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RISK AND TECHNOLOGICAL ADVANCE IN THE URUGUAYAN
LIVESTOCK SECTOR: A QUADRATIC
PROGRAMMING APPROACH

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The importance of the livestock sector to the economy of Uruguay can hardly be overstated. Livestock related exports averaged 83.7 percent of the country's total exports in the period 1967-1973 (Munoz Duran). In recent years, however, the country has faced a problem of a relatively slow rate of adoption of production increasing technologies on the part of livestock producers. This has resulted in low levels of livestock productivity, a low rate of growth in the economy and a deteriorating balance of payment position (Vazquez).

Previous economic research in Uruguay suggests that there are available technologies to producers that result in substantial increases in production. [Uruguay, 1974 a.] These technologies can be represented by an improved system of livestock production as opposed to the prevailing traditional system. Main differences between the two systems are intensive pasture improvements, better sanitary plans for livestock and improved management practices in the improved as compared to the traditional system. Other fixed investments are also required to realize the gains in productivity derived from the higher levels of nutrition provided by the improved pastures and the combined effect of the package of inputs used by the improved system.

Previous research also suggested that the widespread adoption of improved practices by Uruguayan farmers would result in higher profits at the producer level and increased exports. Ranch level models indicated that differences in producer net returns between the traditional and improved systems were as much as fifty percent (Uruguay, 1974 a, 1974 b). Further, shifting to improved conditions in three main livestock producing zones of the country resulted in estimated net export¹ gains of 150 million dollars to the country (Vazquez).

Despite these impressive estimates of potential economic gains from the adoption of available technologies, the level of adoption by livestock producers in Uruguay remains low. The research reported in this paper examines a possible reason for this low level of adoption by evaluating the influence of risk in the decision making process of individual

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¹Net export gains refers to the increase in agricultural exports less the additional import requirements needed to realize such level of exports.

producers, as it relates to the application of available technologies in livestock production in the Basaltic region of Uruguay.² It is hypothesized that the risk associated with implementing improved technologies may be an important factor in producers' unwillingness to adopt such technologies.

METHODS

A quadratic programming model is constructed to incorporate risk into the utility function of producers under both the traditional and improved livestock systems. The model is used to derive expected returns - variance of returns frontiers (E.V. Frontiers), following Markowitz's approach. According to Markowitz, the combination of activities that yields the highest expected returns is not necessarily the one with minimum variance and there must be a rate at which the decision maker gains expected returns by taking on variance or reduces variance by giving up expected returns (Markowitz, 1952).

The quadratic programming model selects the minimum variance combination of activities from all those combinations that yield the same expected returns. The model can be expressed as follows:

$$\begin{aligned} \text{Minimize } F(X) &= dCX + X' QX \\ \text{subject to } AX &>< B \\ X &\geq 0 \end{aligned} \quad (1)$$

where, X is a column vector of activity levels and X' is its transpose,
 C is a row vector of expected values of returns to each activity,
 A is a matrix of technical coefficients,
 B is the vector of resource constraints,
 Q is the variance-covariance matrix of the returns for all activities,
 X'QX is the variance associated with each particular plan which is minimized for any given level of expected returns, and
 d is a non-negative scalar which is parametrically increased from zero to derive the E.V. frontier.

Markowitz's basic E.V. concept is extended using Baumol's gain-confidence limit criterion for portfolio selection and lexicographic utility functions. Baumol's criterion implies the computation of lower con-

²The Basaltic region occupies 3.5 million hectares of land (21 percent of the country's agricultural area), characterized by shallow soils (80 percent) and to a lesser extent deep soils (20 percent). It is primarily a cattle and sheep producing region, and while this analysis is limited to the Basaltic region, the results hold implications for other livestock regions of the country.

confidence bounds of returns (LBR) along the E.V. frontier. For any given level of expected returns the lower confidence bound can be computed as follows:

$$\text{LBR} = \text{CX} - Z (\text{X}'\text{QX})^{\frac{1}{2}} \quad (2)$$

where C, X, and Q are the same as in equation (1) and Z is the standard normal deviate that determines the desired confidence level. A value of Z equal to 1.96 yields an LBR that assures the producer of expected returns above the level of the lower bound with 97.5 percent confidence.

Lexicographic utility functions imply that the producer's decision making involves more than one objective and that different priorities are given to both objectives (Halter and Dean). In this research the lexicographic utility function used is assumed to be of the following form:

$$U = F (R_1, R_2)$$

where R_1 = a risk aversion goal that implies that the producer wants to receive a minimum acceptable (survival) level of net returns with a given probability; and

R_2 = a profit maximizing goal, defined as maximum expected income.

A comparison of estimated lower confidence bounds of expected returns and lexicographic utility functions are used in this analysis to evaluate the influence of risk on Uruguayan livestock producers' decisions to adopt output increasing technologies.

DATA REQUIREMENTS

Linear programming models previously built for typical ranches of the Basaltic zone provided basic data on resource constraints, activity coefficients and net returns for the risk programming model.

The set of activities used to represent the traditional system of production includes cow-calf, stocker-steer raising and fattening as the main beef production operations. Sheep related activities include breeding ewes and weather raising for wool production as well as production and fattening of lambs for sheep meat production. Livestock activities in the improved model are also related to beef, wool and sheep meat production. A larger number of activities are included in the improved system reflecting the additional production and marketing choices of producers in the system. A most important difference in the two systems is the fact that resource requirements and production coefficients are substantially dif-

ferent between the models as a result of higher productivity of improved system.³

RESULTS

Separate quadratic programming models were developed for the traditional and improved systems of production. Alternative ranch plans that minimize variance of returns for any given level of expected returns attainable within the resource constraints of the ranch are depicted along the E.V. frontiers for the traditional and improved system (Figure 1). Movements upward along the E.V. frontier in the traditional system represent plans where more resources are brought into production up to plan 8T, the point where all available land is used (Figure 1, line A). Increases in net returns beyond plan 8T are realized by reallocating resources from beef and wool production to sheep meat which is a relatively more risky enterprise than is the beef or wool production.

Similarly, the increase of variance of returns in the improved system between plans 8I and 11I is due to the different methods of land improvement and to the different selling activities that enter the solutions (Figure 1, line B). Beyond plan 8I, returns can only be increased at the expense of the greater risks involved in the improvement of land by means of conventional meadows, and the production and sale of yearling lambs. Depending upon subjective income-variance preferences, producers will select a single ranch plan along one of these E.V. frontiers.

In comparing both E.V. frontiers the following conclusions can be drawn: (1) the maximum attainable level of net returns is 38.1 million pesos for the improved model and 25.3 million pesos for traditional model. This represents a potential increase in expected returns of 50.3 percent, which supports the findings of previous research that, when the producer's utility function is restricted to a profit maximizing behavior, the improved system appears as a superior alternative. However, for any given level of expected net returns, the improved model shows higher variance of returns. Hence, considering risk, conclusions concerning the superiority of a ranch plan are less certain and most include producers' preference or aversion to variance of net returns.

Tables 1 and 2 show various production plans along the E.V. frontier, expected net returns, standard deviation of returns and the 97.5 and

³Another major difference between models is the introduction of pasture improvement activities in the improved system. These include simple fertilization of natural species, additions of new species and fertilizer without destroying native species and the use of conventional meadows where deep plowing is necessary.

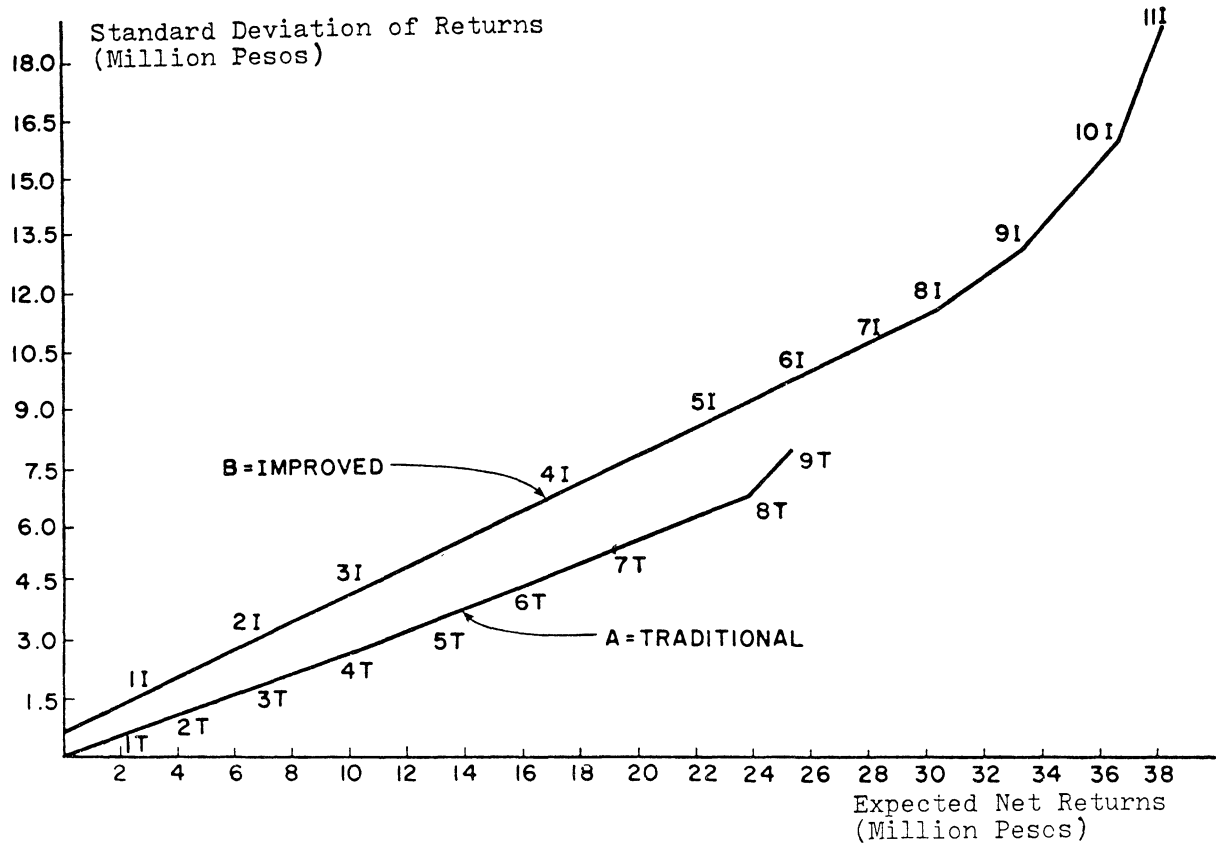


Figure 1. E.V. Frontiers for Traditional and Improved Models for a Typical Ranch in the Basaltic Zone

Table 1. Expected Net Returns, Standard Deviation of Returns and 97.5 and 84.13 Percent Lower Confidence Bounds for a Typical Ranch in the Basaltic Zone Worked under Traditional Conditions, (Uruguay 1973).

Plan	Expected Net Returns	Standard Deviation of Returns	97.5% Lower Bound	84.13% Lower Bound
	CX 1,000 Pesos	$(X'QX)^{\frac{1}{2}}$ 1,000 Pesos	$CX - 1.96(X'QX)^{\frac{1}{2}}$ 1,000 Pesos	$CX - 1.00(X'QX)^{\frac{1}{2}}$ 1,000 Pesos
1T	705	187.7	337.10	517.3
2T	3525.6	938.8	1685.5	2586.8
46 3T	6663	1779.2	3175.7	4883.8
4T	9828	2668.9	4596.9	7159.1
5T	12994.8	3558.6	6019.4	9436.2
6T	16160	4448.2	7441.5	11711.8
7T	19326	5337.8	8863.9	13988.2
8T	23634.9	6573	10751.8	17061.9
9T	25366	7822.1	10034.7	17543.9

Table 2. Expected Net Returns, Standard Deviation of Returns and 97.5 and 84.13 Percent Lower Confidence Bounds for a Typical Ranch in the Basaltic Zone worked under Improved Conditions, (Uruguay, 1973).

	Expected Net Returns 1,000 Pesos	Standard Deviation of Returns 1,000 Pesos	97.5% Lower Bound 1,000 Pesos	84.13% Lower Bound 1,000 Pesos
Plan	CX	$(X'QX)^{\frac{1}{2}}$	$CX-1.96(X'QX)$	$CX-(X'QX)$
1I	2217	1485.2	0	732
2I	6754	3012.7	849	3741
47 3I	10172	4225.5	1890	5947
4I	16124	6338.3	3700	9785
5I	22075	8451.1	5511	13624
6I	25553	9685.7	6569	15868
7I	28071	10606.4	7282	17465
8I	30139	11398.1	7799	18741
9I	33093	12890.8	7827	20202
10I	36328	15829.86	5301	20498
11I	38129	18671.2	1532	19458

84.13 percent LBR's for the traditional and improved models, respectively.⁴ Examination of the 97.5 percent LBR of expected net returns for the traditional model allows one to reject plans 1T through 7T, since movements along the upward sloping portion of the LBR imply increases in expected net returns as well as increases in the lower bound of returns. Only in the negatively sloping segment does the investor have to consider trading off greater expected return against reduced safety (Figure 2). Producers in the traditional system would consider plans 8T through 9T as their relevant alternatives (Figure 2, line A). Following the same reasoning, producers in the improved system would only consider plans 9I through 11I as the rational choices (Figure 2, line B).

For either system, the selection of a specific plan of production depends upon the individual risk preferences of the producer. In comparing both systems, no one system dominates the other in that it offers alternatives with both higher expected net returns and higher lower bound of expected returns. Under conditions of high risk aversion, traditional producers would not shift to the improved system because of a lack of willingness to take additional risks associated with the higher levels of expected returns.

The use of lexicographic utility functions as a decision criterion has been suggested in agricultural economics research (Halter and Dean, Berry and Robison). Assuming a lexicographic utility function such as that described in equation (3), the following conclusions can be drawn for a producer where survival level of returns needs to be attained with a probability of 97.5 percent (Figure 2):

(1) For survival level of returns above 10.7 million pesos, neither of the systems can meet the risk aversion goal⁵;

(2) if the survival level of returns falls between 10.7 and 7.8 million pesos, the producer would select the traditional system since the improved system will not ensure the survival level of returns at the desired probability level. According to the second objective specified in the lexicographic utility function, plan 9T will be selected; and

⁴According to Baumol, the higher the confidence level selected by the decision maker, the more conservative he must be considered since he must be taking into account less possibility of loss (Baumol, p. 180). Therefore, a producer that selects a 97.5 percent confidence level should be considered a relatively more conservative (higher degree of risk aversion) than a producer that selects an 84.13 percent confidence level.

⁵Barry and Robison suggest that in this situation the producer would presumably select the alternative that comes closest to meeting the risk aversion goal, which in this case is plan 8T in the traditional system.

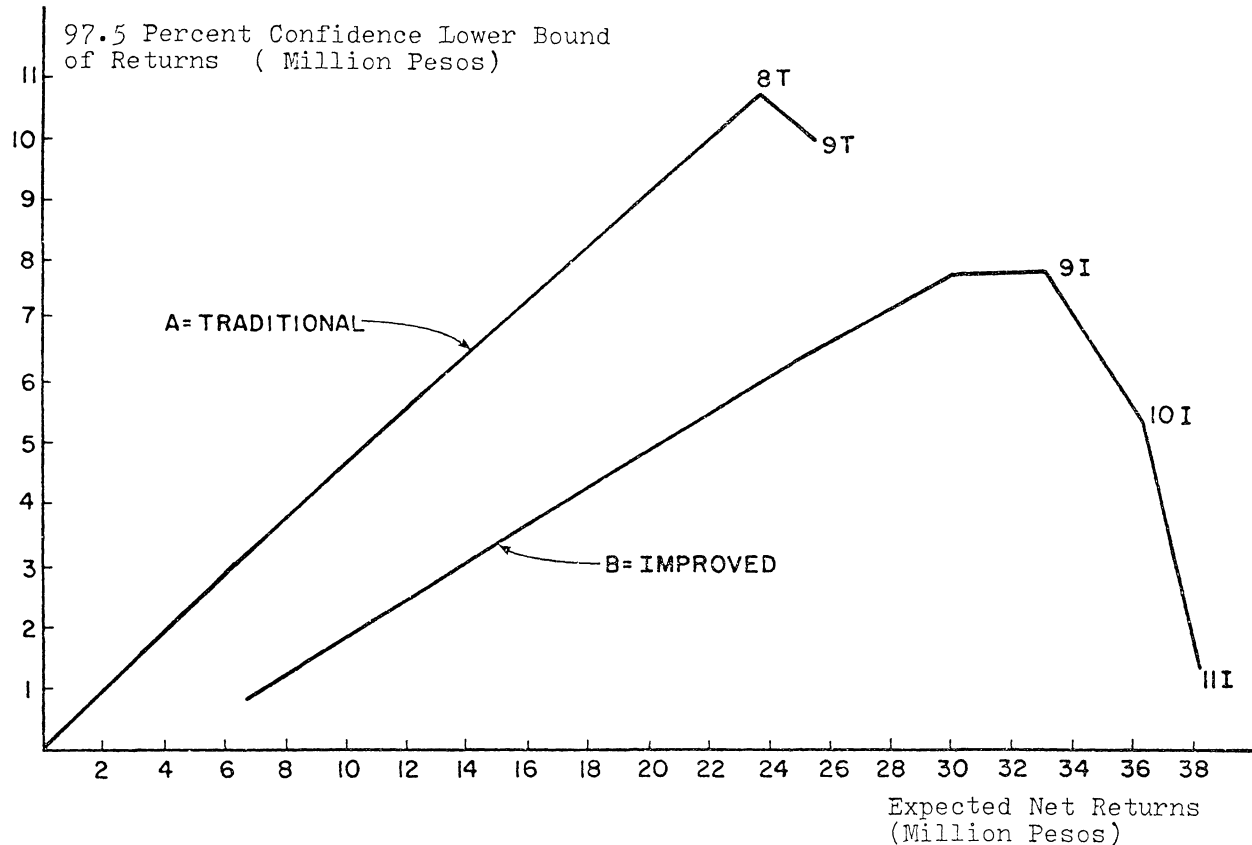


Figure 2. 97.5 Percent Confidence Lower Bounds of Expected Net Returns in the Traditional and Improved Systems of Production for a Typical Ranch in the Basaltic Zone

(3) for survival levels of returns below 7.8 million pesos, the producer selects the improved system since plan 9I satisfies the risk aversion goal and has higher expected net returns than any plan of the traditional system.

The analysis performed for a more liberal producer that seeks at least 84.13 percent confidence that his returns will not fall below the lower bound (one standard deviation below the expected returns) is depicted in Figure 3. In this case, the improved system dominates the traditional system since plans 10I and 11I offer higher expected returns and higher-lower bound of returns than any plan in the traditional system.

An analysis of the effect of parametrically changing the amounts of capital available for the improvement of pastures and to purchase additional cattle and sheep, indicates that restricted levels of capital result in lower levels of maximum expected net returns attainable. Under these conditions the decision of shifting to the improved system would still depend upon the individual producer's risk preferences, but would require a lower aversion to risk.

CONCLUSIONS AND POLICY IMPLICATIONS

The analysis of decision making under risk indicates that the adoption of new technologies for livestock production in Uruguay depends upon the specific risk preferences of the producer. As opposed to results obtained under the assumption of a profit maximizing behavior (linear programming results), decisions that include risk aversion as an objective do not show the improved livestock system to be necessarily a superior alternative. High degree of risk aversion, or survival levels of income above 7.8 million pesos could explain why livestock producers have been reluctant to adopt technologies in the past. Risk associated with price and yield variations appears to play an important role in producer decisions and under certain circumstances may be a decisive factor in the adoption of modern yield increasing technologies.

Since the favorable impact of widespread use of these modern technologies on producers' net returns and on Uruguay's balance of payments has been demonstrated in previous research, it follows that government policy directed toward reducing risks at the producer level would have a positive payoff. Diversification in the type of beef exports to include canned beef and cooked beef could partially avoid the country's direct dependence on world market fluctuations. This would tend to stabilize prices paid to ranchers. Another alternative would be to diversify geographically the destination of the country's exports. Forward contracting and bilateral agreements would also tend to reduce price variability.

Fertilizer price has been subsidized by the Uruguayan government in the past. Such subsidies could be directly used for input price stabili-

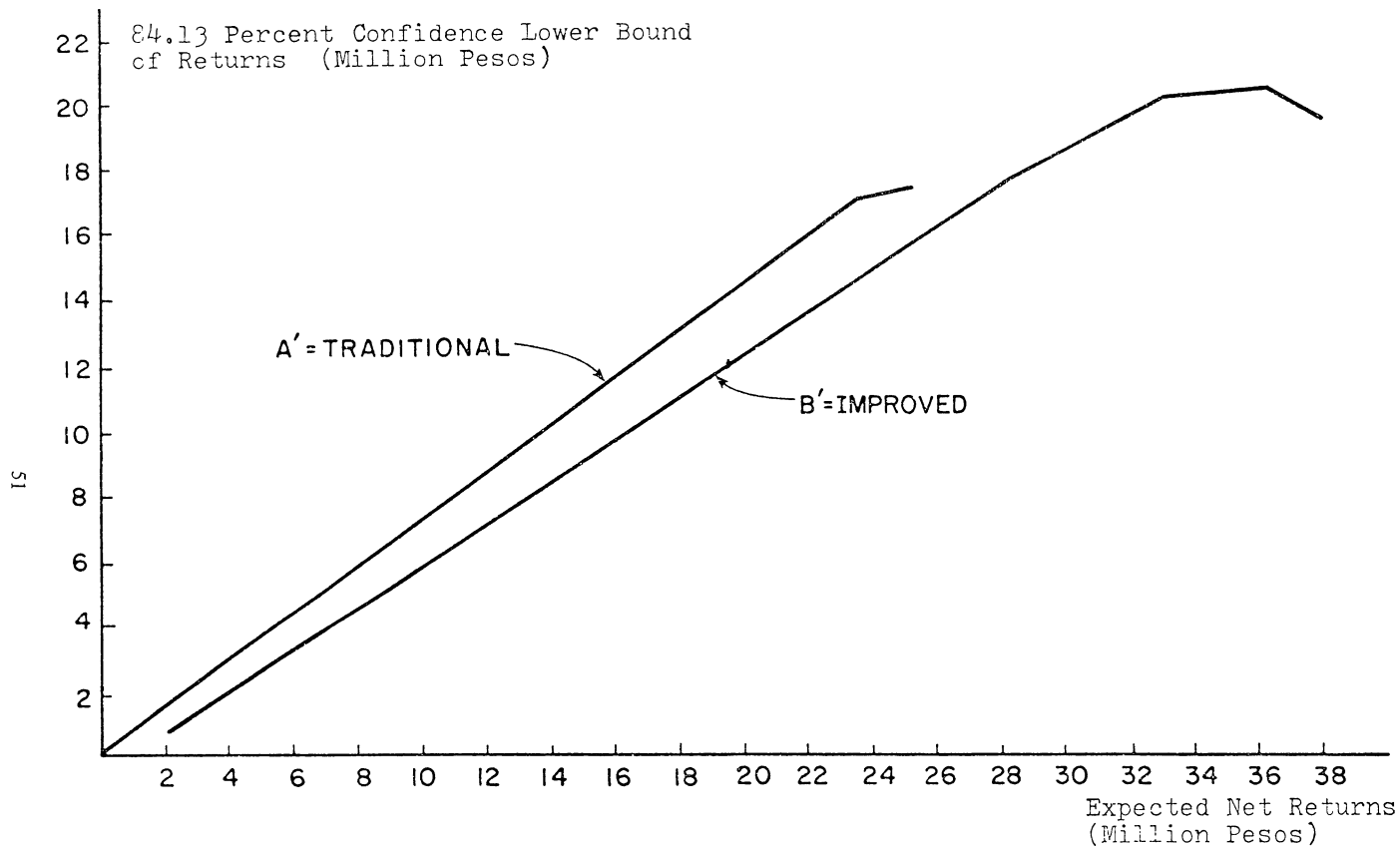


Figure 3. 84.13 Percent Confidence Lower Bounds of Expected Net Returns in the Traditional and Improved Systems of Production for a Typical Ranch in the Basaltic Zone

zation at the producer level. With respect to yield variations, differential tax policies and government sponsored insurance programs could be used to guarantee minimum levels of income high enough to enable conservative producers to adopt new technologies.

The need for further research to better understand the importance of risk on the decision environment of farmers is emphasized by the findings of this research. A significant finding of this study relates to the limitations of linear programming techniques as farm management decision making tools. This procedure ignores alternative combination of activities other than the profit maximizing solution. As indicated by the present research, such alternatives may yield a relatively small loss in returns with substantial reductions in variance of returns.

Limitations in the use of quadratic programming are related to the need to obtain reliable estimates of the variance-covariance matrix and the need for information about individual farmers risk preferences. It appears, however, to be a useful technique for understanding producer behavior and for providing assistance in actual farm management decision making where risk aversion is an objective of producers.

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