
L 99-226	5,363 (74.0%)	5,409 (74.7%)	5,339 (73.7%)	5,292 (73.1%)
L 99-233	4,986 (74.3%)	5,032 (75.0%)	4,962 (74.0%)	4,915 (73.3%)
HoCP 00-950	5,314 (74.1%)	5,360 (74.7%)	5,290 (73.8%)	5,243 (73.1%)
Average	5,063 (74.3%)	5,110 (75.0%)	5,039 (74.0%)	4,992 (73.3%)
		+47	-24	-71

[1] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

sugarcane over the whole cycle of one year under a certain diesel fuel price compared to the same farm producing all different stages of sugarcane over the whole cycle of one year under a different diesel fuel price. As presented in Table 4.7, the current diesel price of $2.30 per gallon was used in this study as a base line and was increased by $0.50 and $1.00. The increase in the price of diesel did not have an impact on the third stubble breakeven yield, which remained in 74.3%.

Third stubble breakeven yield analysis changing some production factors was made in

Table 4.7 Breakeven 3rd stubble results - impact of changes in projected diesel price.

	Breakeven third stubble yield[1]		
Variety	Base Case $2.30/gal.	+ $0.50/gal $2.80/gal.	+ $1.00/gal. $3.30/gal.
HoCP 96-540	4,902 (74.3%)	4,903 (74.3%)	4,904 (74.3%)
L 97-128	4,752 (74.7%)	4,753 (74.7%)	4,754 (74.8%)
L 99-226	5,363 (74.0%)	5,364 (74.1%)	5,365 (74.1%)
L 99-233	4,986 (74.3%)	4,988 (74.3%)	4,989 (74.4%)
HoCP 00-950	5,314 (74.1%)	5,315 (74.1%)	5,317 (74.1%)
Average	5,063 (74.3%)	5,064 (74.3%)	5,065 (74.3%)

[1] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

order to determine the impact of changing these production factors on the breakeven third stubble sugar per acre yield needed to keep a third stubble in production. All of these analyses were made using the concept of a whole farm production rotational acres approach which includes different stages of sugarcane production in a single period of time. Impact of changes in projected third stubble harvest costs was evaluated to determine changes in third stubble breakeven yield. Actual variable production cost data from 2010 was used as a baseline for this study having $433 per acre as a base and actual scenario of total variable production costs for one year of production of a farm producing through third stubble. Harvest cost is one of the most fluctuating costs of all variable production costs in agricultural production and especially in sugarcane. One factor that could affect the harvest cost is the rain, which would slow down the harvest process increasing the harvest cost.

As shown in table 4.8, as harvest cost was increased by $25 and $50 per acre, the third stubble breakeven yield increased from 74.3% to 75.2% and 76.2% respectively. The impact of production cost increases are mitigated somewhat since they are assumed to apply only to the third stubble crop. Once again, although there are some changes in the magnitude of sugar per

Table 4.8 Breakeven 3rd stubble results - impact of changes in projected 3rd stubble harvest costs.

	Breakeven third stubble yield[1]		
	Base Case	+25	+50
Variety	\$433 TVC/A[2]	\$452 TVC/A[2]	\$471 TVC/A[2]
HoCP 96-540	4,902 (74.3%)	4,966 (75.3%)	5,029 (76.2%)
L 97-128	4,752 (74.7%)	4,815 (75.7%)	4,879 (76.7%)
L 99-226	5,363 (74.0%)	5,427 (74.9%)	5,490 (75.8%)
L 99-233	4,986 (74.3%)	5,050 (75.3%)	5,114 (76.2%)
HoCP 00-950	5,314 (74.1%)	5,378 (75.0%)	5,442 (75.9%)
Average	5,063 (74.3%)	5,127 (75.2%)	5,191 (76.2%)
		+64	+128

[1] Percentage value equals 3rd stubble breakeven yield as a percent of the simple average yield of plantcane, 1st and 2nd stubble yields.

[2] Total variable cost per acre (TVC/A) for third stubble crop production includes cultivation and harvest costs.

acre breakeven third stubble yields, yield as a percentage of the prior three years yields remains relatively stable over a range of third stubble production cost increases.

4.3 OPTIMAL CYCLE LENGTH

Linear programming was used to evaluate third stubble crop production decisions in a whole farm context producing a mix of sugarcane varieties. Linear programming models were utilized to evaluate optimal variety mix and crop cycle length with and without the inclusion of net return risk in the analysis. As shown in Table 4.9 the maximum net returns goal of \$147,198 was achieved using variety HoCP 00-950 as the only variety planted over the entire farm operation, when there were no acre limitations on individual varieties. No acre limitations on individual variety referred to the possibility of having as many acres of each variety as possible for feasible acreage solutions. As expected, this solution with the highest level of income risk measured by the mean absolute deviation of net returns is also the linear programming model solution. A second net returns goal of \$143,604 was achieved by planting 879.13 acres of variety L 99-226 and 120.86 acres of variety HoCP 00-950. Finally, a third net returns goal of \$143,110

Table 4.9 Sugarcane variety selection MOTAD results with no acre limitations on individual variety.

			Total Variety Acres (Crop Cycle Length)				
Solution	Obj. Function	MAD[2]	HoCP 96-541	L 97-129	L 99-226	L 99-233	HoCP 00-950
1	$143,110	52,133	-	-	1,000.00 (5)	-	-
2	$143,604	54,001	-	-	879.13 (5)	-	120.86 (5)
3[1]	$147,198	74,875	-	-	-	-	1,000.00 (5)

[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

was achieved having the variety L 99-226 as the only one planted in the whole farm. For all three net returns scenarios, results showed that the crop cycle length should be of five years, which means that third stubble should be kept in production.

Table 4.10 shows three different possible net returns scenarios when acres planted of a single variety were limited to 50% of the total area of the farm. In other words, no single variety should exceed the 50% of the total planted area of the farm. A maximum net returns goal of $145,154 was achieved planting 500 acres of variety L 99-266 and 500 acres of variety HoCP 00-950. In this case, 50% of the farm was planted with one variety and the other 50% was planted with a different one, respecting the restriction of a 50% acre limitation. A second net returns goal of $81,673 was achieved by planting 500 acres of variety L 99-266 and 68.73 acres of variety HoCP 00-950. A third and lower net returns goal was achieved with the production of 500 acres of variety L99-226. For all three different profit scenarios, results showed that production should be kept until third stubble; therefore the crop cycle length should be five years.

Table 4.11 shows seven different possible net returns scenarios when acres planted of a single variety were limited to a 30% of the total area of the farm. No single variety should exceed the 30% of the total planted area of the farm. Since this study was based on a 1000-acre farm, no single variety should exceed 300 hundred acres of plantation. A maximum net returns goal of $129,104 was achieved planting 100, 300, 300 and 300 acres of varieties HoCP 96-541, L 99-226, L 99-233 and HoCP 00-950, respectively. This solution was the same solution obtained after running a linear programming solution with no risk constraint. The scenario with the lowest net returns under the 30% acre limitations constraint was $42,933 obtained from planting only 300 acres of variety L 99-226. All seven different net returns scenarios results

Table 4.10 Sugarcane variety MOTAD results with a 50% acre limitation on individual variety.

			Total Variety Acres (Crop Cycle Length)				
Solution	Obj. Function	MAD[2]	HoCP 96-541	L 97-129	L 99-226	L 99-233	HoCP 00-950
1	$71,555	26,066	-	-	500.00 (5)	-	-
2	$81,673	30,712	-	-	500.00 (5)	-	68.73 (5)
3[1]	$145,154	63,003	-	-	500.00 (5)	-	500.00 (5)

[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

Table 4.11 Sugarcane variety MOTAD results with a 30% acre limitation on individual variety.

			Total Variety Acres (Crop Cycle Length)				
Solution	Obj. Function	MAD[2]	HoCP 96-541	L 97-129	L 99-226	L 99-233	HoCP 00-950
1	$42,933	15,639	-	-	300.00 (5)	-	-
2	$49,004	18,427	-	-	300.00 (5)	-	41.24 (5)
3	$87,092	37,802	-	-	300.00 (5)	-	300.00 (5)
4	$120,759	56,003	-	-	300.00 (5)	300.00 (5)	300.00 (5)
5	$125,517	58,944	61.98 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
6	$128,690	61,110	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
7[1]	$129,104	61,698	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)

[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

showed that production should be kept until third stubble, therefore the crop cycle length should be five years.

Results from the linear programming and MOTAD analysis suggest that if the relationship between plant cane and stubble yields on commercial farms have similar relationships to each other as observed in research plot yield tests that third stubble crops, in general, should be kept in production for later harvest in order to maximize whole farm net returns above variable production costs. As expected, net return income risk can be lowered by expanding the diversity of sugarcane varieties produced on the farm. Very little decline in whole farm net returns was observed in producing two versus one major varieties on the farm operation. A larger decrease in expected net returns was observed when the variety mix was expanded to three major varieties in production.

Table 4.12 shows different possible returns under different risk scenarios for alternative target levels of whole farm net returns from \$110,000 to \$160,000. No acre limitations on individual variety were imposed for this case. Maximum net returns goal of \$147,198 (the linear programming solution) was achieved for each critical target with different risk implications. The most risky scenario for achieving maximum net returns had a mean absolute deviation of 67,965 and was reached using variety HoCP 00-950 as the only variety planted on all 1,000 acres after setting a critical target of \$160,000. The least risky scenario had expected net returns of \$144,518 with a mean absolute deviation of 29,198 by planting 655.72 acres of variety L99-233 and 344.28 acres of variety HoCP 00-950. For all alternative target income level scenarios evaluated, results showed that the optimal level of sugarcane production required keeping land in sugar production through harvest of a third stubble crop, a crop cycle length of five years.

Six different possible returns under different risk scenarios, when acres planted of a

Table 4.12 Sugarcane variety selection Target MOTAD results with no acre limitations on individual variety for alternative income targets.

				Total Variety Acres (Crop Cycle Length)				
Solution	Target Return	Objective Function	MAD[2]	HoCP 96-542	L 97-130	L 99-226	L 99-233	HoCP 00-950
1	$110,000	144,518	29,198	-	-	-	655.72 (5)	344.28 (5)
2[1]	$110,000	147,198	33,718	-	-	-	-	1,000.00 (5)
1	$120,000	145,504	34,862	-	-	-	414.34 (5)	585.66 (5)
2[1]	$120,000	147,198	37,718	-	-	-	-	1,000.00 (5)
1	$130,000	146,491	40,526	-	-	-	172.96 (5)	827.04 (5)
2[1]	$130,000	147,198	41,718	-	-	-	-	1,000.00 (5)
1[1]	$140,000	147,198	46,852	-	-	-	-	1,000.00 (5)
1[1]	$150,000	147,198	55,965	-	-	-	-	1,000.00 (5)
1[1]	$160,000	147,198	67,965	-	-	-	-	1,000.00 (5)

[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

single variety was limited to 50% of the total area of the farm (Table 4.13). For all six target returns, the objective function was the same solution obtained from the linear programming with no risk constraint, which is the solution that maximizes economic net returns. Maximum net returns of $145,154 were obtained by planting 500 acres of the farm with variety L 99-226 and 500 acres with variety HoCP 00-952. Difference between the six answers is in the level of risk faced by the farmer. The most risky scenario for achieving maximum net returns had a mean absolute deviation of 67,965 while the less risky scenario for achieving the same net returns had a mean absolute deviation of 30,271, implying that the probabilities of falling under critical target returns of $110,000 are less than the probabilities of falling under critical target returns of $160,000. For all returns scenarios results showed that the crop cycle length should be of five years, which means that third stubble should be kept in production.

Table 4.14 shows various possible returns under different target income levels and risk scenarios, when acres planted of a single variety were limited to a 30% of the total area of the farm. The maximum net returns goal of $129,104 was achieved for each critical target under different risk scenarios. The most risky scenario for achieving maximum net returns of $129,104 had a mean absolute deviation of $80,384 and was reached planting 100, 300, 300 and 300 acres of varieties HoCP 96-541, L 99-226, L 99-233 and HoCP 00-950, respectively, all of them until third stubble of production. The less risky scenario throws returns of $128,863 with a mean absolute deviation of 33,706 and was obtained by planting 24.5, 75.5, 300, 300 and 300 acres of varieties HoCP 96-541, L97-129, L 99-226, L 99-233 and HoCP 00-950, respectively, keeping HoCP96-541 until second stubble and the rest until third stubble of production.

Table 4.13 Sugarcane variety selection Target MOTAD results with 50% acre limitations on individual variety for alternative income targets.

				Total Variety Acres (Crop Cycle Length)				
Solution	Target Return	Objective Function	MAD[2]	HoCP 96-541	L 97-129	L 99-226	L 99-233	HoCP 00-950
1[1]	$110,000	145,154	30,271	-	-	500.00 (5)	-	500.00 (5)
1[1]	$120,000	145,154	35,691	-	-	500.00 (5)	-	500.00 (5)
1[1]	$130,000	145,154	43,691	-	-	500.00 (5)	-	500.00 (5)
1[1]	$140,000	145,154	51,691	-	-	500.00 (5)	-	500.00 (5)
1[1]	$150,000	145,154	59,691	-	-	500.00 (5)	-	500.00 (5)
1[1]	$160,000	145,154	68,083	-	-	500.00 (5)	-	500.00 (5)

[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

Table 4.14 Sugarcane variety selection Target MOTAD results with 30% acre limitations on individual variety for alternative income targets.

				Total Variety Acres (Crop Cycle Length)				
Solution	Target Return	Objective Function	MAD[2]	HoCP 96-541	L 97-129	L 99-226	L 99-233	HoCP 00-950
1	$110,000	128,863	33,706	24.50 (4)	75.50 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2	$110,000	129,002	33,854	-	100.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
3	$110,000	129,064	34,031	60.01 (5)	39.99 (5)	300.00 (5)	300.00 (5)	300.00 (5)
4[1]	$110,000	129,104	34,366	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
1	$120,000	129,002	41,529	-	100.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2[1]	$120,000	129,104	42,366	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
1	$130,000	129,002	49,529	-	100.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2[1]	$130,000	129,104	50,366	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
1	$140,000	129,002	57,529	-	100.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2[1]	$140,000	129,104	58,366	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
1	$150,000	129,002	67,314	-	100.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2[1]	$150,000	129,104	68,384	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)
1	$160,000	129,057	79,892	54.00 (5)	46.00 (5)	300.00 (5)	300.00 (5)	300.00 (5)
2[1]	$160,000	129,104	80,384	100.00 (5)	-	300.00 (5)	300.00 (5)	300.00 (5)

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[1] The linear programming solution with no risk constraint.

[2] Mean absolute deviation (MAD) is included as a measure of net return risk.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Sugarcane is a perennial agricultural crop grown primarily for the juices expressed from its stalks that are later processed into raw sugar and finally refined into white sugar. As a perennial crop, one planting of sugarcane will allow three or more annual harvests before replanting is necessary. The first crop harvested is generally referred to as the plant cane crop, with succeeding annual harvests referred to as stubble crops.

The production of sugarcane in Louisiana is a major contributor to the agricultural economy of the state. In terms of market value of final product, sugarcane is the leading agricultural row crop commodity produced in Louisiana; therefore, the importance of economic research in this field in order to keep this industry prosperous is high.

Sugarcane production costs per acre have risen dramatically over the past several years, while raw sugar market prices, with the exception of the past two years, have historically varied within a rather narrow range. Although producing higher yielding sugarcane varieties does have a major impact on farm economic viability, the perennial crop nature of sugarcane production also requires acute attention to farm management production decisions in optimizing whole farm net returns. One of the most critical production decisions on sugarcane farms is determining the optimal crop cycle length, which involves the determination of the optimal number of stubble crops to keep in production, prior to plowing out the existing crop and replanting, with the goal of maximizing producers' net returns.

The general objective of this study was to determine the economically optimal crop cycle length for major sugarcane varieties currently being produced in Louisiana. The specific objectives of the project included the specification of the mathematical acreage relationships which directly impact the production of a vegetatively propagated perennial crop in a whole farm context; the development of producer decision rules to be used to determine breakeven sugar levels on third stubble sugarcane crops for major varieties in the state; the evaluation of the impact of changes in production factors on developed crop replacement rules; and the optimal cycle length for current variety combinations in a whole farm context.

After identifying the five currently most important sugarcane varieties in Louisiana, different models were developed to address the study problems. It was found that the five currently most important varieties in Louisiana, listed in order of importance in terms of percentage of planted area in the state, are HoCP 96-540, L 97-128, L 99-226, L 99-233 and HoCP 00-950 representing the 50%, 17%, 11%, 6% and 2% of the total planted area of the state, respectively.

Third stubble breakeven yields for the five most important varieties in Louisiana were determined and results indicate that on average, third stubble should be kept in production if its production exceeds 5,063 pounds of sugar per acre. If sugar per acre yields of plantcane, first stubble and second stubble were averaged, third stubble should be kept only if its production exceeds 74.3% of that average. Differences in percentages among the five varieties were minimal, concluding that 74.3% of the simple average of plantcane, first stubble and second stubble yields could be used to decide whether to if keep a third stubble in production. Results of changes in production factors such as raw sugar price, diesel price, planting ratio and harvest costs indicated that this 74.3% was not significantly affected when the changes were analyzed in a whole farm context. Linear programming methods were used to determine the way to achieve maximum possible returns for a sugarcane operation in a whole farm context, and to determine optimal crop cycle length. This part of the study was made based on a 1000-acre farm.

A maximum net return goal of $147,198 was achieved using variety HoCP 00-950 as the only variety planted in the whole operation, when there were no acre limitations on individual variety. No acre limitations on individual variety referred to the possibility of having as many acres of each variety as wanted. Results showed that the crop cycle length should be of five years, which means that third stubble should be kept in production.

Another scenario where no single variety should exceed the 50% of the total planted area of the farm was developed and results showed that maximum net returns goal of $145,154 was achieved planting 500 acres of variety L 99-266 and 500 acres of variety HoCP 00-950. In this case 50% of the farm was planted with one variety and the other 50% was planted with a different one, respecting the restriction of 50% acre limitation. Results showed that production should be kept until third stubble; therefore the crop cycle length should be of five years.

Finally, a third scenario where no single variety should exceed the 30% of the total planted area was developed and results showed that maximum net returns goal of $129,104 was achieved planting 100, 300, 300 and 300 acres of varieties HoCP 96-541, L 99-226, L 99-233 and HoCP 00-950 respectively. Results showed that production should be kept until third stubble; therefore the crop cycle length should be of five years.

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