AN ANALYSIS OF DIVERSIFICATION ALTERNATIVES FOR WHEAT-STOCKER PRODUCERS THROUGH CULTIVAR SELECTION

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CHAPTER I

INTRODUCTION

Wheat-Stocker Production in Oklahoma

Climate, soils, vegetation, and other physical features combine together to provide Oklahoma with an opportunity for the joint production of wheat and stocker cattle. In most years, winter wheat provides high quality forage which is utilized by livestock from late-fall to early spring (Walker et al., 1988). In 1991, there were 7.4 million acres of wheat planted and 5 million acres harvested in Oklahoma (Oklahoma Agricultural Statistics, 1991). Previous studies have estimated that 30 to 70 percent of Oklahoma wheat acreage is grazed, with the majority of the state's wheat producing regions having grazing on more than 50 percent of their planted acreage (Harwell, 1976). It has been estimated that about 1.5 million stocker cattle are grazed in years when there are favorable weather conditions for wheat growth (Tweeten, 1982).

Wheat-stocker production provides a significant contribution to the Oklahoma agricultural economy. By grazing wheat forage produced during the early phases of wheat growth, producers may receive additional revenue with little or no adverse effects on wheat grain production (Croy, 1984). Over the past two decades, grazing stocker cattle on wheat pasture has been the most profitable cattle production enterprise available to Oklahoma stockmen (Bernardo and Wang, 1991). In 1991, cattle and calves had a value of production of approximately $1.5 billion while winter wheat had a value of production of $399 million. These two commodities constitute over 66 percent of the total value of all agricultural products for the state (Tarrant, 1993). Clearly, improved efficiency of the combined production of wheat and stocker cattle is requisite to the maintenance of a strong agricultural economy in Oklahoma.

The production activities involved in the joint production of wheat and stocker cattle enterprises can be categorized into planning, implementation and realization phases. In the planning phase, producers evaluate alternative enterprises and must select the production practices to be employed. Budgets may be developed to compare costs and returns of alternative enterprises. Based upon technical efficiency measures and cost-return relationships, the preferred enterprise or enterprise combinations are selected. In wheat-stocker cattle production, this process involves answering questions related to wheat variety, stocker cattle characteristics (breed, sex, background, etc.), acreage allocation, stocking density, purchasing and selling weight of cattle, and market arrangements such as forward contracting or hedging.

In the implementation phase of production, wheat-stocker producers undertake agricultural operations such as plowing, planting, harvesting, etc. in crop production and receiving, feeding, etc. in livestock production. Land preparation for wheat production is typically undertaken during the months of June and July. Planting date decisions are influenced by various factors. Wheat can be planted as early as mid-August and as late as December; but for maximum fall and early winter forage, a late-August planting date is recommended. Typically, small-grain forage crops are planted 4 to 6 weeks earlier than small grains intended for grain production to provide additional early season forage (Bruckner and Raymer, 1990).

The implementation phase also includes the grazing of cattle on wheat pasture. Grazing is initiated when 8-10 inches of top growth is present and sufficient root development has taken place (Donnelly and McMurphy, 1983). Typically, stocker cattle are placed on pasture in early-November (Tarrant, 1993). Many Oklahoma producers purchase English or English-cross stockers weighing between 400-500 pounds in late-August through September. The stockers are usually placed in a 10 to 30-day receiving program before they are placed on wheat pasture (Walker et al., 1988). In normal years, fall-winter grazing will last between 85 and 135 days, depending upon weather conditions and wheat crop development (Tarrant, 1993). Cattle are then combined on a smaller pasture during the spring graze-out period. Using a continuous grazing system, stocker cattle are typically grazed at a stocking density of 0.5 acres/head during spring grazing (Walker et al., 1988). Typically, average daily gains range from 1.75 to 2.25 pounds per day during fall and winter, and increase to approximately 2.25 to 2.75 pounds per day in the spring (Tarrant, 1993).

The utilization of wheat pasture for grazing depends on various factors. Government program payments, producer's financial conditions, and attitudes toward risk, all influence wheat pasture grazing decisions. Government program provisions can significantly alter the utilization of wheat pasture for grazing. Set-aside acres necessary for program compliance often offer producers opportunities to either graze-out stockers or produce a hay crop. Other program provisions, such as the 0-92 option allows producers the flexibility to allocate additional portions of their base acreage to grazing without sacrificing a significant share of their deficiency payment.

A wheat producer can also consider the option of leasing wheat pasture for grazing in order to utilize the forage resource. If the wheat producer does not want to purchase stocker cattle, but wishes some income from wheat forage, the wheat pasture can be leased to those in need of additional feed. Lease arrangements are useful for producers with limited financial resources to purchase cattle or for those who wish to decrease their exposure to risk. Most wheat pasture leases fall under one of three categories: $/cwt/month, $/pound of gain, or $/acre. The average price of each option fluctuates somewhat from year to year, reflecting current forage supply and demand conditions of the region (Tarrant, 1993).

The realization phase of production includes harvesting and disposal of agricultural products. Typically, wheat harvest occurs in June across the state of Oklahoma. The threshing, hauling and storing activities for crop production and transporting activities for both the crop and livestock production comprise a significant portion of the total cost of production.

Producers attempting to utilize the wheat forage resource face a challenging economic environment and several difficult decisions. First, and foremost, there are a number of competing enterprises which may utilize the same resources and generate a fairly competitive level of income. Rye, oats and triticale are examples of other small-grain enterprises that can be utilized for fall/winter forage production (Bruckner and Raymer, 1990). A number of alternative livestock enterprises can also utilize small-grain pasture. Any type of ruminant animal (horse, sheep, goats, etc.) can utilize wheat forage. Cow-calf producers utilize wheat pasture to a large degree to decrease winter feeding costs (Tarrant, 1993). In order for the combined production of wheat and stocker cattle to remain competitive, new methods with the potential to lower their costs of production must be introduced. This requires the consideration of alternative methods of production and estimation of the income expected from these alternatives. At the same time, it is necessary to also consider the income variability associated with these alternatives.

Problem Statement

The combined production of wheat and stocker cattle under conditions of risk and uncertainty is the central problem addressed in this study. Risk and uncertainty cause a reduction in the reliability of future levels of production and income. Uncertainty exists when expectations are within a range of possible outcomes, as opposed to certain yield or price outcomes (Rawlins and Bernardo, 1991).

Income instability results from production, marketing and financial uncertainties. Market uncertainty is caused by input and output price fluctuation. Pricing in wheat-stocker production systems is complex. Prices of wheat grain and stocker cattle determine the allocation of resources to each of the enterprises. When the price of wheat is high relative to the price of stocker cattle, producers may employ conservative wheat pasture grazing practices to avoid potential damage of the wheat crop by cattle. They may even eliminate the grazing enterprise under these conditions. In contrast, wheat can be produced for grazeout or a producer may stock heavy and/or keep livestock on wheat pasture for a longer period of time if cattle profitability is high relative to wheat. Since prices fluctuate, where to operate along this continuum is a problem requiring constant monitoring of cost and return relationships.

Production risk is very important in the production management decision-making process. The primary source of uncertainty in the production of both wheat and stocker cattle is derived from variability in the amount and timing of rainfall and other climatic variables which affect grain yield and the quality and quantity of forage produced.

Different wheat cultivars produce different levels of forage production in the early, mid- and late-season periods, principally due to variability in the cultivars' minimum temperature requirements for growth (Bruckner and Raymer, 1990). Lack of soil moisture and increased weed and insect populations are additional problems associated with insufficient precipitation. Forage crops are seriously damaged by insects, particularly in years with above-average fall and winter temperature (Bruckner and Raymer, 1990). The stocker cattle component introduces the added production risk of converting forage produced into pounds of beef. Associated with this conversion are uncertainties concerning genetics, disease, response to feed and several other variables (Rawlins and Bernardo, 1988).

Financial risk is the other principal source of risk that wheat-stocker producers face. Included among the factors that account for this added source of variability are: a) modified government programs for many U.S. commodities, b) rapid changes in crop inventories, c) devaluation of the U.S. dollar, d) variation in world production, and e) expanded and unpredictable fluctuations in foreign demand (Barry and Fraser, 1976).

From the foregoing discussion, it is obvious that wheat-stocker production is a risky process. A producer's attitude towards risk plays a great role in his/her choice among a number of uncertain alternatives. A risk averting producer will sacrifice some amount of expected income to reduce the probability of low income or loss. Given a choice of a certain return and a risky alternative with an expected return equal to the certain return, the risk averter will select the certain alternative. A risk neutral producer will select the alternative with the highest expected value, regardless of the probabilities of gain or loss. In contrast, a risk preferring producer choosing between two alternatives with equivalent expected values will select the alternative with the higher probability of high outcomes. Therefore, depending on their attitude towards risk, producers will differ in their selection of enterprise combinations and resource allocation.

Wheat-stocker cattle producers have several means at their disposal to cope with risk. Market risk can be reduced through the adoption of hedging strategies, forward contracting, and participation in government commodity programs. Maintenance of liquidity, financial reserves, and leverage management are popular approaches to managing financial risk. Means of reducing production risk include employing lower stocking densities, supplemental feeding when forage is in short supply, and leasing pasture to cattle operators. A risk management strategy that has not been well studied involves the selection of wheat varieties. Two risk management strategies related to the selection of wheat varieties are introducing improved cultivars, or diversifying by producing several wheat cultivars in the same production year.

Plant breeders release improved seed of wheat varieties after breeding and evaluating performance for a number of years. Table 1.1 shows a list of important wheat varieties which have been produced in Oklahoma from 1954 to 1990, and the percentage of wheat acreage planted to each variety. Most varieties are not continually produced on a significant share of acres for more than 15 years, and there is a continual change in the number of acres devoted to a single variety over time. The average life of a variety is approximately 10 years. Farmers continually seek to increase their efficiency and/or reduce their risk of loss by dropping unreliable varieties and shifting to new and improved varieties.

A wheat-stocker producer must be concerned with several different aspects of cultivar selection, including the interrelationship and balance between the grain and stocker cattle components of the production system. New and different production

Table 1.1 Oklahoma Wheat Varieties and Percentage Seeded Acreage, 1954-90

Variety	1954	1959	1964	1969	1970	1971	1972	1973	1974	1975	1976	1979	1984	1986	1990
Triumph Group	40.5	59.0	64.9	58.8	53.0	52.5	51.1	44.8	37.6	36.1	32.4	23.9	6.4	5.1	0.0
Improved Triumph	0.0	0.0	26.5	30.8	21.8	18.1	20.7	21.0	15.8	14.1	15.2	0.0	0.0	0.0	0.0
Triumph	0.0	0.0	26.6	17.8	20.5	20.7	18.1	10.2	0.0	0.0	0.0	11.3	1.5	1.9	2.3
Triumph 64	0.0	0.0	4.1	4.8	6.9	9.4	8.3	10.3	9.5	12.1	13.7	12.6	4.9	3.2	0.0
Super Triumph	0.0	0.0	7.7	5.4	3.8	4.3	4.0	3.3	12.3	9.9	3.5	0.0	0.0	0.0	0.0
Scout	0.0	0.0	0.0	14.8	21.7	17.8	18.4	18.7	19.3	17.5	16.8	11.1	4.7	4.2	2.5
Danne	0.0	0.0	0.0	0.0	0.0	0.0	1.6	6.7	9.9	9.1	7.6	3.2	0.8	0.4	0.0
Sturdy	0.0	0.0	0.0	0.0	4.4	7.8	9.1	6.6	6.6	6.0	6.6	0.0	0.0	0.0	0.0
Sage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.1	0.0	0.8	0.5	0.0
Wichita	19.0	21.0	14.4	9.7	7.9	9.5	4.8	4.4	3.8	3.8	2.6	0.0	0.0	0.0	0.0
Centurk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.8	5.0	3.5	0.0	0.0	0.0	0.0
Agent	0.0	0.0	0.0	0.5	1.5	0.6	2.2	3.2	2.9	1.8	1.0	0.0	0.0	0.0	0.0
Caprock	0.0	0.0	0.0	0.0	0.2	0.8	1.2	1.7	2.7	3.1	3.0	0.0	0.0	0.0	0.0
Tam W101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.6	8.2	16.6	35.8	30.2	20.5	5.9
Palo Duro	0.0	0.0	0.0	0.0	0.0	1.1	1.2	1.8	1.6	1.3	0.8	0.0	0.0	0.0	0.0
Yukon	0.0	0.0	0.0	0.0	0.4	2.2	2.2	1.9	1.6	1.0	0.5	0.0	0.0	0.0	0.0
Concho	0.0	8.2	3.2	3.0	1.5	1.9	2.9	1.9	1.4	1.7	1.0	0.0	0.0	0.0	0.0
Tam W103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.0	0.0	0.0	0.0
Kaw 61	0.0	0.0	11.3	9.3	4.0	3.2	2.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pronto	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tenmarq	1.7	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turkey	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blackhull	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Comanchie	9.6	3.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pawnee	4.8	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Variety Unknown	23.5	5.8	4.7	3.9	5.4	2.6	1.2	3.9	6.2	4.7	4.6	14.1	7.4	9.4	3.2
Vona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	22.9	7.9	0.7
Payne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.0	3.1	1.2
Wings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.6	2.3	0.0

Table 1.1 (Continued)

Newton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.3	2.0	0.6
Osage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.8	0.6	0.0
Chisholm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	23.1	30.8
Mustang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.7
Hawk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	4.2	0.0
Pioneer Group	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.7	0.0
Pioneer 2157	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	29.2
Other Pioneer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.5
Tam 105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	3.6	1.4
Wrangler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
Arkan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.5
Northrup King 812	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.0
Mesa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
Pioneer 2180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2
Siouxland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Century	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Stallion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Thunderbird	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Tam 200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Hawk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Tam 107	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Other Hard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6
Soft Variety	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8

technologies must be evaluated as to their effect on the entire system and not just one isolated component. Analysis of individual components of the production system can result in overlooking important interactions between production segments, and thus result in inefficient decisions. Also, changes in the relative profitability of grain production versus livestock grazing can alter variety selection decisions over time.

Another risk management practice is to produce several cultivars in a single production season. Wheat cultivars differ in their growth characteristics. The varietal characteristics in which the cultivars may differ include maturity, plant height, disease and insect resistance and winter hardiness (Johnston et al.). Heat, frost, lodging, insect infestation and cold injury are some of the threats that cultivars may escape due to their inherent characteristics. It is difficult to predict which of these problems will occur during the production period of wheat; thus, one way to manage such uncertainty is to diversify with cultivars that have different characteristics. Because wheat-stocker producers are concerned with both grain and forage performance, one might expect a greater number of cultivar characteristics to influence economic performance than if grain production was the only concern. Therefore, diversification opportunities through cultivar selection may be increased relative to a setting where crop production is the sole concern.

Diversification requires moving away from monoculture crop production into multi-crop crop production which may be more profitable or at least may have a greater profit potential (Teague and Lee, 1988). Diversification is usually thought of in terms of enterprises; however, one can also diversify by employing different production practices within the same enterprise. For example, among available wheat varieties are early-, medium-, and late-maturing cultivars. Planting varieties with these characteristics provides the opportunity that one or more of the cultivars may escape damage if one of the natural calamities occurs. Such farm plans provide security of income. According to Hazell and Norton (1986) farmers who behave in a risk-averse way prefer farm plans that provide a satisfactory level of security even if this means sacrificing income on average. More secure plans may involve producing less of risky enterprises, diversifying into a greater number of enterprises to spread risks, and using established technologies rather than venturing into new technologies. The decision of farmers to plant several cultivars is consistent with Hazel's notion regarding the behavior of risk-averse producers.

Objectives of the Study

The general objective of this study is to evaluate potential diversification opportunities for wheat-stocker producers through cultivar selection. The specific objectives are:

1. to evaluate selected wheat pasture management and stocker production alternatives and analyze their farm-level interaction on a representative central Oklahoma farm;
2. to estimate the expected value and variability of net returns from wheat and stocker production using alternative wheat cultivars; and,
3. to estimate risk efficient combinations of wheat and stocker production enterprises for producers characterized by alternative risk preferences and economic conditions.

Procedures

This study will utilize a mathematical programming approach to determine risk efficient combinations of wheat and livestock enterprises for wheat-stocker producers in central Oklahoma. The first step in developing the programming model will require the collection of technical relationships of forage and grain response to alternative wheat varieties. The principal data source for this information will be a three-year wheat variety study conducted at various locations across central Oklahoma. This information will be combined with cost and price information to estimate expected returns and costs for alternative wheat varieties. Data reporting resource requirements and production levels of various stocker production alternatives will also be collected. Forage requirements, input levels, and livestock gains will be estimated from a combination of available experimental data and National Research Council (NRC) net energy and intake relationships. These data will be coupled with historic price data to estimate economic returns from the various enterprises under alternative environmental and market conditions.

A Target-MOTAD model will be developed to select the risk efficient combinations of wheat and cattle enterprises under alternative risk attitudes and economic conditions. Activities in the model will consist of wheat production activities (grain and forage production for each cultivar) and stocker grazing alternatives. Wheat production alternatives will include the production of different varieties, which provide different grain and forage yields. The concept of Target-MOTAD model formulation is based on the assumption that decision makers wish to maximize expected returns, but are also concerned about net returns falling below critical target levels (Hazell and Norton, 1986).

The Target-MOTAD model will first be formulated using forage and grain production data from experimental variety trials. Risk efficient solutions will be derived for alternative risk preferences as dictated by the target income level and permissible deviation from the target.

Use of experimental data has several limitations in representing the production risk and production alternatives available to producers. In order to better represent production risk in the Target-MOTAD model, crop simulation will be used to provide forage and grain yield data. The CERES-Wheat model will be used to incorporate weather uncertainty into the Target-MOTAD model. To validate the CERES-Wheat model for the study area, simulations will be conducted for each site/year combination included in the wheat variety trial data. To determine the set of parameters used to describe each variety, genetic coefficients in the simulation model will be parametrically varied, and grain and forage yields will be estimated for the 9 site/year combinations. Genetic coefficients which provide the "best" estimate of grain and forage yield for each variety will be statistically determined. The Target-MOTAD model will be reformulated using the simulated grain and forage production data, and new risk efficient solutions estimated.

Organization of the Study

The remaining chapters will present in greater detail how the objectives of the study are accomplished. A review of relevant literature and economic theory addressed in the study will be provided in Chapter II. Specifically, the review will include discussion of previous research on the topics of variety evaluation, diversification, and the economics of wheat grazing. The review will also integrate relevant economic theory with the techniques and findings of the previous studies.

Chapter III will focus on development of the farm-level economic model. Alternative mathematical programming techniques used in identifying risk efficient farm plans will be discussed. The Target-MOTAD mathematical programming framework used in this analysis for determining optimal farm plans will then be presented.

Description of the data will be presented in Chapter IV. Physical and economic data required to generate enterprise budgets and used in determining risk efficient farm plans will be summarized. Generally, the categories of data include actual forage and grain yields, simulated forage and grain yields, livestock production data, and economic data. The characteristics and components of the CERES-Wheat simulation model will be outlined, and emphasis will be placed on the validation and application of the model to cultivar selection.

Chapter V will include a discussion of model application and analysis of results. Risk efficient farm plans developed from application of the Target-MOTAD model to a representative farm in central Oklahoma will be presented. A comparison of results using observed and simulated wheat production data will also be presented.

The final chapter will consist of a summary of the analysis of the results and an evaluation of the achievements of the stated objectives of the study. Specifically, it will include a summary of the method of analysis, results, and general conclusions. Limitations of the study and the need for further research will also be addressed.

CHAPTER II

REVIEW OF RELEVANT ECONOMIC THEORY AND LITERATURE

The production of wheat and stocker cattle is an extremely complex production system involving dynamic processes and multiple enterprise interactions. The joint production of wheat and stocker cattle is characterized by a large amount of production risk, and this risk is often a major factor in limiting the efficient use of the wheat pasture resource. Producers face several short-term and long-term decisions which influence the productivity of both their wheat and stocker cattle enterprises. The principal decisions considered in this analysis concern variety selection and the potential use of varieties as a means of diversification to reduce income variability. Economic theory and literature germane to this problem is presented below. Theoretical considerations in the joint production of wheat and stocker cattle are first discussed and followed with a review of previous economic studies of the wheat pasture enterprise. Next, a theoretical treatment of the variety selection decision is provided, and alternative methods for comparing varieties is given. Finally, the economics of diversification as a risk management tool are discussed. A review of previous applications of various research tools to evaluate diversification opportunities concludes the chapter.

The Economics of Wheat Pasture Grazing

The usual illustrative technique applied to the product-product relationship in economics is the production possibility curve. Harwell (1976) applied this concept to the production of both grain and grazing from a given tract of wheat land, as illustrated in Figure 2.1. The vertical axis measures wheat produced in bushels, while the horizontal axis marks the output of grazing in animal unit months. Line ABCE traces the various combinations of production that are possible from the given acreage of land and other fixed resources. The application of the production possibility curve to this application is somewhat misleading, however, because it ignores the dynamics of wheat pasture grazing. Utilization of wheat pasture can be increased in two principal ways: (1) by increasing the stocking density during the fall-winter grazing season, or (2) by increasing the duration of the grazing season. Each of these alternatives has very different implications on the shape of the production possibility curve.

If grazing is increased by prolonging the grazing season, the production possibility curve might resemble ABCD. OF represents the AUMs of grazing available prior to jointing using a conventional stocking density. The grazing of wheat into the jointing stage severely reduces grain yields (Tarrant, 1993). Therefore, additional grazing would significantly lower grain yields until eventually point D is reached, where yields are zero. Additional grazing may be available through the graze-out period, and OE units of grazing would be obtained. It follows that if more than OH bushels of grain are desired, it would be necessary to terminate wheat pasture at a date prior to jointing, and this would reduce grazing output to less than OF. In this example, wheat and beef enjoy a supplementary relationship prior to some point in mid-March. If grazing activity occurs past jointing, however, wheat and beef rapidly adopt a competitive relationship.

If grazing is increased by increasing the stocking density, the production possibility curve might be represented by ABCE. In this case, grain yield reductions

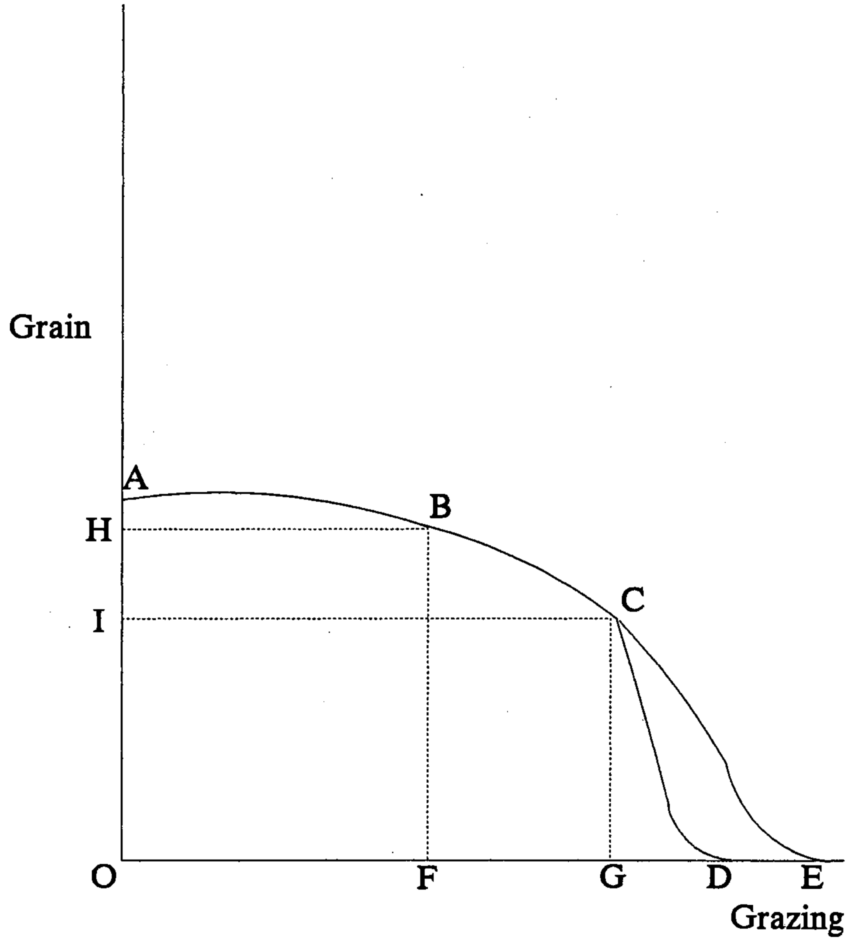

Figure 2.1. Production Possibility Curves Between Grain and Grazing From One Unit of Wheat Land in One Cropping Season.

occur at lower levels of grazing, but are not as dramatic as when grazing occurs past jointing.

Harwell (1976) also discussed the implications of early planting on the shape of the production possibility curve. Some producers plant wheat earlier, perhaps in mid- to late August, in order to initiate pasturing activity sooner. The practice realizes more per-acre nutrient production prior to the onset of cold mid-winter weather, when wheat tends to go into a semi-dormant stage. The production possibilities curve represented by AB in Figure 2.2 shows a complementary range between the two products when wheat is seeded early. The diagram also indicates that grain potentials are probably not as high in early seeded wheat (as compared to Figure 2.1) but that grazing capability is benefited. Lush, ungrazed wheat excessively depletes moisture during the fall months and is more susceptible to mid-winter freeze damage; both phenomena are detrimental to grain yields (Harwell, 1976).

According to Harwell, during years of drought, prospects for a grain crop are markedly diminished and it has become customary to harvest the wheat with cattle rather than risk a complete crop failure. Production possibilities curve CD in Figure 2.2 indicates that not only is grain potential much less because of drought, but grazing output may also curtailed. Again, this treatment ignores the dynamics of the production system. Drought may occur any time during the production season, and the timing of the drought significantly affects the shape of the production possibility curve. A drought in the fall and winter may significantly limit grazing, but only marginally impact grain yields.

The production possibility curve may be used to determine the optimal trade-off between grain and grazing. The product-product model may be expressed in terms of a fixed outlay of costs; that is, the product transformation curve depicts combinations of

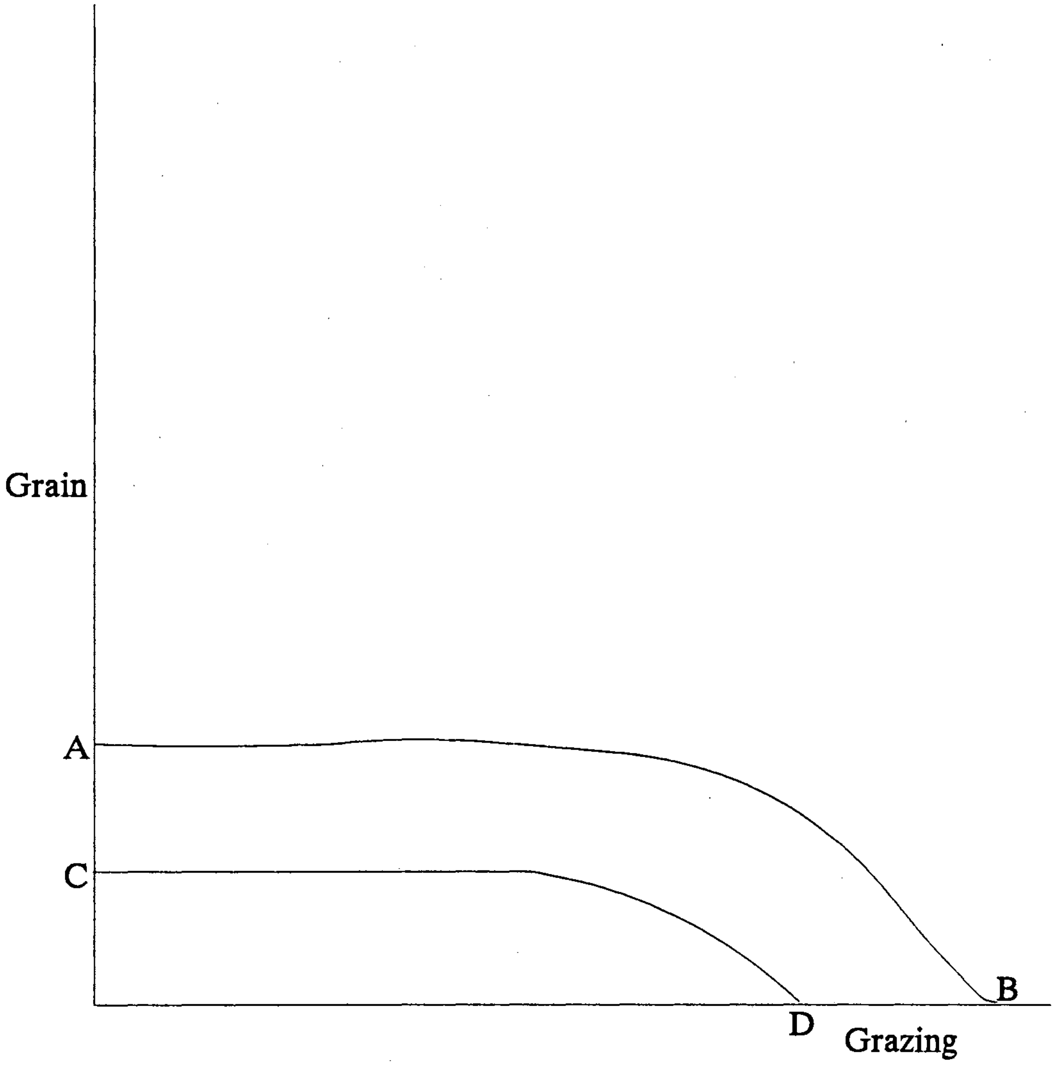

Figure 2.2. Production Possibility Cruves Between Grain and Grazing From Early Seeded Wheat Land and in Drought Conditions.

products (grain and forage) that can be produced at a given cost outlay. The goal is to maximize revenue to the given costs, which means that the maximum profit point occurs at the point of maximum total revenue. Figure 2.3 depicts both costs and returns graphically. Line AD represents all the combinations of grain and grazing that can be produced on a tract of land at a given cost outlay, since the resources contributing to production are held constant. The slope of a revenue line is determined by the ratio of product prices. Although the slopes of revenue lines PP and P'P' are determined by the price of wheat and pasture, their precise position is determined by the amount of revenue which is derived from wheat and stocker production on the tract of land. Per-acre revenues from the grain crop exceed those from grazing in the case of line PP, whereas line P'P' indicates a situation where the price advantage lies with pasturing the wheat. At the combination of products where the revenue line is tangent with the production possibility curve, revenues are at maximum. Such a situation is shown in Figure 2.3 for the two price situations at points B and C.

Mathematically, the production problem can be viewed as a non-separable process with input control. The two production processes may be expressed as:

$$\begin{aligned} y_c &= f(X_c) \\ y_w &= g(X_w, y_c) \end{aligned} \tag{2.1}$$

where, y_c and y_w are the total production levels of cattle and wheat and X_c and X_w are the input vectors for cattle and wheat, respectively. Technical interaction between the two products is present in that $\partial y_w/\partial y_c < 0$ beyond some crucial level of y_c. Given a fixed set of resources, $\bar{x}$, the production processes can be represented using a product transformation function, $\bar{x} = h(y_c, y_w)$.

Maximizing revenue from the resource base yields the objective function:

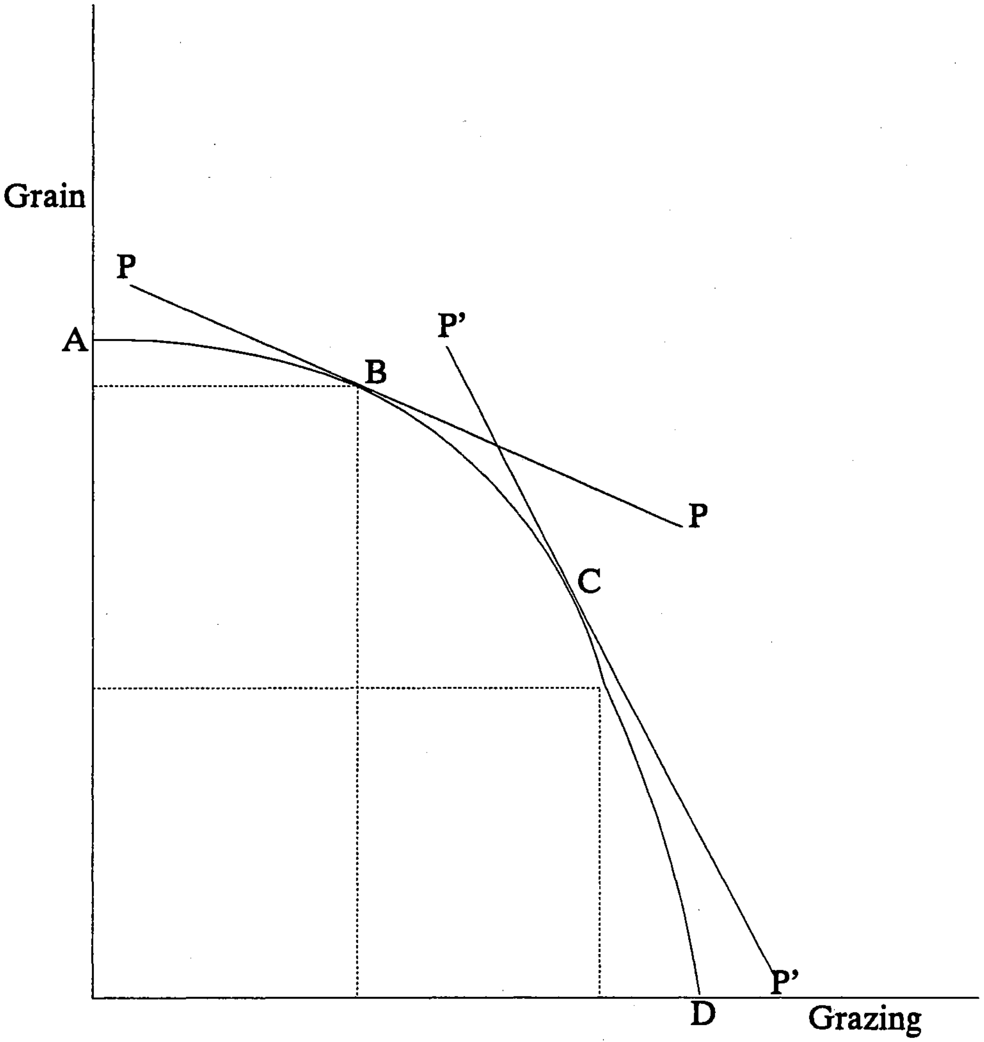

Figure 2.3. Aggregate Production Possibility Curve Between Grain and Grazing From Wheat Production.

$$L = P_c y_c + P_w y_w + \lambda(\bar{x} - L(y_c, y_w)) \qquad (2.2)$$

where, P_c and P_w are the values of a unit of y_c and y_w, respectively. Solution of the first-order conditions yields the following optimality condition:

$$P_c/P_w = L_c/L_w \qquad (2.3)$$

where $Lc = \partial L/\partial y_c$ and $Lw = \partial L/\partial y_w$.

As illustrated in Figure 2.3, revenue maximization implies that the slope of the product transformation function equals the slope of the iso-revenue line.

Review of Previous Economic Analyses of Wheat Grazing Systems

Despite the importance of wheat pasture grazing in the Southern Great Plains, there have been limited research applications focusing on the economics of the wheat pasture production system. While several more general livestock modeling efforts have incorporated the wheat pasture component, few studies have focused exclusively on wheat pasture decision making.

Harwell (1976) developed a recursive linear programming model to predict aggregate response of wheat-stocker producers to changes in environmental , economic, and policy variables. This study involved characterizing wheat grazing activity through a survey of extension specialists throughout the Southern Plains. Interdependence in the wheat and beef cattle enterprises was shown to be important in intertemporal adjustments to selected price and policy forces.

Rodriguez et al. (1988) developed a Wheat Grazing Systems (WGS) model to conduct economic analyses of wheat-stocker cattle production systems in the Southern Plains. The model combines the CERES-Wheat crop growth simulation model with a stocker intake-growth model to represent the combined wheat-stocker production system. Wheat growth and phasic development are simulated on a daily basis using climatic, hydrological, phenological, and biophysical relationships. A wheat-stocker interface subroutine is called at various stages of crop development to determine stocker intake and performance, as well as the effect of grazing on the wheat plant.

The effect of grazing on grain yield was represented by reducing the leaf area index (LAI), which affects plant growth by reducing carbon fixation, increasing soil evaporation, and decreasing transpiration as well as the rate of leaf area senescence. Grazing also affects the rate of ear growth, grain filling, and ultimately, grain yield by reducing the accumulation of above ground biomass in the average wheat plant. Analysis of observed and predicted data of three winter grazing seasons under different grazing treatments showed that the Wheat Grazing System (WGS) model correctly predicted the general pattern of declining grain yield as the grazing period was lengthened. The observed and predicted grain yields were correlated with an r^2 of 74%.

National Research Council (NRC) procedures were used to determine the weight gain from grazing stocker cattle. Average daily gain per steer was predicted as a function of net energy available for gain and live weight. The model was evaluated by comparing observed and predicted data of weight gain of three grazing seasons. The observed and predicted weight gain were correlated with an r^2 of 79%.

The same authors used the WGS model to investigate the risk associated with stocking density, and beginning and termination date of the grazing season when weather was a source of variation in the system. A total of 91 combinations of beginning/ending dates of the grazing season and stocking densities (managerial strategies) were considered. Each was simulated under typical management conditions of western

Oklahoma for fifty grazing seasons using a stochastic daily climatic simulator. Stochastic dominance analysis was used to select efficient strategies assuming the producers were utility maximizers and utility was a function of net returns. Optimal stocking densities were shown to be sensitive to producer risk preferences, ranging from 0.6 steer/ha for risk averters to 2.7 steer/ha for risk neutral decision makers. A grazing season spanning from November 1 to March 15 was efficient under all risk preferences.

Honeycutt (1988) modified the Wheat Grazing Systems model to determine the optimal level of supplemental forage stocks with which to start the winter grazing season given alternative stocking rates, weather uncertainty, and seasonal variations in hay prices. Lower stocking densities produced average net revenues which were lower in variability, and reduced the importance of producers' decisions regarding the quantity of forage stocks to maintain. Higher stocking densities increased average net returns, but increased variability. Decisions concerning forage stocks prior to the season become much more important under these strategies.

Tarrant (1993) combined experimental data with economic models to determine strategies for selecting grazing termination dates for wheat pasture stockers. Grazing past jointing date diminishes grain yield and removal of cattle too early results in an opportunity cost of lost livestock revenue. Tarrant estimated jointing dates and grain yield using the CERES-Wheat crop simulation model. These data were combined with experimental data from a grazing termination study to determine the effect of livestock grazing past jointing date on grain yield. The penalty function was applied to potential grain yields estimated from CERES-Wheat to determine actual grain yields if grazing occurred after jointing.

To determine the economic significance of jointing date information, the authors compared the expected net return earned from using the forecast optimally and net returns earned under calendar date strategies. Total net returns under alternative grazing termination date strategies were estimated using wheat and stocker production budgets based upon the adjusted grain yield and livestock production. Generalized stochastic dominance (GSD) procedures were used to determine the risk efficient set of alternative cattle removal date strategies and to determine the value of information.

The analysis indicates that even when jointing prediction errors were considered, the jointing date termination strategy generated higher expected net return levels than any of the calendar date strategies. Tarrant (1993) found that the value of information was shown to be sensitive to prior knowledge assumed. When prior knowledge dictated the use of an early grazing termination date, the jointing date information took on an extremely high value for the risk preferrer. When prior knowledge dictated the use of a later termination date, the risk preferrer was less willing to pay for the information because of the higher probability of attaining high net returns under the calendar date strategy. For the strongly risk averse producer, the reverse circumstance occurred. The jointing date information had a much higher value to the strongly risk averse producer when prior knowledge dictated the use of a later termination date.

The Economics of Variety Selection

Wheat varieties are production technologies. As with any technology, new varieties are continually introduced and existing ones disappear as producers attempt to improve the efficiency of agricultural production. Risk is an important consideration in evaluating the technology adoption decision. Because of past experience, the use of the existing technology is considered safe, while the use of the new technology is considered risky.

The choice between existing and new technologies (varieties), or the use of a combination of the two technologies (varieties) depends on the attitude of the producer towards risk. Following procedures outlined in Robinson and Barry (1987), a firm-level decision model may be developed to analyze the variety adoption decision. Assume the firm's resource base L (e.g., land) may be divided between the new and the existing varieties. For simplicity, assume the net return, R_2 per unit of L using the existing technology is assumed to be risk-free and net return per unit of L using the new variety is assumed to be a random variable and may be expressed as $R_1 + \epsilon$. That is, net return from the new variety may be expressed as having a certain component (R_1) and a risky component (ϵ) with mean zero and variance σ_ϵ^2.

In maximizing utility, the firm must optimally allocate the resource base between a risky and a safe alternative. Assuming L is fixed and s units of L are allocated to the new variety, the expected income is stated as follows:

$$E(y) = R_1 s + R_2(L-s) \tag{2.4}$$

and variance of income is:

$$\sigma_y^2 = s^2 \sigma_\epsilon^2 \tag{2.5}$$

The certainty equivalent income is written as:

$$\max\ Y_{CE} = R_1 s + R_2(L-s) - \frac{\lambda}{2} s^2 \sigma_\epsilon^2 \tag{2.6}$$

Taking the first derivative of equation 2.6 with respect to s and solving for s yields the optimal allocation between the two varieties.

$$s = \frac{R_1 - R_2}{\lambda \sigma_\epsilon^2}\ for\ 0 \leq s \leq L \tag{2.7}$$

The quadratic nature of the risk factor guarantees that s in equation 2.7 is an optimal value. Moreover, expression 2.7 shows that the expected return from the new technology must exceed the safe return from the existing technology for the new technology to be adopted (s > 0).

According to Robinson and Barry (1987), the rate of variety adoption (s) is reduced by increases in risk aversion or by increases in the perceived riskiness of the new variety, at least for decision makers characterized by constant or decreasing absolute risk aversion. These results may be mathematically expressed as follows:

$$\frac{ds}{d\lambda} = \frac{-(R_1 - R_2)}{\lambda^2}\sigma_\epsilon^2 < 0 \qquad (2.8)$$

$$\frac{ds}{d\sigma_\epsilon^2} = [-\frac{(R_1 - R_2)}{\lambda(\sigma_\epsilon^2)^2}] - [\frac{(R_1 - R_2)}{\sigma_\epsilon^2\lambda^2(\frac{\partial\lambda}{\partial\sigma_\epsilon^2})}] < 0 \qquad (2.9)$$

where $\frac{\partial\lambda}{\partial\sigma_\epsilon^2} > 0$ for decision makers having decreasing absolute risk aversion, and $\frac{\partial\lambda}{\partial\sigma_\epsilon^2} = 0$ for decision makers having constant absolute risk aversion.

Review of Previous Evaluations of Variety Rankings and Stability

Risk efficient cropping patterns and diversification require moving away from monoculture crop production into a multi-crop production which may be more profitable or at least may have a greater profit potential (Teague and Lee, 1988). Wheat-stocker producers may be able to produce different cultivars of wheat as a means of managing risk in their operations. Genotype-environment studies have shown different varieties performance in both grain and forage production (Bruckner and Raymer, 1990; Eskridge, 1990; Eberhart and Russell, 1966). These studies have focused on the stability of a variety's performance across environments and have attempted to rank varieties based upon their yield variability.

Eberhart and Russell (1966) used regression analysis to evaluate the stability of corn cultivars across environments. These authors indicated that identifying the superior variety was difficult in the presence of genotype-environment interaction because when varieties were compared over a series of environments their relative rankings were usually different. Thus, the authors first made preliminary selections to identify varieties that interact less with the environment, and then applied a model to rank varieties for stability. The following model was employed to define the stability parameters used to describe the performance of a variety over a series of environments.

$$y_{ij} = M_i + B_i I_j + \sigma_{ij} \tag{2.10}$$

where:

y_{ij} = variety mean of the i^{th} variety at the j^{th} environment,

M_i = the i^{th} variety mean over all environments,

B_i = the regression coefficient that measures the response of the i^{th} variety to varying environments,

I_j = the environment index, and

σ_{ij} = the deviation from regression of the i^{th} variety at the j^{th} environment, and

The stability parameters were estimated by regressing each variety on the environmental index-average yield of all varieties in a particular environment. The stability parameters were the regression coefficients (B_i) and the sum of squared deviations (σ_{ij}). A stable variety was one with regression coefficient ($B_i = 1$) and the deviation from the regression as small as possible ($\sigma_{ij} = 0$).

The analysis indicated that genetic mixtures (heterogeneity) possess greater stability of production, broader adaptation to environment and greater protection against disease than single lines. Application to a set of maize yield trials showed that the difference in stability of two single lines was due to the different response of the lines to varying environments, and hybrids are superior in stability than the single lines.

Eskridge (1990) used a Kataoka safety-first model in his genotype-environment interaction study to select stable cultivars and established different selection indices depending on the range of environment under which the trials were conducted. Four selection indices to rank cultivars were identified; in each case, the cultivar with the largest value was preferred (Table 2.1). Application of this model requires one to estimate each cultivar's mean yield and stability, as well as to assume a specified value of α, the utilization of which provided a lower confidence limit which represents the lower yield that could occur with an $\alpha\%$ chance. The authors employed the EV index when the trials were conducted in environments which were restricted; FW and SH indices were used when the trials were conducted over a diverse set of environments, and ER index was used to compare a given set of cultivars over a broad range of environments. Also, rank correlation between the mean and index rankings was estimated to quantify how similarly the indices rank the entries. Results indicated that the FW, SH and ER indices all produced similar entry rankings; however, the EV index produced rankings which were poorly correlated with those of the other indices.

Eskridge, Byrne and Crossa (1991) used Roy's safety-first model to rank cultivars in the presence of genotype-environment interaction. In using this model, the authors estimated each variety's mean yield and stability as well as assumed some minimum acceptable yield value, d, and selected the variety of producing a yield that was less than or equal to d. Three different selection indices (Table 2.2) were identified. The authors calculated rank correlation to quantify the similarity of entry rankings when d was set at

Table 2.1.Safety-first selection indices with four definitions of stability

	Stability Definition	Index form for cultivar i	Abbreviation
1.	variance across environments	$\bar{Y}_i - Z(1-\alpha)S_i$	EV
2.	Finlay and Wilkinson's regression coefficients	$\bar{Y}_i - Z(1-\alpha)[(b_i-1)^2S_y^2(1-\frac{1}{q})]^{1/2}$	FW
3.	Shulka's stability variance	$\bar{Y}_i - Z(1-\alpha)[\hat{\sigma}_E^2 + \hat{\sigma}_r^2]^{1/2}$	SH
4.	Finlay and Wilkinson's regression coefficients	$\bar{Y}_i - Z(1-\alpha)[(b_i-1)^2S_y^2(1-\frac{1}{q}) + S_{ji}^2]^{1/2}$	ER

Table 2.2. Selection indices which minimize the probability of disaster based on three different definitions of stability.

Stability Definition	Index form for cultivar i	Abbreviation
1. Shukla's (1972) stability variance	$[\bar{Y}_i - d]/\hat{\sigma}_i$	SH
2. Eberhart and Russell's (1966) approach	$[\bar{Y}_i-d]/[(b_i-1)^2S_y^2/1-\frac{1}{q}) + S_{\sigma i}^2]^{1/2}$	EK
3. Finlay and Wilkinson's (1963) approach	$[\bar{Y}_i-d]/[(b_i-1)^2S_y^2(1-\frac{1}{q}]^{1/2}$	FW

3.2 t/ha. The rank correlations for the SH and ER indices were larger than 0.7 and larger than 0.9 for the FW index, indicating consistent entry orderings for all values of d. The mean yield produced rankings different from FW, SH, and ER and most of the rank correlations were less than 0.4. Based on these results, the authors concluded that the inclusion of a measure of stability (or risk) might markedly alter the rankings of varieties compared to considering only the mean yield.

Bruckner and Raymer (1990) evaluated forage production characteristics of cultivars for four small-grain species, including rye, wheat, triticale and oats. Forage yield trials were conducted for 12 cultivars for each of the four species in 12 environments to evaluate cultivars for average and potential yield dependability of production and seasonal forage distribution. The results indicate significant differences in total forage production and seasonal distribution of forage production. Differences were mainly attributed to variability in each cultivar's minimum temperature requirements for growth. In comparing forage yields of species in subsets of environment, which included cold-stress and noncold-stress, wheat species produced significantly more total forage in a noncold-stress environment. Also, analysis of species-environment interaction using fitted regression lines, showed that wheat species produced greater forage yields in high-yielding environments. However, cultivars of wheat species showed greater variation in seasonal and total forage production. All wheat cultivars were similar in terms of mid-season production, but significant differences existed in late-season production. Also, wheat cultivars showed variation for cold injury, cold tolerance and forage yield response in cold-stress and noncold-stress environments.

Krenzer et al. (1992) conducted a study to characterize genotype x environment

(GE) interactions for fall and winter forage production in hard red winter wheat and to identify cultivars with favorable levels of stable forage production. Eighteen cultivars were grown in six environments. Forage was clipped until the early joint stage when canopy height reached approximately 20 cm. Fall forage produced prior to winter dormancy, and winter regrowth before early joint, were both influenced by GE interactions. The mean correlation of each cultivar with all other cultivars ranged from 0.91 to 0.97 for fall forage and 0.84 to 0.93 for winter forage. Based on Shukla's stability variance (σ_i^2), three cultivars were unstable $(\sigma_i^2 > 0)$ for fall forage, whereas 10 cultivars were unstable for winter forage. Cultivars with low mean correlations were also classified as unstable. Rank stability differences for fall forage primarily resulted from three genotypes showing exceptionally high stability rather than lack of stability. It was determined that changes in rank order would not be expected to hinder selection of hard red winter wheat genotypes stable for fall forage production. Fall forage yield differences were sufficiently large to be important to wheat-stocker cattle producers.

The Economics of Diversification

In simple terms, diversification is the production of more than one product, whereas specialization is the production of only one product. There are conditions under which diversification and specialization are appropriate strategies for managing risk. According to Robinson and Barry (1987), the major factors affecting diversification are: (1) the correlation of stochastic returns between assets, (2) the number of assets held, and (3) the economies of scale in production. A less than perfect correlation between the returns of assets allows for gain from diversification by reducing risk costs, although the gains in risk reduction diminish as the number of assets increases. In contrast, economies of scale, which reduces average cost as production increases, favor specialization.

In production processes where the input-output relationship is linear, diversification can be used as a risk control strategy; whereas in a phenomenon where increases are experienced in output per unit of input over a given range, there is an advantage of economies of scale which provides an incentive to specialize. This effect can partially offset the risk reduction that could have resulted from diversification.

Frequently, a firm faces a tradeoff between the benefits associated with economies of scale and diversification. In diversifying, the firm loses the possible gains from economies of scale, and thus, accepts lower expected returns. However, the firm also gains from risk reduction. Alternatively, to specialize, significant economies of scale must be expected in order to offset the risk reduction advantage of diversification. Thus, the net gain from diversification depends on the risk-return tradeoff.

Specialization of production is based on the assumption that the additional return from the economies of scale is sufficient to offset the cost of risk that the producer bears by not diversifying production. According to Robinson and Barry (1987), the cost of risk in expected value-variance analysis may be expressed as a quadratic expression. Assuming a stochastic return with a variance of σ_i^2 on asset q_i and a risk-averse individual with risk aversion coefficient λ, the total risk cost ($RC(q_i)$), average risk cost ($RC(q_i)/q_i$), and marginal risk cost ($RC'(q_i)$) may be expressed as follows:

$$RC(q_i) = \lambda/2 \; q_i^2 \; \sigma_i^2 \tag{2.11}$$

$$\frac{RC(q_i)}{q_i} = \lambda/2 \; q_i \; \sigma_i^2 \tag{2.12}$$

$$RC'(q_i) = \lambda q_i \sigma_i^2 \tag{2.13}$$

If the production function is linear, the total, average and marginal risk costs increase monotonically, implying that no economies of scale for risk exist.

Robinson and Barry (1987) demonstrated how optimal output is determined when production functions are both linear and nonlinear. In the case where production is linear, they assumed input q_i, which has a cost of 1, to yield output q_i with a return of $(1 + r_a + E)q_i$, where r is a rate of return and E is a stochastic element with zero expectation and variance σ_i^2. Therefore, the certainty equivalent is as follows:

$$y_{ce} = (1 + r_i)\ q_i - q_i - \lambda/2\ q_i^2\ \sigma_i^2 = r_i\ q_i - \lambda/2\ q_i^2\ \sigma_i^2 \tag{2.14}$$

The first-order condition is:

$$\frac{\partial y_{ce}}{\partial q_i} = r_i - 2\ (\frac{\lambda}{2})\ q_i\ \sigma_i^2 = 0 \tag{2.15}$$

or,

$$r_i = \lambda\ q_i\ \sigma_i^2 \tag{2.16}$$

Thus, the optimal output occurs at the point where rate of return (r_i) equals the marginal cost of risk ($\lambda q_i \sigma_i^2$).

In the case of a nonlinear production function, $q_i = f(x_i)$, where economies of scale exist and the marginal product increases first at an increasing rate and then at a decreasing rate, the marginal cost function takes on the traditional u-shape. The certainty equivalent income from the nonlinear production function, assuming an output price of $P + \epsilon$, where ϵ has a mean of zero and a variance of σ_i^2 is as follows:

$$\max y_{ce} = Pq_i - c(q_i) - \lambda/2\ q_i^2\ \sigma_i^2 \tag{2.17}$$

The first-order condition for an optimal q_i, which equates output price to marginal production cost (MPC) plus marginal risk cost (MRC), is:

$$P = c'(q_i) + \lambda q_i \sigma_i^2 \tag{2.18}$$

Adding the marginal risk cost, $\lambda q_i \sigma_i^2$ to the u-shaped marginal cost of q, yields $c'(q_i) + q_i \sigma_i^2$ in Figure 2.4.

The marginal production cost and the marginal risk cost together determine the optimal level of production. The marginal risk cost is linear but the marginal production cost is falling initially, then starts to rise eventually. The range over which marginal costs decrease determine the minimum output. The greater the range over which marginal costs decrease, the larger the minimum output. If any output is produced it must be at an output greater than that corresponding to the minimum of the marginal risk cost. Thus, an incentive exists for specializing in producing q_i to achieve the lower marginal costs from producing larger quantities of q_i. The linear increase in marginal risk cost provides no such specialization incentive; this incentive comes from the cost function, $c(q_i)$.

According to Robinson and Barry (1987), diversification is most effective when the production process is linear and economies of scale in production are not available. This result may be illustrated by considering a firm with a budget of W_o who has to choose between outputs q_i and q_j with expected returns and variances of return (R_i, σ_i^2) and (R_j, σ_j^2) respectively, and covariance $\sigma_{ij} = \rho\sigma_i\sigma_j$ where ρ is a correlation coefficient and $-1 \leq \rho \leq 1$.

The certainty equivalent of the portfolio is stated as:

$$y_{ce} = R_i\, q_i + R_j\, q_j - \frac{\lambda}{2}\,(2q_i\, q_j\, \rho\, \sigma_i\, \sigma_j + q_i^2\, \sigma_i^2 + q_j^2\, \sigma_j^2) \tag{2.19}$$

subject to

$$W_o = q_j + q_i \tag{2.20}$$

Replacing q_j by $(W_o - q_i)$ to introduce the budget constraint yields the constrained certainty equivalent.

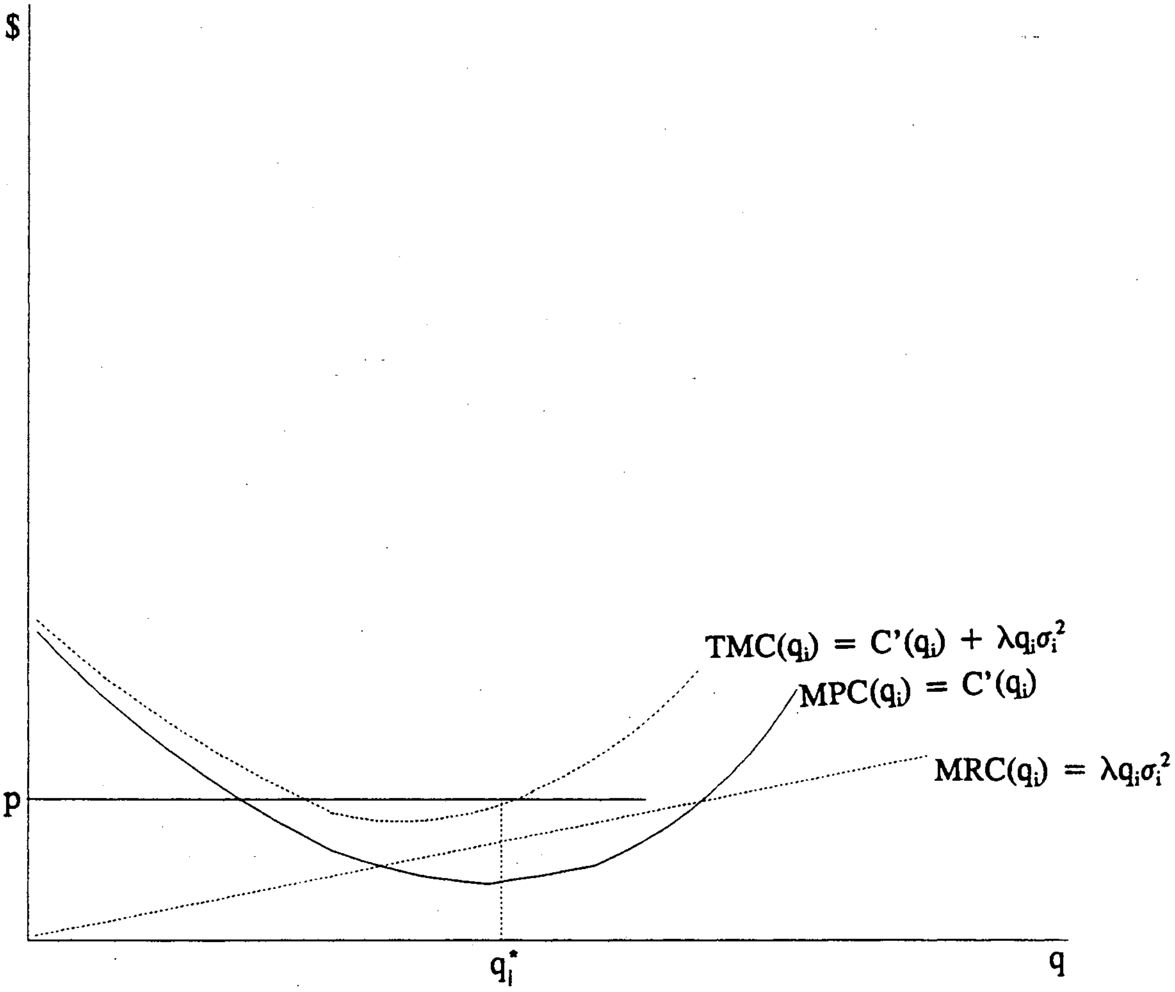

Figure 2.4. Marginal Product Cost, Marginal Risk Cost, and Total Marginal Cost.

$$y_{ce} = R_i q_i + R_j (W_o - q_i) - \frac{\lambda}{2} [2q_i (W_o - q_i)\rho\sigma_i\sigma_w^1 + q_i^2 \sigma_i^2 + (W_o - q_i)^2 \sigma_j^2] \qquad (2.21)$$

If returns on q_i and q_j are perfectly correlated ($\rho = 1$), then equation (2.21) becomes

$$y_{ce} = R_i q_i + R_j (W_o - q_i) - \frac{\lambda}{2} [q_i r_i + (W_o - q_i)\sigma_j]^2 \qquad (2.22)$$

Suppose that $\sigma_i = \sigma_j$ and $\rho = 1$, then the total risk cost in (2.22) will be quadratic, regardless of the diversification between q_i and q_j. Therefore,

$$RC\ (q_i + q_j) = \frac{\lambda}{2} (W_o^2\ \sigma_i^2) \qquad (2.23)$$

If total risk costs are quadratic functions of W_o, then marginal risk costs are linear in W_o and no risk reduction is possible from diversification between q_i and q_j. That is, the expected returns and the risk of the portfolio change in the same proportion as the weights on q_i and q_j change in portfolio.

For no correlation ($\rho = 0$) the certainty equivalent is:

$$y_{ce} = R_i q_i + R_j (W_o - q_i) - \frac{\lambda}{2} [q_i^2\ \sigma_i^2 + (W_o - q_i)^2\ \sigma_j^2] \qquad (2.24)$$

Assuming $\sigma_i = \sigma_j$ and $\rho = 0$, the total risk cost is less than indicated in (2.23) since $(q_i - W_o) < 0$.

$$RC(q_i + q_j) = \frac{\lambda}{2}[2q_i(q_i - W_0) + W_0^2]\sigma_i^2 < \frac{\lambda}{2}(W_0^2\ \sigma_i^2) \qquad (2.25)$$

If $\rho = -1$, risk costs are reduced still further than when $\rho = 0$ assuming $q_i < W_0$, such that

$$RC(q_i + q_j) = \frac{\lambda}{2}[4q_i(q_i - W_o) + W_o^2]\sigma_i^2 < \frac{\lambda}{2}[2q_i(q_i - W_o) + W_0^2]\sigma_i^2 < \frac{\lambda}{2}(W_0^2\sigma_n^2) \qquad (2.26)$$

The above mathematical derivations imply that the extent to which diversification is advantageous depends on the price and yield correlation for the enterprises selected. If both prices and yields for the enterprises tend to move up and down together, little is gained by diversifying. However, the more these values tend to move in opposite directions, the greater will be the benefit that will be obtained by diversifying.

Review of Previous Economic Evaluations of Diversification

Although not specifically designed to analyze enterprise diversification, several studies have used risk programming models to assess risk-return tradeoffs. Most of these applications employed quadratic programming or MOTAD procedures to assess diversification opportunities and derive expected income-variance efficiency frontiers.

Schurle and Erven (1979) applied risk programming methods to evaluate diversification strategies on a representative farm in northwestern Ohio. Using eight years of production data, Schurle and Erven found that changes in crop mix could reduce the coefficient of variation of gross margins by 33 percent. This reduction in risk was accompanied by a 28 percent reduction in expected net returns. By introducing a high-valued crop, such as tomatoes, small reductions in risk could be achieved with little decline in expected net returns.

Teague and Lee (1988) applied risk programming techniques to evaluate diversification opportunities available to Florida citrus producers. MOTAD procedures were used in determining citrus mix (oranges and grapefruit) and tree densities under alternative risk preferences and alternative capital availability assumptions. The authors found that risk neutral producers choose the citrus crop (grapefruit) and tree densities with the highest expected net return; and risk averse producers choose a mix of citrus crops each with relatively less tree density. Producers whose risk preferences are represented by the higher bound of the risk aversion coefficient idle some acreage. Also, sensitivity tests indicate reductions in the amount of capital available resulted in shifts towards less dense plantings.

Brink and McCarl (1978) assessed the role of risk in crop acreage allocation among corn, soybeans, wheat and double crop soybeans in the upper Midwest. The tradeoff between return expectation and risk was estimated by deriving a set of farm plans by parameterizing the risk aversion coefficient in the range of 0 to 1.95. Farmers' risk aversion was estimated by minimizing the difference between their actual behavior and the model results. A risk aversion coefficient of zero (i.e., the profit-maximizing risk neutral criterion) minimized the difference between the majority of the present plans and the derived plans. Of the 38 farmers considered in the study, 25 of them had estimated coefficients that were less than 0.25. Estimated risk aversion coefficients ranged as high as above 1.25, indicating a substantial diversity among individuals. Also, a test of the null hypothesis of no significant difference among acreage differences for each of the four crops was rejected at the 0.01 level of significance, indicating difference in acreage allocation to each crop under consideration.

Dillon (1992) applied risk programming methods to evaluate diversification opportunities in cultivar selection for Arkansas soybean producers. The specific objective of this study was to determine sacrifices of expected yield and income necessary to decrease the variability of yield thereby reducing the fluctuation of profits. A mean-variance (E-V) model was developed comprising alternative cultivars of soybeans and wheat, as well as alternative planting dates. The risk neutral producer planted all of the land (320 acres) to a single soybean cultivar on June 10th. As risk aversion increased, wheat production entered the optimal solution and the planting date of soybeans was altered to June 20th. Based on the results of this analysis, Dillon recommended the reliance upon negative covariance between agricultural enterprises when dealing with risk associated with fluctuating yields; and yield variability reducing research must be used to complement negative covariance of agricultural enterprises.

Risk programming models have also been applied to evaluate diversification opportunities in livestock operations. In an early study, Whitson (1975) applied quadratic programming to evaluate diversification opportunities for a representative ranch in the Rolling Plains of Texas. Alternative livestock enterprises, grazing systems, and marketing strategies were included as potential risk reducing strategies. The ranch's forage base was exclusively native range; therefore, managerial responses did not include adjustments to forage enterprises.

Gebremeskel and Schumway (1979) used MOTAD programming to evaluate risk management strategies on a representative ranch in Texas. These researchers considered alternative forage and cattle risk management strategies including herd size, forage system, livestock enterprise, and marketing strategy. This research revealed that the income - mean absolute deviation trade-off curve faced by livestock producers is much steeper than those estimated for most crop producers. The ability for livestock producers to significantly reduce risk without large expected income losses was attributed to the negative relationship between cattle prices and forage yields. They also reasoned that profit maximizing LP solutions are unlikely to be adopted by producers due to the fact that they are characterized by much higher risk levels with little improvement in expected net returns.

Rawlins and Bernardo (1991) applied risk programming techniques to evaluate diversification opportunities for livestock producers in Eastern Oklahoma. An adaptation of the basic risk programming specification was used to represent both intake and nutrient considerations when allocating available forage among cattle enterprises. Risk efficient ranch organizations were derived for a representative ranch using both MOTAD and Target-MOTAD formulations. Diversification of forage enterprises, introduction of cow-calf enterprises, and use of retained ownership of weaned calves were identified as important risk management strategies. As many as five alternative forage enterprises were included in the efficient ranch plan when the producer's willingness to bear risk was significantly constrained.

CHAPTER III

MODEL DEVELOPMENT

Several farm planning models have been developed to systematically evaluate the effect of alternative production systems on profitability. Procedures have also been developed to account for the influences of risk and uncertainty in farm plan formation. Model selection depends on the objective to be attained, availability of information, and one's ability to solve the model. Whole farm budgeting and deterministic linear programming are two conventional techniques employed to develop farm plans under conditions of certainty. When risk is incorporated into farm planning, mathematical models such as quadratic programming, minimization of the absolute deviations (MOTAD), or Target-MOTAD formulations can be used. In this chapter, the conceptual framework for farm decision making under conditions of certainty and uncertainty is discussed. The analytical model used in this study is then presented.

Developing Farm Plans Under Conditions Of Certainty

Marginal analysis, budgeting and linear programming are the main tools that have been used in allocating resources among competing enterprises under conditions of certainty. In applying the principle of marginal analysis, for instance, in the case of factor-product relationship, a farm-firm maximizes profit by allocating resources until the cost of input is equal to the revenue of the product produced by the corresponding output

(Ferguson and Gould, 1975). This means that the fixed resources (land, management, etc.) are allocated to the most profitable activities to the point that a change in resource allocation among the activities can't increase returns. In product-product relationships, if sufficient resources are available, the equi-marginal return principle can be used to allocate resources. However, if a limited amount of resources are available, product-price relationships can be employed to determine the profit maximizing allocation. In the case of two products, the output levels are determined where the marginal rate of product transformation equals the inverse price ratio. Budgeting and linear programming are two popular techniques used to apply these theoretical concepts to empirical decision making.

Budgeting is an analytical tool used by farmers to project farm income (Kadlec, 1985). There are several kinds of budgets that are useful in farm-level decision making; those relevant to this study are enterprise budgets and whole-farm budgets. An enterprise budget is a listing of all estimated income and expenses associated with a specific enterprise to provide an estimate of profitability (Kay, 1981). The whole farm budget is the physical and financial plan for the organization and operation of the total farm or ranch (Kay, 1981). A problem with the use of whole farm budgeting in developing whole farm plans is determining the proper combination of enterprises when a number of fixed resources and many potential enterprises are available for use in the farm plan. Identification of the optimal plan requires considerable "trial and error" to assess potential combinations of the available enterprises.

Linear programming can be used to solve large whole-farm planning problems that involve a number of fixed resources and many potential enterprises. According to Kadlec (1985), linear programming has three advantages over the budgeting technique.

First, it ensures that the combination of products or enterprises selected is the most profitable possible from the alternatives considered, given the set of input-output relationships and resource restrictions. Second, with the linear programming method it is possible to consider many more alternative organizations than would be feasible with budgeting. Third, linear programming provides information that is not available from budgeting. For example, shadow prices indicate the amount that an additional unit of a limiting resource would increase gross income, and reduced costs estimate the loss in net income that would occur if one unit of an enterprise was not included in the efficient organization.

Linear programming models utilize the same concepts as marginal analysis in determining the optimal allocation of resources to the activities producing the greatest return. Application of linear programming requires the specification of: (a) resource requirements and any specific constraints on their production, (b) the fixed resource constraints of the farm, and (c) the forecasted net returns of the alternative activities. Often times, the objective of farm-level linear programming models is to find the farm organization that provides the largest possible total gross margin given limits on the resources available to the farm decision-maker. To accomplish this objective, linear programming models make a number of assumptions about the nature of the production process, the resources and activities. The most important of these assumptions are optimization, fixedness, finiteness, determinism, continuity, homogeneity, adaptivity and proportionality. For a detailed discussion of these assumptions, the reader is referred to Hazell and Norton (1986).

Following Hazell and Norton (1986), the standard farm-level linear programming model can be written as:

$$\max Z = \sum_{j=1}^{n} c_j x_j \tag{3.1}$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \le b_i \qquad (i=1, 2,...m) \tag{3.2}$$

$$x_j \ge 0 \qquad (j=1, 2,...,n) \tag{3.3}$$

where:

x_j = the level of the jth farm production activity,

c_j = the forecasted net return of a unit of the jth activity,

n = total number of possible production activities,

a_{ij} = the quantity of the ith resource required to produce one unit of the jth activity,

b_i = the amount of the ith resource available, and

m = the total number of resources available.

Developing Farm Plans Under Conditions of Risk and Uncertainty

Production is a dynamic phenomenon, and therefore production and price uncertainty affect expected productivity and expected income (Antle, 1983). A production process is said to be dynamic when there is a need to quantify action, inputs and the result achieved thereof at each point in time. Since outcome is uncertain, the entire process of production is said to be risky. The range of possible outcomes may be expressed as a probability distribution, and these probability distributions represent the level of risk present (Robinson and Barry, 1987).

Risk has been defined in many different ways. In 1921, Knight suggested a distinction between risk and uncertainty on the basis of probability. Knight argued that if the probabilities are known, the problem is one of risk. In contrast, if the probabilities are unknown, as in most cases of agricultural production, the problem is one of uncertainty. Over time, the terms "risk" and "uncertainty" have become almost interchangeable in the literature. According to Antle (1983), risk or uncertainty are equivalent and mean very simply that some variables in the objective function are random variables.

In applied research, risk is generally defined as variability of income or net returns. Risk is often measured by measures of dispersion such as variance, standard deviation, or the coefficient of variation. Sometimes risk is defined as a chance of loss or the probability that random net income will fall below some disaster level. Definitions differ depending on how a problem is approached from a risk analysis perspective. For instance, Freund (1956) introduced risk in farm planning models and described risk as variance of net revenues. Hazel (1971) defined risk as negative deviations from the mean. Some researchers like Roy (1952), Telser (1955), and Kataoka (1963) defined risk using a safety-first measure. In these models it is assumed that the probability of not achieving some critical value of gross margin together with the expected income are the crucial elements of the decision objective.

Incorporating Risk Attitudes in Farm Modelling

The effect of risk on farm organization depends on the decision maker's risk attitude and expectation of the level of risk. The expected utility model represents these components by evaluating the utility values of different monetary outcomes using probability weights to represent the likelihood of occurrence (Robinson and Barry, 1987).

The Bernoullian utility theorem provides a useful theoretical basis for the analysis of the behavior of individuals in a stochastic environment, that is, an environment in which the outcomes of alternative actions which influence the welfare of the individual are not known with certainty. The theory and empirical application of risk management has concentrated on the analysis of the trade-off between expected income and risk as measured by the variability of income. This theory is based on the explicit or implicit assumption that decision makers possess positive marginal utility for money. Further, most decision makers are assumed to be willing to trade-off some expected income to reduce the probability of incurring a loss resulting from an uncertain event.

Consumer theory is built upon the assumption that individuals derive utility from the consumption of goods and services which can be purchased with money income. Hence, indirectly, utility is a function of income (Freund, 1956; Varian, 1984). Similarly, a producer's utility function can be written as:

$$U = f(y) \tag{3.4}$$

where y is the income earned from the execution of a specific farm plan. If the utility function of the farmer were known and tractable, a unique optimal farm plan could be determined by maximizing this function. Expected utility theory has been very useful for explaining qualitative aspects of the behavior of managers, including farmers; however, its empirical application has been limited due to difficulty in to precisely quantifying the utility functions of individuals.

According to Robinson and Barry (1987), risk attitude is reflected by the characteristics of the utility function. Based on the general characteristics of the utility functions, risk attitudes may be ordered into risk-averse, risk-neutral and risk-preferring categories. The shape of the utility function is one means of characterizing a person's attitude towards risk. Concavity reflects diminishing marginal utility ($u''(y) < 0$);

convexity reflects increasing marginal utility ($u''(y) > 0$); and a linear utility function reflects constant marginal utility ($u''(y) = 0$). These three forms of utility functions are shown in Figure 3.1.

Pratt (1964) used the concept of risk premium, the difference between expected value and certainty equivalents, to order individuals based upon risk preference. The risk premium is always positive for risk-averse decision makers in order to provide the compensation needed for risk bearing. For risk neutral decision makers, the risk premium is zero. For risk-preferring decision makers, the risk premium is negative, indicating their willingness to pay a premium for the opportunity to take chances and realize high net return outcomes.

The relationship between the shape of the utility function and the risk premium is important. Concave utility functions imply a positive risk premium, convex functions imply a negative risk premium, and linear utility functions imply zero risk premium. Also, the curvature of the utility function influences the risk premium. The risk premium is high when the utility function bends significantly. As the function bends less in a downward or negative direction, the risk premium decreases. As the curvature approaches zero, the utility function approaches a straight line, and the risk premium approaches zero. Thus, the certainty equivalent of a risk neutral decision with a linear utility function is the expected value of the monetary outcome. Robinson and Barry suggest the use of risk premium to order individuals according to their degree of risk aversion. The larger the risk premium, the more risk averse the individual given the choices and the amounts of risk involved.

Neither the shape of the utility functions, nor the sign of the risk premium can be used to order individuals beyond the class of risk averters, risk neutral or risk preferrers.

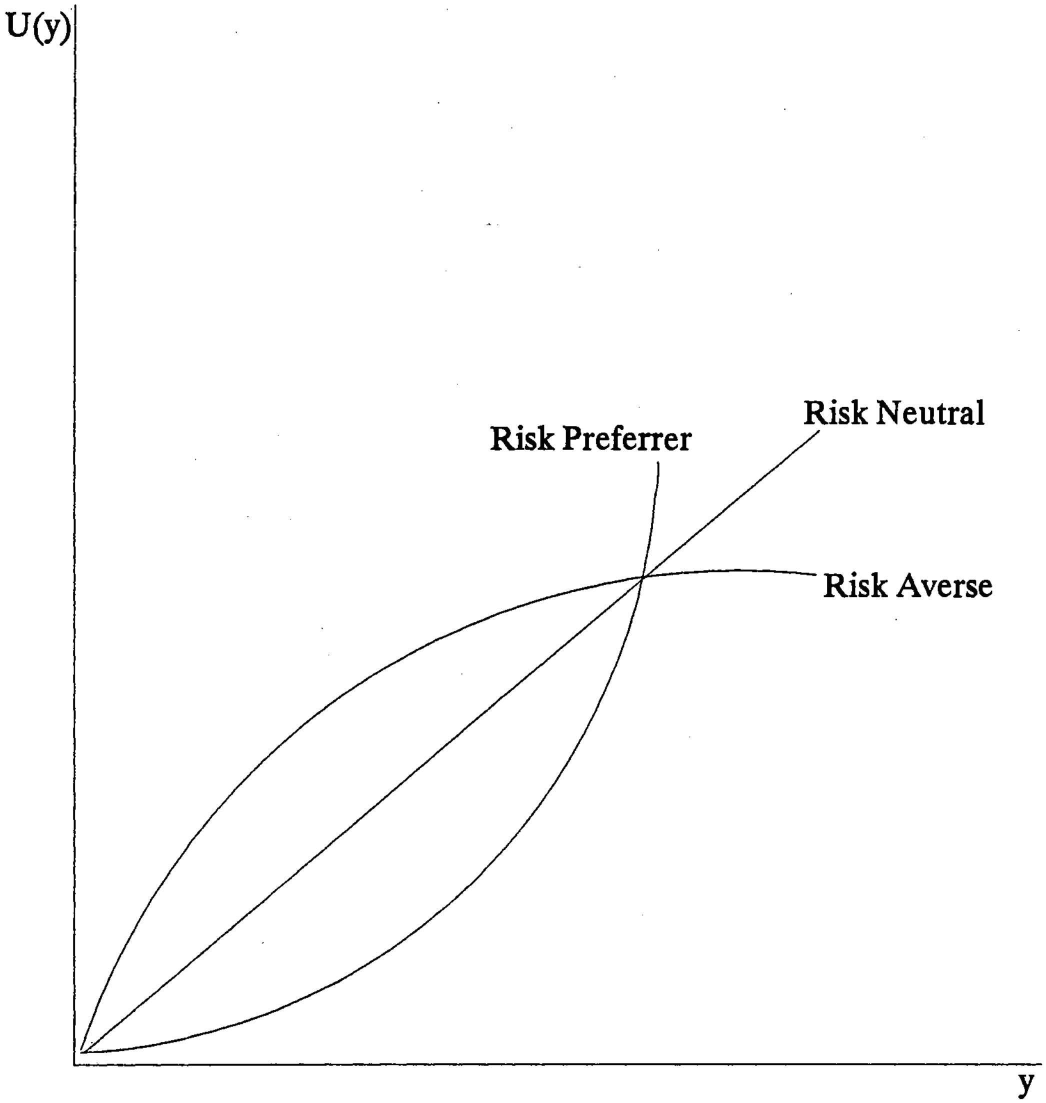

Figure 3.1. Representative Utility Functions for Risk Preferring Risk Neutral, and Risk Averse Decision Makers

That is, they can't be used to order individuals according to their degree of risk aversion. Utility functions can't be used to order individuals based upon their risk preferences because they are subject to linear transformations. Risk premiums have limited capacity to order individuals based upon risk preferences because people have different risk attitudes depending upon the situations they encounter. For example, Kahneman and Tversky (1979) illustrated that people can exhibit risk preferring characteristics in loss situations and risk-averse characteristics in gain situations. Thus, the risk premium can only provide a risk attitude measure for a particular level of risk and over a particular range of wealth, but may not accurately depict risk attitudes in the large.

Pratt (1964) and Arrow (1971) used the absolute risk aversion function [R(y)] to order individuals according to their degree of risk aversion. Pratt and Arrow defined the absolute risk aversion function as follows:

$$R(y) = \frac{-U''(y)}{U'(y)} \tag{3.5}$$

This measure is not affected by linear transformation of the utility function. It has positive value for risk averters, a zero value for risk neutral decision makers, and negative values for risk preferrers. For all decision makers whose Von Neumann-Morgestern utility functions have derivatives $U'(y) > 0$ and $U''(y) < 0$, $R(y)$ will be positive and implies risk aversion. In addition, the sign of $R'(y)$ indicates how risk attitudes change as wealth increases. If $R'(y) < 0$, decision makers are said to display decreasing absolute risk aversion. This implies that the risk premium for a monetary outcome decreases as the decision maker moves to higher wealth levels. Similarly, $R'(y) = 0$ implies constant absolute risk aversion, and the risk premium is constant regardless of changes in the decision maker's wealth. Finally, $R'(y) > 0$ implies increasing absolute risk aversion, suggesting that the risk premium increases as wealth increases.

To rank risky choices using the Expected Utility Model, one must choose the functional form that best describes a farmer's behavior. According to Hazell (1986), one way to select from a set of risky alternatives is to first elicit the functional form from the farmer by providing a series of choices between risky outcomes. This procedure provides a series of observations along his utility function, U(y), and regression analysis may be used to determine the best fitting functional form as well as a set of estimates for its parameters. Once the utility function is known, the utility maximizing set of alternatives can be selected. The second method is to assume a functional form and, in the absence of knowledge about the functional parameters, solve a farm model for alternative parameter values. The set of optimal farm plans can then be provided to the farmer, and he/she can make the final choice, thus revealing his/her risk preferences. A third approach is to derive a set of plans corresponding to some past year and select the parameter values that provide the closest match between the model's prediction and the farmer's actual farm plan. Such methods are often expensive and practical considerations often force analysts to assume functional forms that are computationally convenient. Utility functions are unique to decision makers and may not be stable over time. They may change with income level and other socioeconomic conditions of the household (Dillon and Scandizzo (1978); Binswanger (1980)). As a result, Hazell (1982) concluded that direct elicitation of utility functions is not likely to be widely adopted for farm planning.

Officer and Halter (1968) assumed that a farmer's utility function is best described by the quadratic function. If the decision makers are risk averse, a quadratic utility function of the following form can be used to order risky choices:

$$U(y) = \alpha y + \beta y^2 \tag{3.6}$$

where α and β are constants. If y is stochastic with expected value E(y) and variance σ^2, then the expected value of equation (3.6) can be written as:

$$E[U(y)] = \alpha E(y) + \beta E(y^2) \tag{3.7}$$

Since σ^2 equals $E(y^2) - [E(y)]^2$ we can add and subtract $[E(y)]^2$ without altering the equality and obtain:

$$E[U(y)] = \alpha E(y) + \beta\{E(y^2) - [E(y)]^2 + [E(y)]^2\} \tag{3.8}$$

$$E[U(y)] = \alpha E(y) + \beta\{V(y) + [E(y)]^2\} \tag{3.9}$$

$$E[U(y)] = \alpha E(y) + \beta V(y) + \beta[E(y)]^2 \tag{3.10}$$

where E(y) is the mean of income and V(y) denotes the variance of income. Equation (3.10) shows that the farmer's utility function can be expressed in terms of mean and variance such that:

$$U = f\,(E, V) \tag{3.11}$$

where E denotes mean income and V equals variance of income. By holding U constant at U^*, E-V indifference curves (or frontiers) can be traced and plotted in E, V space.

Equation (3.10) may be used as a decision rule for ranking risky farm plans. According to this rule, the farmer would rank farm plans in terms of their expected (mean) income, E(y), and their variance of income, V(y). If $\alpha > 0$ and $\beta < 0$, then the farmer will prefer plans having higher expected income and lower variances of income, *ceteris paribus*. Therefore, the expected value-variance (E,V) criterion may be derived from Expected Utility Theory if a farmer is assumed to have a quadratic utility function.

Binswanger (1980), Brink and McCarl (1980), and Dillon and Scandizzo (1978) ordered individuals according to their degree of risk aversion based on the tradeoff between the expected value and variance at the equilibrium point on EV sets. An expected value-variance efficient choice set is shown as points along ACB in Figure 3.2. Points on the EV frontier are said to be risk efficient in that they provide the lowest level of risk for a given level of expected return. Assume that point C on the EV frontier is the equilibrium choice set. Individuals who select choices above point C are considered less risk-averse than those selecting choice actions below point C. However, this ordering based on EV slope coefficients is applied only to local risk attitudes, and decision makers must be assumed to have a constant risk aversion function to make global inferences.

Risk Efficiency Criteria

A risk efficiency criterion is a decision rule which may be used to compare two or more alternatives in terms of expected income and risk. In general, for a given level of expected income, an alternative with less risk (variance) is relatively more risk efficient than an alternative with more risk. A number of risk efficiency criteria have been developed to overcome the problems associated with directly estimating individual utility functions. The advantage of using these criteria is that they may be applicable for classes of, rather than for individual, decision makers.

Mean-variance (EV), mean-absolute deviation (MAD), first degree stochastic dominance (FSD), second degree stochastic dominance (SSD), and stochastic dominance with respect to a function (SDRF) are examples of risk efficiency criteria. These criteria are widely used in both theoretical and empirical analysis. They are appropriate tools for risk analysis in situations where a person's, unknown utility function satisfies the assumptions of the criteria.

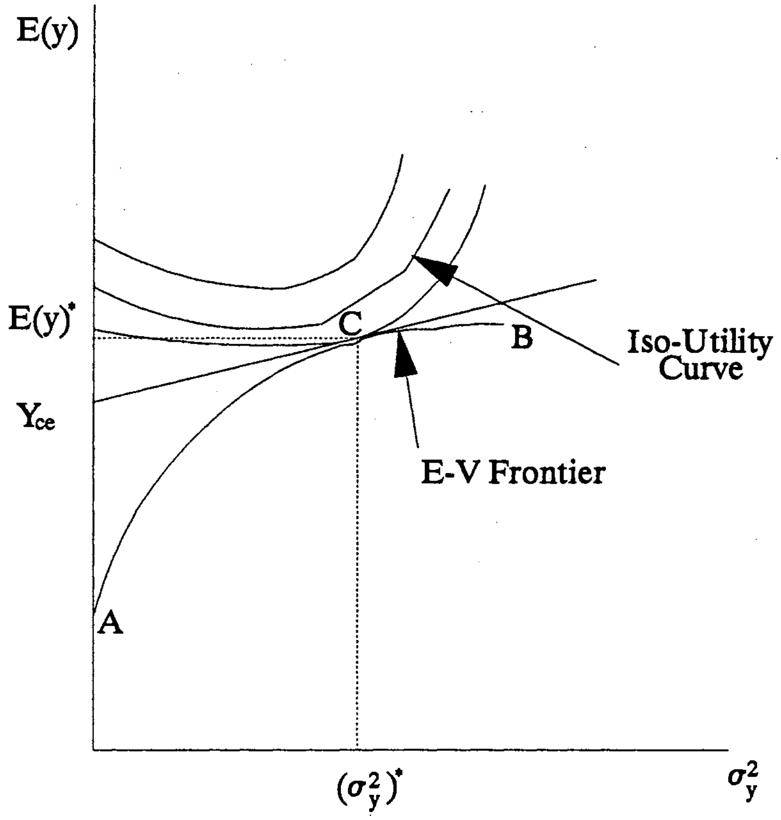

Figure 3.2. The E-V Frontier, Iso-Utility Curve, and the Optimal E, V Farm Plan.

Stochastic dominance techniques are appealing because they require only that utility function properties rather than specific forms, be specified. When function restrictions are imposed on the utility function, stochastic dominance can be used to describe decision makers' preference. If U is an individual utility function, then first-degree stochastic dominance (FSD) eliminates options for an individual with increasing marginal utility, $U'(y) > 0$. This assumption places no bounds on the absolute risk aversion function, since $U''(y)$ can take any value. Thus, the decision-making class consistent with FSD is defined as:

$$-\infty < R(y) < \infty \tag{3.12}$$

However, according to Robinson and Barry (1987), FSD has the disadvantage of having limited ordering capacity. That is, by using FSD, choices often can't be ranked against one another since the number of choices in the efficient set is large.

By using second-degree stochastic dominance (SSD), the ordering capability can be improved. SSD is used to develop risk efficient sets for individuals whose utility functions are characterized by increasing utility ($U' > 0$) and who are risk averse ($U'' < 0$). The function $R(y)$ and the applicable class of decision makers are limited to the risk-averse class with $R(y) > 0$:

$$0 < R(y) < \infty \tag{3.13}$$

In addition to having relatively low discriminatory power, FSD and SSD efficiency criteria are limited by the fact that arbitrary classification of decision makers based on the derivatives of their utility function is quite restrictive if decision makers display both risk-preferring and risk-averse attitudes.

Stochastic dominance with respect to a function (SDRF) is an evaluative criterion that orders choices without the restrictions of a particular utility function or specified characteristics of risk attitude. SDRF orders uncertain outcomes for decision makers whose absolute risk averse functions lie within specified lower and upper bounds (Barry, 1984). Utilizing a lower bound $R_1(y)$ and an upper bound function $R_2(y)$ on the absolute risk aversion function, the class of decision makers is defined by

$$R_1(y) \leq R(y) \leq R_2(y) \qquad (3.14)$$

Under SDRF, distribution "f" is preferred over "g" by decision makers in the class described by equation (3.14) when

$$\int [G(y) - F(y)]\, U'(y)\, dy \geq 0 \qquad (3.15)$$

for all utility functions meeting the condition $R_1(y) \leq R(y) \leq R_2(y)$ for all y.

A stochastic dominance algorithm is not available that develops and selects dominant plans from a set of individual activities. Rather, plans must first be generated by some selection process and then tested for stochastic dominance. This feature limits the power of risk efficiency criteria in selecting risk efficient farm plans from a potentially infinite number of possible farm organizations.

Determination Of Efficient Farm Plans Under Risk

Farmers face a variety of sources of price, yield and resource risk which make their incomes unstable from year to year. There are many possible economic outcomes, and in a mathematical programming context, the actual outcome each year depends on the realized values of the c_j, a_{ij} and b_i coefficients in the model (Hazell and Norton, 1986). Each farm plan has a probability distribution of income f(y). The decision problem is to rank farm plans on the basis of their income distributions, and select the one that best meets the farmer's goals (i.e., that provides the maximum utility).

Risk programming is a technique which can be used to identify risk efficient farm plans for several of the risk efficiency criteria, given a set of alternative farm activities and resource constraints. Risk programming is a technical procedure which can be used to evaluate the infinite number of possible combinations of different levels of alternative enterprises to find the enterprise combination that maximizes the expected utility for alternative assumptions regarding risk preferences.

Risk programming techniques are useful even if the specific utility function is not known. In this case, a set of solutions, expressed as combinations of specific activity levels for different levels of expected income, can be generated. The set of solutions is termed "risk efficient", since it shows the activity levels that minimize risk (expressed in terms of one of the risk measures) at each level of expected income. Therefore, decision makers with resource constraints and production alternatives similar to those included in the programming model, but with different utility functions, can maximize their own expected utility by choosing one of the solutions in the risk efficient set.

When developing risk programming models, it is important to identify the key elements of risk to be studied. The problem of risk and uncertainty may stem from: (a) uncertainties in activity costs, yields and prices (objective function risk); (b) changes in production technology (technical coefficient risk); and (c) uncertainties in the availability of resources (right-hand side risk). Most risk programming models deal with objective function coefficient uncertainty. Farm prices and yields are major sources of risk that affect the objective function. In many studies these two sources of risk are combined to consider only variability in gross margins for individual crop and livestock enterprises.

Quadratic programming has been considered as a useful method to incorporate risk in farm planning models. Freund (1956) developed the mean-variance (E-V) model, which is best expressed in matrix form, as follows:

$$\text{Max } E[U(X)] = X'U - \phi X'\sigma X \tag{3.16}$$

subject to

$$AX \leq B \tag{3.17}$$

$$X \geq 0 \tag{3.18}$$

where X is a vector of activity levels, U is vector of expected returns, B is a vector of resource constraints, σ is a variance-covariance matrix, ϕ is a risk aversion coefficient, and A is matrix of technical coefficients.

An alternative form of mean-variance (E-V) model reported by Hazel and Norton (1986) is:

$$Min\ V = \sum_{j}^{n}\sum_{k}^{m} x_j x_k \sigma_{jk} \tag{3.19}$$

such that

$$\sum_{j} \bar{c}_j x_j = \lambda \tag{3.20}$$

$$\sum_{j} a_{ij} x_j \leq b_i \qquad (i = 1, 2, ..., m) \tag{3.21}$$

$$x_j \geq 0 \qquad (j = 1, 2, ..., n) \tag{3.22}$$

where:

σ_{jk} = covariance of gross margins between the jth and the kth activities,

$\bar{c}_j$ = the expected gross margin of the jth activity, and

λ = a scalar equal to expected total gross margin.

The major difference between these two formulations is the specification of ϕ and λ. The advantage of using Freund's formulation is that the risk aversion parameter associated with each point on the frontier is directly determined (Boisvert and McCarl, 1990).

Quadratic programming (QP) assumes that a farmer's utility is a function of expected income (E) and associated income variance (V). QP further assumes that the farmer is a risk averter (Hazell, 1971). By parameterizing λ, a sequence of solutions is obtained for increasing levels of total gross margin and variance until the maximum possible total gross margin under the resource constraints has been attained. This maximum value corresponds to the standard linear programming problem of maximizing expected total gross margin subject to constraints (3.20) to (3.22). The set of farm plans having minimum variance for each expected level of income defines the efficient E-V frontier. According to Hazell and Norton (1986), given an E-V expected utility function, a risk averse farmer's iso-utility curve will be convex when plotted in E-V space. That is, along every iso-utility curve, the farmer would prefer a plan with a higher V only if E were also greater $(ie,\ \frac{\partial E}{\partial V} > 0)$, and this compensation must increase at an increasing rate with increases in V $(i.e.,\ \frac{\partial E^2}{\partial^2 V} > 0)$.

Given a set of efficient farm plans, the acceptability of any particular plan to an individual farmer will depend on his or her preferences among various expected income and associated variance levels as described by his E-V utility functions. When the function can be measured, a unique farm plan can be identified where the iso-utility curve is tangent to the E-V efficient frontier. In Figure 3.2, the tangency point for the iso-expected utility line E[U(y)] and the E-V set AB occurs at choice C, yielding expected income $E(y)^*$ and variance $(\sigma_y^2)^*$.

Despite the popularity of the E-V model as a tool of analysis in farm planning under risk, problems do arise in its application. According to Levy and Hanok (1970), if returns are normally distributed, then mean-variance solutions are members of the second-degree stochastic dominance (SSD) efficiency set and are consistent with the expected utility theorem. However, if returns are not normally distributed, then the researcher using mean-variance analysis must determine or assume that the decision maker has a quadratic utility function. Thus, the results derived from mean-variance analysis are not necessarily SSD efficient. In addition to these theoretical limitations, mean-variance analysis also has empirical limitations. According to Frankfurter, Phillips, Seagle (1971) and Schurle and Erven (1979), these shortcomings include errors in measuring the model coefficients and sensitivity of the efficient frontier to minute changes in coefficient values. Mean-variance analysis also requires a quadratic programming algorithm, which may be expensive to run for large models.

The Minimization of Total Absolute Deviation (MOTAD) model is a linear programming alternative to approximate the E-V efficient set. The MOTAD model is formulated to identify a set of risk efficient farm plans based on expected income and mean absolute income deviation. In the MOTAD model, risk is measured by absolute deviation from mean returns rather than by the variance of total returns. The mean absolute deviation (MAD) of income is defined as:

$$A = \frac{1}{s}\sum_{h=1}^{s} \left| \sum_{j=1}^{n} (c_{hj} - g_j)x_j \right| \tag{3.23}$$

where:

A = mean absolute deviation.

s = the number of states of nature,

n = the number of activities,

c_{hj} = the gross margin for the j^{th} activity for the h^{th} state of nature,

g_j = the sample mean gross margin for the j^{th} activity, and

x_j = the level of j^{th} activity.

Because the sum of negative gross margin deviations from the mean must equal the sum of the positive gross margins deviations from the mean, the MOTAD model can be reduced to minimize only the sum of absolute values of the negative total gross margin deviations. The total negative gross margin deviations can be defined as:

$$Y_{\bar{h}} = \left| \sum_{j=1}^{n} (c_{hj} - g_j)x_j \right| \tag{3.24}$$

where $\sum_{j=1}^{n} (c_{hj} - g_j)\, x_j$ is negative if $(c_{hj} - g_j) < 0$ and zero otherwise. The MOTAD model can be written as:

$$Min \sum_{n=1}^{s} Y_{\bar{h}} \tag{3.25}$$

subject to

$$\sum_{j=1}^{n} (c_{hj} - g_j)\, x_j + Y_{\bar{h}} \geq 0 \tag{3.26}$$

$$\sum_{j=1}^{n} F_j x_j = \lambda \tag{3.27}$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \tag{3.28}$$

$$x_j,\ Y_{\bar{h}} \geq 0 \tag{3.29}$$

where:

$Y_{\bar{h}}$ = the absolute value of total negative gross margin deviations,

F_j = the expected gross margin for the j^{th} activity, and

λ = a scalar equal to expected total gross margin.

The model can be solved parametrically for various values of λ to trace out an E-A frontier. Anderson et al. (1977) suggested an alternative formulation for MOTAD where expected returns are maximized with a parametric constraint on the sum of negative deviations. This formulation can be written as:

$$\max \sum_{j=1}^{n} F_j x_j \tag{3.30}$$

such that

$$\sum_{j=1}^{n} (c_{hj} - g_j)\, x_j + Y_{\hbar} \geq 0 \tag{3.31}$$

and

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \tag{3.32}$$

$$\sum_{h=1}^{s} Y_{\hbar} \leq \lambda \tag{3.33}$$

$$x_j,\ Y_{\hbar} \geq 0 \tag{3.34}$$

Even though the MOTAD model has been used extensively, it has received significant criticism. Some researchers have argued that it may prove misleading if the decision maker's utility function is not quadratic or the distribution of returns is not normal. Also, the MOTAD model does not generate solutions that meet the second-degree stochastic dominance (SSD) test (Tauer, 1983). However, the MOTAD approach is more appealing empirically than mean-variance if distributions are skewed (Thomson and Hazell, 1972). The major advantage of MOTAD over the E-V model is that solutions can be generated by a linear programming algorithm.

Tauer (1983) developed a modification of MOTAD that is generally called Target-MOTAD. The concept of Target-MOTAD formulation is based on the assumption that decision makers often wish to maximize expected returns, but are concerned about net returns falling below a critical target level. In Target-MOTAD, expected returns are maximized with restriction on the level of negative deviations from the target. Mathematically, the model is stated as:

$$\max E(Z) = \sum_{j=1}^{n} c_j x_j \tag{3.35}$$

subject to

$$\sum a_{ij} x_j \leq b_i \qquad i = 1,\ldots,m \tag{3.36}$$

$$T - \sum_{j=1}^{n} c_{hj} x_j - yh \leq 0 \qquad h = 1,\ldots,s \tag{3.37}$$

$$\sum_{h=1}^{s} p_h y_L = \lambda \qquad \lambda = M \Rightarrow 0 \tag{3.38}$$

$$x_j,\ y_r \geq 0 \tag{3.39}$$

where:

E(Z) = is the expected net return of the plan or solution,

b_i = level of resources or constraint i,

T = target level of return,

c_{hj} = return of activity j for state of nature h,

y_h = deviation below T for state of nature h,

P_h = probability that state of nature h will occur,

λ = a constant parameterized from M to 0,

m = number of constraint and resource equations,

s = number of states of nature or observations, and

M = a large number.

Tauer (1983) compared the performance of MOTAD and Target-MOTAD models to analyze the risk-return performance of three crop activities with net revenue data for five years. He conducted stochastic dominance analysis using frequency intervals and showed that all Target-MOTAD solution results were SSD efficient, but all MOTAD solution results were not SSD efficient.

Description of the Analytical Model

The purpose of this study is to identify risk efficient wheat-stocker production systems. Alternative wheat production processes are represented by different wheat varieties and/or production practices which differ in grain and forage yield potential. Alternative livestock production systems are represented by stocker activities which differ in weight gain and input requirements. These activities interact to provide farm plans that maximize expected utility.

To determine the efficient farm plan requires the specification of the objective function, the technical constraints, and the possible net return shortfalls reflective of cumulative income variability associated with variability in prices, yields and inputs. The basic structure of the model is first presented in equation form; then, additional detail is reported using an abbreviated tableau.

Return above variable costs from a farm plan may be estimated as:

$$\mathrm{NR} = \sum_{i=1}^{n} P_g Y_w X_w - \sum_{i=1}^{n} C_w X_w + \sum_{s=1}^{m} P_s W_s Y_s - \sum_{s=1}^{m} C_s Y_s \tag{3.40}$$

where:

NR = farm-level net return above variable costs,

P_g = price of wheat grain (\$/bu),

Y_w = yield of wheat activity w (bu/ac),

X_w = number of acres of wheat activity w,

C_w = variable cost of production for wheat activity w (\$/ac),

P_s = price of stockers of weight W_s (\$/cwt),

W_s = live weight of stockers sold from stocker activity s (cwt/hd),

Y_s = number of head of stocker activity s,

C_s = variable costs of producing stocker activity s (\$/hd),

n = number of wheat production activities, and

m = number of stocker production activities.

The contribution of an activity to the net return is influenced by the productivity and amount of resources used in the production process. The resource requirement to produce a unit of the activities and the total amount of resources available influence the organization and financial performance of the farm. The principal resource requirements specified for the production of wheat and stockers are land, labor, and capital. Constraints on the availability of labor, capital and forage resources can be stated mathematically as:

$$\sum_{w=1}^{n} X_w \leq L \tag{3.41}$$

$$\sum_{w=1}^{n} k_w X_w + \sum_{s=1}^{m} k_s X_s \leq K \tag{3.42}$$

$$\sum_{w=1}^{n} r_w X_w + \sum_{s=1}^{m} r_s X_s \leq R \tag{3.43}$$

$$\sum_{s=1}^{m} f_s X_s \leq \sum_{w=1}^{N} g_w X_w \tag{3.44}$$

where:

L = land resource limit (ac),

k_w and k_s = capital requirements of wheat activity w (\$/ac) and stocker activity s (\$/hd),

K = capital resource limit (\$),

r_w and r_s = labor requirements of wheat activity w (hr/ac) and stocker activity s (hr/hd),

R = labor resource limit (hr),

f_s = forage requirement of stocker activity s (lb/hd), and

g_w = forage production of wheat activity w (lb/ac).

Variation inherent in prices received and paid by farmers, levels of output produced from the activities, and resource requirements of the activities used in undertaking the process of production must be considered in determining the efficient farm plan. In this study, this variation is represented by the sum of the negative income deviations falling below a critical target. In representing risk in this portion of the model, it is necessary to consider the return that the producer targeted to obtain and the return that is produced by the efficient organization of the farm at different states of nature. The negative difference between the targeted income and the realized income contributes to the level of risk estimated in the model. The Target-MOTAD model minimizes the deviations between the target income and income arising under various states of nature. If there are t states of nature, then the deviation of income from the target income under t^{th} state of nature (Y_t) is

$$Y_t = T - NR_t \tag{3.45}$$

where:

T = the target level of return, and

NR_t = estimated net return in subperiod t (as calculated in equation 3.40).

Equation (3.45) defines the deviations below the target income (T) in each year. These deviations are multiplied by the probability of the state of nature in which they occur to give the expected sum of deviations below the target income.

$$\sum_{t=1}^{s} p_t Y_t = \lambda \qquad \lambda = M \rightarrow 0 \tag{3.46}$$

where:

p_t = probability of state of nature or observation t,

λ = a constant parameterized from M to O,

M = a large number, and

s = the number of states of nature.

In summary, the analytical model may be written as:

$$\max E(Z) = \sum_{j=1}^{n} f_j x_j \qquad (3.47)$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad i = 1,\ldots,m \qquad (3.48)$$

$$T - \sum_{j=1}^{n} f_{tj} x_j - Y_t \leq 0 \qquad t = 1,\ldots,s \qquad (3.49)$$

$$\sum_{t=1}^{s} p_t Y_t = \lambda \qquad \lambda = M \rightarrow 0 \qquad (3.50)$$

Equation (3.47) is the objective function and maximizes expected return. Equation (3.48) represents the technical resource constraints. Equation (3.49) measures the income from the solution under state of nature t. If that revenue is less than the income target T, the difference is transferred to equation (3.50) via variable Y_t. Equation (3.50) sums the negative deviations after weighting them by their probability of occurring (p_t). By parameterizing λ, an efficient E-A frontier may be traced out.

A more detailed description of the Target-MOTAD model is provided in the abbreviated linear programming tableau presented in Table 3.1. The model is comprised of five principal classes of activities: (1) one-acre wheat grain and forage production activities; (2) per-head livestock production activities; (3) livestock and wheat sell activities; (4) forage deviation activities; and (5) income deviation activities used to

Table 3.1. Abbreviated Tableau of Target-MOTAD Model

	VAR1	VR1G	VAR2	VR2G	VR1R	VR2R	FRG12	STK1	STK2	STK3	STK1S	STK2S	STK3S	BSP1	STK11	SLK11	STK33	SLK33	STK11S
1)OBJ	-d1	-d1'	-d12	-d12'	-r1	-r2		-c1	-c2	-c3	-e1	-e2	-e3	-w1	-c11	+c11	-c33	+c33	-e11
2a)AFG1	-F11	-F11	-F21	-F21			1	a11	a12	a13	a11'	a12'	a13'						
2b)AFG2	-F12	-F12	-F22	-F22			-1								a211		a233		a211'
2c)AFG3		-F13		-F23															
3a)SUPL1											s11	s12	s12	-1					
3b)SUPL2																	s211		
4)GRAIN	-G1		-G2		-G1	-G2													
5)LAND	1	1	1	1	1	1													
6a)STK1								-1							1				
6b)STK2									-1										
6c)STK3										-1							1		
6d)STK1S											-1								1
6e)STK2S												-1							
6f)STK3S													-1						
6g)STK11															-1				
6o)STK33																	-1		
6p)STK11S																			-1
6x)STK33S																			
7a)LAB1								L11	L21	L31	L11	L21	L31						
7b)LAB2															L12		L32	L12	
7c)LAB3																			
8a)CAP1								K11	K21	K31	K11	K21	K31						
8b)CAP2															K12		K32	K12	
8c)CAP3																			
9a)FRG11	-f111	-f111	-f211	-f211				a11	a12	a13	p11	p12	p13						
9z)FRG93		-f139		-f239															
10a)WTDV1	-g11		-g21		-g11	-g21													
10i)WTDV9	-g19		-g29		-g19	-g29													
11a)NRDV1	-d11	-d11'	-d21	-d21'	-r11	-r21	-c11	-c21	-c31	-e11	-e21	-e31	-w1	-c111	+c111	-c331	+c331	-e111	
11i)NRDV9	-d19	-d19'	-d29	-d29'	-r19	-r29	-c19	-c29	-c39	-e19	-e29	-e39	-w9	-C119	+C119	-c331	+c339	e119	
12)EXSFT																			

Table 3.1. (Continued)

	SLK11S	STK33S	SLK33S	BSP2	STK111	STK333	STK111S	STK333S	SLWHT	SLWT1	SLWT9	FDV11	FDV93	TDEV1	TDEV9	
1)OBJ	+e11	-e33	+e33	-w2	+c111	+c333	+e111	+e333	+cw							
2a)AFG1																<=0
2b)AFG2		a233'														<=0
2c)AFG3					a3111	a3333	a3111'	a3333'								<=0
3a)SUPL1																<=0
3b)SUPL2		a233		-1												<=0
4)GRAIN									1							<=0
5)LAND																<=L*→1
6a)STK1																<=0
6b)STK2																<=0
6c)STK3																<=0
6d)STK1S																<=0
6e)STK2S																<=0
6f)STK3S		1														<=0
6g)STK11					1											<=0
6o)STK33						1										<=0
6p)STK11S						1										<=0
6x)STK33S		-1						1								<=0
7a)LAB1																<=B1
7b)LAB2		L32														<=B2
7c)LAB3					L13	L33	L13	L33								<=B3
8a)CAP1																<=K1
8b)CAP2		K32														<=K2
8c)CAP3					K13	K33	K13	K33								<=K3
9a)FRG11												-1				<=0
9z)FRG93					a311	a333	p311	p333					-1			<=0
10a)WTDV1									1							<=0
10i)WTDV9										1						<=0
11a)NRDV1	+e111	-e331	+e331	-w21	+c1111	+c3331	+e1111	+e3331	+cw1		-b11		1			>=T
11i)NRDV9	+e119	-e339	+e339	-w29	+c1119	+c3339	+e1119	+e3339		+cw9		-b93		1		>=T
12)EXSFT														py1	py9	=LAMDA

measure the risk inherent in alternative wheat-stocker farm organizations. Four sources of risk are incorporated into the model, including deviations in income from variability in wheat grain yields, income variability from wheat price deviations, income deviations from livestock price variability, and costs associated with not meeting livestock feed requirements. Selected symbols are used in the tableau to represent the actual numerical values in the model. A summary of the rows and activities included in the abbreviated tableau is provided in Table 3.2.

Because forage production, forage quality and animal nutrient requirements differ substantially over time, the winter-wheat pasture period is divided into three two-month subperiods. The abbreviated tableau presented in Table 3.1 includes three subperiods to represent the dynamic dimension of forage supply and demand conditions over the grazing season.

Expected net returns are estimated in row 1, and the coefficients included are the costs and revenues associated with each respective activity (d_{ij} and c_{ij}). Operating costs as well as returns from selling stockers and wheat grain are included. No constraint is set in this row, as this is the objective function row which will be maximized at an associated level of risk.

Row 2a through 2c are forage balance rows and include the average forage production and consumption coefficients in pounds of dry matter, by subperiod. Forage production (F_{ij}) and consumption (a_{kj}) are constrained so that total consumption of forage by all livestock can't exceed the total availability of dry matter of forage during a given subperiod. Forage production data (pounds of dry matter) from experimental trials on different study sites were used to obtain the average forage production for the various wheat varieties. Pounds of dry matter of average forage production in subperiod j by

Table 3.2. Description of Activities and Constraints Presented in Abbreviated Tableau

Activity Description:

VAR1	Production of variety 1 for grain and/or forage (acre).
VR1G	Production of variety 1 for grazeout (acre).
VR1R	Production of variety 1 for grain and grazing rights are leased (acre).
FRG12	Transfer of forage from subperiod 1 to subperiod 2 (lb).
STK1	Unsupplemented stocker activity 1 steers (high gain) in subperiod 1 (head).
STK11	Unsupplemented stocker activity 1 steers (high gain in subperioid 1) using activity 1 (high gain)in subperiod 2 (head).
STK111	Production of unsupplemented stocker activity 11 steers (high gain in subperiod 1 and 2) using activity 1 (high gain) in subperiod 3 (head).
STK1S	Production of supplemented stocker activity 1 steers (high gain) in subperiod 1.
STK11S	Production of supplemented stocker activity 1 steers (high gain in subperiod 1) using activity 1 (high gain) in subperiod 2 (head).
STK111S	Production of supplemented stocker activity 11 steers (high gain in subperiod 1 and 2) using activity 1 (high gain) in subperiod 3 (head).
SLK11	Sell high gain unsupplemented stockers at the end of subperiod 2 (head).
SLK11S	Sell high gain supplemented stockers at the end of subperiod 2 (head).
BSP1	Buy supplemental feed in subperiod 1.
SLWHT	Sell wheat (bu).
SLWHT1	Sell wheat in state of nature 1 (bu).

Table 3.2. (Continued)

FDEV11	Forage deviation in state of nature 1,subperiod 1 (lb).
TDEV1	Total income deviations from the target in state of nature 1 ($).
Constraint (Row) Description:	
OBJ	Objective fuction, maximize net returns.
AVG1	Forage balance row for subperiod 1 (based on average forage production).
SUPL1	Supplemental feed balance row for subperiod 1.
GRAIN	Grain transfer row.
LAND	Land constraint for non-participation in government program.
STK1	Unsupplemented stocker transfer 1, transfers STK1 steers to STK11, STK12, or STK13.
STK1S	Supplemented stocker transfer 1, transfer STK1S steers to STK11S, STK12S, or STK13S.
STK11	Unsupplemented stocker transfer 11, transfer STK11 steers to STK111, STK112, STK113, or SLK11.
STK11S	Supplemented stocker transfer 11, transfers STK11S steers to STK111S, STK112S, STK113S, or SLK11S.
LAB1	Labor constraint in subperiod 1.
CAP1	Capital constraint for subperiod 1.
FRG11	Forage deviation row for subperiod 1, state of nature 1 (estimates forage shortfalls in subperiod 1, state of nature 1 based upon optimal plan).
WTDV1	Wheat grain yield deviation row for state of nature 1.

Table 3.2. (Continued)

NRDV	Net return deviation row for state of nature 1
EXSFT	Expected shortfall from target income.

variety i (F_{ij}) are used to measure the total availability of the forage produced by a particular variety during a given subperiod.

National Research Council (NRC) procedures are applied to estimate the forage requirement for each livestock activity. Projected weight gains by the cattle, animal live weight and energy requirements for growth are the variables used to determine the forage requirement for each stocker production activity during each subperiod. Pounds of dry matter of forage requirement for stocker activity k in subperiod j (a_{kj}) are used to measure the quantity of forage utilized by each stocker category in each subperiod. The forage requirement includes both forage intake and non-consumptive uses.

The expected amount of forage supplied is forced to meet or exceed the total forage requirement of the stocker activities during each subperiod. For instance, the total quantity of forage produced in subperiod 1 must be equal to or greater than forage requirement of the stocker cattle grazed in subperiod 1. If there is forage that is not utilized in period 1 (FRG12), it can be transferred to the next subperiod. Forage produced in subperiod 2 plus forage transferred from subperiod 1 must be equal to or greater than forage consumed during subperiod 2 by all categories of stocker cattle. Again, if there is unused forage production, it can be transferred to the grazeout subperiod (subperiod 3). Also, forage production in subperiod 3 (grazeout) plus the forage transferred from subperiod 2 must be equal to or greater than the forage requirement for the different categories of stocker cattle in subperiod 3. If the forage supply is not capable of meeting the forage demand during a specific subperiod, the model forces the stocker to be supplemented with a ration of equal quality. Row 3 estimates the total quantity of supplement purchased in each subperiod and transfers this quantity to the supplement purchase activity.

Rows 3a and 3b estimate purchases of supplemental feeds. These rows specify that consumption of energy supplement shouldn't exceed purchases. Supplemental feeds for supplemented stockers may be fed during subperiods 1 and 2.

Row 4 represents average grain production by the different varieties of wheat. This row specifies that all grain produced will be marketed and the amount of grain sold can't exceed the total sum of grain produced. A homogeneous product is assumed; that is, the market does not discriminate in pricing wheat, even though produced by different varieties. Average grain production by variety i (G_i) is calculated on a per-acre basis. Grain production coefficients are not included in the graze-out activities.

Row 5 represents the land constraint of the model. This row specifies that the sum of all acres used in the production of grain and forage can't exceed the total number of acres available to the producer. The combined production of grain and forage is calculated on a per acre basis.

Rows 6a through 6m represent the livestock transfer activities included in the model. These rows allow the model to transfer the end product of each representative stage of production to the next stage of production, or to sell them. Sets of stocker activities are included for each subperiod. The stocker enterprises differ in terms of potential weight gain, levels of supplementation, etc. In the transfer process, each category of stockers at the end of each subperiod can move to one of several stocker production alternatives in the subsequent subperiod. This process can be expressed in simple algebraic form as:

$$STK_1 - STK_{11} - STK_{12} - STK_{13} \leq 0 \qquad (3.51)$$

where STK_1 is production of stocker activity 1 (high gain) in subperiod 1; STK_{11} is production of stocker activity 1 steers (high gain in subperiod 2) using activity 1 steers

(STK1) in subperiod 1; STK_{12} is production of stocker activity 2 steers (medium gain in subperiod 2) using activity 1 steers (STK1) in subperiod 1; and STK_{13} is production of stocker activity 3 steers (low gain in subperiod 2) using activity 1 steers (STK1) in subperiod 1. That is, stocker activity 1 (high gain) can be transferred to subperiod 2 to either high gain (STK_{11}), medium gain (STK_{12}), or low gain (STK_{13}) stocker activities.

The transfer rows also include livestock sell and purchase activities at the conclusion of each subperiod. Since a stocker of a given weight is assumed to fall in one of the weight categories of stocker activities, forage intake is assumed to be the cause for the differential weight gains. The model will determine which category of the stocker activities to sell at the end of each subperiod. In subperiod 3, there will only be livestock sell activity because of the assumption that the production process terminates at the end of subperiod 3 in mid-May.

Rows 7a through 7c represent labor requirements by subperiod for the livestock activities in the model. The firm is assumed to use hired labor if labor requirements exceed owner-operator labor in a given subperiod.

Rows 8a through 8c represent the capital requirement for livestock activities in the model. Capital accounting is included in the model to determine the amount of operating capital necessary to implement the production plan.

Rows 9a, through 9i are analogous to rows 2a through 2c, but represent individual forage production (f_{ijt}) and consumption coefficients (a_{kj}) in pounds of dry matter by subperiod for each state of nature. These rows allow the model to represent annual variability in forage production produced by each variety. Forage requirements for each stocker activity are the same across all states of nature.

Rows 10a through 10h are analogous to row 4, but these rows represent individual grain production by state of nature. These rows are used to represent annual variability in grain yield production.

Rows 11a through 11i estimate the amount of income risk as measured by deviation falling below the target return. These are deviations resulting from variability in input costs, forage and grain yields, and the prices of stockers and wheat grain.

The sum of the negative and positive deviations below the target income are then transferred to row 12. The positive and negative deviations for each of the n states of nature have an equal probability of occurring and are weighted accordingly. This is accomplished by assigning each deviation a probability of 1/n. The sum of all deviations weighted by the probability of their occurrence gives the mean deviation from the target income. The right-hand side of these constraints may be parameterized to trace out the E-A frontier of efficient farm organizations.

CHAPTER IV

DATA REQUIREMENTS AND DESCRIPTION

This chapter specifies the production requirements and assumptions used in the model. First, the study region and representative farm employed in the study are discussed. Next, the alternative wheat pasture and stocker production activities are outlined, along with the associated production data. Finally, the economic data used in estimating expected net returns and income risk are presented.

The Study Region and Representative Farm

The model will be used to derive risk efficient wheat-stocker organization for a representative farm in northcentral Oklahoma. This area has 39 inches of normal annual precipitation and an average temperature of 59° (Oklahoma Agricultural Statistics). Wheat, alfalfa, and grain sorghum are widely grown crops in this region; however, wheat is the dominant crop to which approximately 51% of the crop land has been allocated. The grazing of cattle on wheat pasture is an important enterprise in the region, and a significant share of net farm income in the region may be attributed to this activity. It is estimated that as much as 70 percent of the region's wheat pasture is grazed by livestock annually (Harwell, 1976).

The representative farm is assumed to consist of 850 acres of land under cultivation. The set of available crop production activities on the farm includes wheat for grain, wheat for winter grazing and grain, and wheat exclusively for grazing stockers. Wheat is assumed to be planted using conventional tillage systems. All of the farm is assumed to be comprised of Kirkland loam soil. The farm is assumed to have discretion in participating in available commodity programs, and all of the land on the farm is included in the farm's wheat program base acres.

Available family labor is assumed to be one full-time person, and additional labor may be hired as needed. All of the necessary operating capital required to execute the selected farm plan is available at the current market interest rate.

Wheat Production Data

Application of the model requires data on wheat grain production, forage production, and wheat forage quality. Development of these data was completed using a series of production studies conducted over several years in Oklahoma and surrounding areas. In the second stage of the analysis, these data were simulated using the CERES-Wheat crop simulation model.

Actual Forage and Grain Yields

Several forms of data have been used to represent production risk in previous risk programming applications. Probably the most frequently used data is time series data derived from a multi-year production experiment on a single location. Such data is often difficult to obtain because most agronomy experiments do not span a long enough time period to provide a reliable approximation of the yield distribution. This problem is particularly true in this application to variety selection because of the relatively short life of wheat varieties. If one were to wait for ten years of variety data to be collected, it is likely that this variety would be at or near the end of its product life cycle. Also, varieties are continually being introduced, and hence, the set of cultivars evaluated in variety trials are continually changing. As a result, a three-year variety trial conducted in three locations each year is used to represent nine different environments (states of nature) in the risk programming model.

Tables 4.1 through 4.4 report grain and forage yield data of 12 varieties for each of the nine environments or states of nature (Krenzer and Austin, 1991; Krenzer, Littlefield and Austin, 1991; Krenzer, Williams and Austin, 1992). The production levels are reported on a per-acre basis, and the ranking of each variety by environment is included to the right of each value. Average production levels by variety are in the right hand column of each table, along with the variety's average rank. At the bottom of each column, the average, minimum, maximum and standard deviations are indicated for each environment.

Table 4.1 reports grain yield data. Grain yield ranges from 9.2 to 59.7 bu/acre with an average of 30 bu/acre. Average grain yields across the 12 varieties range between 25.3 bu/acre for Pioneer 2157 and 33.4 bu/acre for Karl. Comparisons of grain yields across environments shows that average grain production is highest at Chickasha in 1990-91 with an average of 52.2 bu/acre and lowest at Marshall in 1990-91 with a per-acre average of 13.8 bu/acre.

Table 4.2, 4.3 and 4.4 report forage yield data for subperiod 1, subperiod 2, and the grazeout period, respectively. The production levels are expressed in pounds of dry matter per acre. Forage production levels in subperiod 1 (November - December) range from 14 to 3,060 pounds of dry matter forage/acre with an overall average of 760 pounds of dry matter/acre (Table 4.2). Pioneer 2157 provided the highest average production

Table 4.1 Grain Yields and Rankings for Twelve Varieties in Nine Environments.

VARIETY	1989-90 BUFFALO	1989-90 MARSHALL	1989-90 PURCELL	1990-91 CHICKASHA	1990-91 MARSHALL	1990-91 FREDRICK	1991-92 HASKELL	1991-92 MARSHALL	1991-92 FREDRICK	AVERAGE
P2157	16.2(12)	16.7(10)	24.2(8)	45.7(12)	13.1(8)	39.5(7)	14.6(7)	18.1(12)	39.8(8)	25.32(12)
TAM 200	27.5(3)	16.2(11)	21.2(11)	46.1(11)	13.6(6)	46.7(3)	13.7(9)	23.2(11)	46.2(3)*	28.27(9)
MESA	22.1(6)	23.5(5)	24.4(7)	51.1(6)	17.0(2)	39.4(8)*	13.2(10)	30.0(8)	38.5(9)	28.80(8)
KARL	24.2(4)	27.7(3)	28.7(3)	58.5(3)	14.5(4)	38.8(11)	28.3(1)	41.6(2)	38.4(10)	33.41(1)
ABILINE	28.3(2)	27.8(2)	22.4(10)	59.5(2)	17.9(1)	41.6(5)	11.4(11)	39.4(3)	34.8(11)	31.46(5)
ARAPAHOE	28.9(1)	26.3(4)	30.5(1)	49.0(9)	13.9(5)	49.0(1)	14.7(6)	42.0(1)	46.2(3)*	33.39(2)
CHISHOLM	23.4(5)	20.4(8)	19.4(12)	50.3(8)	13.2(7)	39.3(10)	17.0(3)	32.6(5)	43.8(5)	28.82(7)
THUNDERBIRD	20.9(9)	28.0(1)	28.6(4)	50.8(7)	15.9(3)	38.3(12)	16.7(4)	35.4(4)	27.5(12)	29.12(6)
P2180	16.9(11)	15.5(12)	29.1(2)	52.4(5)	9.2(12)	39.4(8)*	14.2(8)	29.5(9)	42.7(7)	27.66(10)
A7846	21.2(7)	20.9(7)	27.4(6)	55.6(4)	12.5(10)	46.8(2)	19.3(2)	28.5(10)	53.8(2)	31.78(4)
TAM W-101	17.1(10)	17.8(9)	23.5(9)	47.7(10)	12.6(9)	39.7(6)	9.4(12)	31.2(7)	43.1(6)	26.90(11)
SIERRA	21.0(8)	22.8(6)	27.8(5)	59.7(1)	12.0(11)	46.1(4)	15.8(5)	32.2(6)	56.5(1)	32.66(3)
AVERAGE	22.30	22.00	25.60	52.20	13.80	42.10	15.70	32.00	42.60	
STD.DEV.	4.20	4.60	3.40	4.80	2.20	3.70	4.50	6.80	7.50	
MINIMUM	16.20	15.50	19.40	45.70	9.20	38.30	9.40	18.10	27.50	
MAXIMUM	28.90	28.00	30.50	59.70	17.90	49.00	28.30	42.00	56.50	

Table 4.2 Forage Yields and Rankings <Subperiod 1> for Twelve Varieties in Nine Environments.

	1989-90		1989-90		1989-90		1990-91		1990-91		1990-91		1991-92		1991-92		1991-92			
VARIETY	BUFF	RK	MARS	RK	PURC	RK	CHIK	RK	MARS	RK	FRED	RK	HASK	RK	MARS	RK	FRED	RK	AVER	RANK
2157	559	1	1069	2	535	1	1218	1	571	3	2678	3	1585	4	608	2	406	1	1025	1
TAM 200	90	6	698	7	302	7	1064	7	466	7	2595	4	1318	6	579	3	106	4	802	6
MESA	35	11	529	10	214	10	1022	9	273	11	1304	12	1261	8	753	1	98	5	609	10
KARL	130	4	921	4	412	4	1155	5	516	4	2429	6	1662	2	317	8	131	3	853	4
ABILENE	36	10	976	3	349	6	1011	10	381	9	1771	10	1031	10	364	6	81	9	667	9
ARAPAHOE	39	9	193	11	193	11	956	11	414	8	1952	9	1176	9	132	12	88	7	571	11
CHISHOLM	102	5	881	6	383	5	1056	8	485	6	2453	5	1314	7	234	10	25	11	770	7
THUNDERBIRD	189	3	596	9	480	3	1167	4	721	1	3060	1	1587	3	485	4	94	6	931	3
2180	288	2	1355	1	531.40	2	1216	2	487	5	2142	8	1786	1	382	5	314	2	945	2
7846	81	7	911	5	293.45	8	1112	6	372	10	2275	7	1261	8	206	11	68	10	731	8
TAM W-101	49	8	654	8	239.95	9	1214	3	619	2	2706	2	1392	5	341	7	87	8	811	5
SIERRA	14	12	193	11	142.45	12	548	12	136	12	1332	11	948	11	297	9	0	12	401	12
AVERAGE	134		748		239		1061		453		2225		1360		392		125			
STD.DEV.	148		329		126		176		146		524 243		175		112					
MINIMUM	14		193		142		548		136		1304		948		132		0			
MAXIMUM	559		1355		535		1218		721		3060		1786		753		409			

Table 4.3 Forage Yields and Rankings <Subperiod 2> for Twelve Varieties in Nine Environments.

	1989-90		1989-90		1989-90		1990-91		1990-91		1990-91		1991-92		1991-92		1991-92			
VARIETY	BUFF	RK	MARS	RK	PURC	RK	CHIK	RK	MARS	RK	FRED	RK	HASK	RK	MARS	RK	FRED	RK	AVER	RK
2157	998	2	452	6	553	8	279	8	85	10	221	1	321	11	608	12	331	4	428	8
TAM 200	777	9	561	4	830	4	291	7	102	6	107	9	886	3	725	10	354	3	515	4
MESA	1059	1	612	3	822	5	378	4	124	3	216	2	838	4	813	6	492	1	595	2
KARL	848	6	617	2	603	6	419	2	90	9	181	5	806	5	897	2	163	9	514	5
ABILENE	722	11	440	7	517	10	326	5	167	1	191	4	512	7	803	7	113	11	421	9
ARAPAHOE	675	12	319	11	586	7	409	3	101	7	98	10	321	11	686	11	46	12	360	12
CHISHOLM	811	8	262	12	410	12	224	10	109	5	95	12	474	8	859	4	247	6	388	11
THUNDERBIRD	833	7	428	8	469	11	186	11	109	5	216	3	583	6	883	3	189	8	433	7
2180	939	4	735	1	877	2	291	7	149	2	126	8	1050	1	902	1	362	2	603	1
7846	891	5	394	9	542	9	239	9	99	8	96	11	429	10	754	8	238	7	409	10
TAM W-101	950	3	558	5	870	3	312	6	120	4	146	7	905	2	731	9	295	5	543.00	3
SIERRA	762	10	334	10	1038	1	427	1	65	11	159	6	453	9	858	5	159	10	473	6
AVERAGE	855		476		676		315		110		154		632		793		249			
STD.DEV.	111		136		177		76		26		48		241		89		119			
MINIMUM	675		262		410		186		65		95		321		608		46			
MAXIMUM	1059		735		1038		427		167		221		1050		902		492			

Table 4.4 Forage Yields and Rankings <Grazeout> for Twelve Varieties in Nine Environments.

	1989-90		1989-90		1989-90		1990-91		1990-91		1990-91		1991-92		1991-92		1991-92			
VARIETY	BUFF	RK	MARS	RK	PURC	RK	CHIK	RK	MARS	RK	FRED	RK	HASK	RK	MARS	RK	FRED	RK	AVER	RANK
2157	3940	2	2696	3	2323	9	1258	11	1857	6	3178	1	2329	3	2799	7	331	12	2301	8
TAM 200	3547	5	2622	6	2756	6	1941	6	1476	8	3019	5	2312	4	3194	2	412	3	2364	6
MESA	8755	1	2554	7	2558	7	1657	8	1394	9	3173	2	2272	6	2556	12	366	10	2809	1
KARL	3689	3	2813	2	3071	2	2417	4	2146	4	2942	6	2385	2	2966	5	407	4	2537	2
ABILENE	3495	7	2653	4	3275	1	2476	2	2545	2	2708	11	1669	10	2909	6	395	6	2458	4
ARAPAHOE	3450	8	2445	10	2899	5	2432	3	3117	1	2802	9	2043	8	2677	10	380	8	2472	3
CHISHOLM	2563	12	2001	12	2117	10	1706	7	1638	7	2755	10	1668	11	2975	4	356	11	1975	11
THUNDERBIRD	2697	11	2544	8	2921	4	2486	1	1941	5	3129	3	2285	5	3219	1	406	5	2403	5
2180	2930	10	3020	1	1861	12	1347	10	791	12	2910	8	2457	1	3025	3	431	1	2086	10
7846	3578	4	2651	5	2519	8	1499	9	1358	10	2941	7	2124	7	2684	9	415	2	2197	9
TAM W-101	3196	9	2435	11	1891	11	1258	11	1293	11	3096	4	1466	12	2626	11	370	9	1959	12
SIERRA	3505	6	2515	9	3020	3	2093	5	2383	3	2692	12	1898	9	2781	8	389	7	2364	7
AVERAGE	3779		2579		2601		1881		1828		2945		2076		2868		388			
STD.DEV.	484		233		451		470		614		170		314		207		27			
MINIMUM	2563		2001		1861		1258		791		2692		1466		2556		331			
MAXIMUM	8755		3020		3275		2486		3117		3178		2457		3219		431			

in subperiod 1 and Sierra the lowest. Comparison of forage yields of subperiod 1 across environments shows that average forage production is highest at Fredrick in 1990-91 with an average of 2,224 pounds of dry matter/acre and lowest at Fredrick in 1991-92 with an average yield of 125 pounds of dry matter/acre.

Forage production levels in subperiod 2 (January - February) range from 46 to 1059 pounds of dry matter/acre with an average production of 473 pounds/acre (Table 4.3). On an average basis, Pioneer 2180 provided the highest production in subperiod 2 (603 pounds/acre), while Chisholm produced the lowest forage (360 pounds/acre). Comparison of forage yields of subperiod 2 across evaluation sites shows that average forage production is highest at Buffalo in 1989-90 with an average yield of 855 pounds/acre and lowest at Marshall in 1990-91 with an average yield of 110 pounds/acre.

Forage production levels in Table 4.4 correspond to the grazeout period and range from 331 to 3,755 pounds of dry matter/acre, with an average of 2,327 pounds/acre. On an average basis, Mesa provided the highest production, and Tam W-101 provided the lowest forage yield during the grazeout period. Comparison of forage yields of the grazeout period across the evaluation sites shows that average forage production is highest at Buffalo in 1989-90 with an average of 3,779 pounds of dry matter forage/acre and lowest at Fredrick in 1991-92 with an average yield of 110 pounds of dry matter forage/acre.

Comparison of the forage yield data illustrates that there are significant differences in forage production levels for the twelve varieties in each of the three subperiods. In subperiod 1, Pioneer 2157 provided the highest level of forage production, while in subperiod 2 Pioneer 2180 was the highest forage producer. Mesa produced the most forage in the grazeout period. This difference in yield performance over the grazing subperiods may provide an incentive for managers to produce more than one variety to take advantage of the forage producing qualities of alternative varieties.

The unavailability of a several year data set reporting grain and forage yields for several varieties at a single location necessitates the use of the nine environments to represent production risk in the study. Two of the varieties (Tam W-101 and Pioneer 2157) have been used in variety trials conducted on a single site over several years. Forage and grain measurements were not taken in all years and trials were not conducted in some years. Nonetheless, these data can be used to compare the variability observed over time on a single site with the variability represented using the nine environments. Variability in grain production (as measured by the coefficient of variation) observed in this time series data was .39 for Tam W-101 and .43 for Pioneer 2157. This compares to coefficients of variation for the nine environments of .49 and .48, respectively. Similarly, coefficients of variation for forage production were .48 and .45 for the multiple-year data, and .54 and .44 for the nine environments. Thus, it appears that the use of the nine environments to represent production risk, results in a reasonable approximation of the yield variability present in time series data.

Simulated Forage and Grain Yields

The use of actual (experimental) forage and grain yield data from the nine environments limits the specification of risk in the model in two ways. First, one may argue that production risk represented in the data may not reflect the true yield distributions facing the producer since the data was not collected on a single site. Second, use of the data set limits the specification of risk to just nine states of nature. In addition, additional production decision variables (e.g., planting date, seeding rate) cannot be addressed in the study since these factors were held constant in the experimental data. To address these concerns, a second set of wheat production data was developed by applying the CERES-Wheat crop simulation model. Application of the simulation model in deriving production data for the wheat activities provides a means of holding all site characteristics constant and generating yield distributions represented by increased states of nature. In addition, additional wheat production activities can be included in the model, representing the use of different management practices (e.g., seeding rate, planting date).

CERES-Wheat is a difference equations model that simulates daily growth and development of a wheat plant using climatic, hydrological, phenological, and biological relationships. Phasic development of the wheat plant is simulated and dependent upon both plant genetics and environment. The model simulates extension growth of leaves and stems, as well as senescence of leaves, biomass accumulation, and partitioning (Ritchie and Otter, 1985). Inputs required by the CERES-Wheat model include weather, soil, genetic, and management data.

Because the model's genetic parameters can be specified by the user, the model can be employed in evaluating the response of alternative wheat varieties under different climatic conditions. Genetic information includes a coefficient of sensitivity to day length, a coefficient of sensitivity to vernalization, the grain filling rate, the thermal time between grain filling and maturation, the number of grains produced per plant, and the weight of a single tiller stem at the end of elongation. Although sets of genetic coefficients are provided by the developers for some varieties, the users (Ritchie and Otter, 1985) have found the coefficient values to be very site specific. They recommend that the coefficients be estimated using experimental data from the study region. In addition, coefficient values have not been determined for most of the newer varieties being considered by producers today.

To estimate the genetic coefficients for the 12 varieties, the model was calibrated to estimate grain and forage yields in the study region. The model was first applied to estimate grain and forage production yields over a 10-year period for the Tam W-101 variety in Kingfisher and Perkins, Oklahoma. Historical weather data from each of the locations was used in the simulations, and the soil data was specified to reflect each site's soil characteristics. The results were compared with available data from ten years of variety trials conducted at these two locations. The model explained 79 percent of grain yield variability and 72 percent of forage variability observed on the two sites over the 10-year period.

To estimate the genetic coefficients for the twelve varieties, simulations were conducted for each of the nine environments reflected in the wheat variety data. Historical weather data and soil data from the appropriate site and year were employed. For each environment, 216 simulations were conducted by systematically varying the genetic coefficients. Based on the results of a correlation analysis, the set of genetic coefficients that best predicted observed grain and forage yields in the nine environments was determined for each variety.

Each genetic coefficient set was then used in a 12-year (1978-1993) simulation using historical weather data from Kingfisher, Oklahoma. As a result, forage production data from 12 states of nature were available for use in the farm-level decision model. Three planting dates were also evaluated: earliest planting, early planting, and traditional planting dates. Alternative seeding rates were evaluated, but simulated yields did not vary significantly across the three seeding rates selected. The combination of 12 varieties, three planting dates, and graze-out and grain activities yields a total of 72 wheat production activities for use in the mathematical programming model. Average simulated yield and forage production levels for the twelve varieties are reported in Table 4.5. In general, the model is more accurate in predicting grain yield and tends to over-estimate forage production levels.

Forage Quality

Livestock use energy for various body functions including essential muscular activity, maintenance of body temperature, growth, and milk production. The weight gained or lost by an animal relates directly to the positive or negative relationship between intake and energy expenditure. Forage quality is often measured in terms of the quantity of energy available from consumption of a unit of the feedstuff.

The energy in feeds can be expressed in terms of gross energy (GE), digestible energy (DE), metabolizable energy (ME), and net energy (NE). This nomenclature recognizes the ways the various energies are utilized by the animal. GE is the amount of heat resulting from the complete oxidation of food, feed, or other substances. DE is GE minus fecal energy. In practice GE is measured over a period of time followed by collection of fecal excretion for a representative period. ME is defined as the GE of feed minus energy in the feces, urine, and gaseous products of digestion. A common expression used to estimate metabolizable energy is:

$$ME = DE^{*}0.82 \tag{4.1}$$

NE_m (net energy for maintenance) and NE_g (net energy for gain) are more commonly used for formulating rations for cattle than any other energy system. NE_m is the amount of energy needed to maintain a constant body weight. Animals of known

Table 4.5. Average Simulated Grain and Forage Yields for Twelve Varieties.

Variety	Grain (bu/A)	Forage Period 1 (lb/A)	Forage Period 2 (lb/A)	Forage Period 3 (lb/A)
2157	27.2	882	1325	3350
TAM 200	29.4	781	1172	3460
Mesa	30.1	746	1119	3547
Karl	33.7	800	1200	3481
Abilene	31.4	720	1079	3498
Arapahoe	32.7	584	876	3622
Chisolm	29.6	726	1089	3426
Thunderbird	27.8	861	1292	3359
2180	26.6	939	1409	3191
7846	30.1	668	1002	3339
TAM W-101	31.8	781	1171	3460
Sierra	29.4	615	923	3267

weight fed for zero energy gain, have a constant level of heat production. The NE_g measures the increased energy content of the carcass after feeding a known quantity of feed energy.

Forage quality data were collected from a set of six different studies reporting the digestibility of wheat forage by month over the grazing season (Belyea et al., 1978; Bruckner and Hanna, 1990; Cherney and Marton, 1982; Johnson et al., 1973; Mader et al., 1983; West et al., 1988). Net energy for maintenance (NE_m) and net energy for gain (NE_g) are the forage quality measurements actually used to estimate energy. Digestible energy values were converted to metabolizable energy using equation 4.1. NE_m and NE_g were then estimated as polynomial functions of metabolizable energy (ME) using the following relationships (National Research Council, 1984):

$$NE_m = 1.37ME - .138ME^2 + .0105ME^3 - 1.12 \tag{4.2}$$

$$NE_g = 1.42ME - .174ME^2 + .0122ME^3 - 1.65 \tag{4.3}$$

Livestock Production Activity Data

Description of Stocker Enterprises

Stocker cattle comprise those classes of livestock between weaned calves and cows or bulls. In the process of livestock production, it is the weaning time of calves that is important for cattlemen to make decisions whether to terminate or continue with livestock production activities. That is, cattlemen can either raise calves and sell them to stocker cattle producers or integrate the business vertically by expanding the business to include a stocker enterprise. For this study, it is assumed that producers purchase stocker cattle to utilize their wheat forage production. The profitability of the wheat stocker production system depends on the length of grazing, weight gain and price movements over the grazing season.

How long stocker cattle can be kept on the farm depends on the availability of forage, expected performance and other factors influencing production. As stated earlier, winter wheat pasture typically can be grazed from the month of November through the month of May. For this study, a 185-day period (November 10 through May 14) was considered the period in which stocker cattle can graze winter wheat pasture. All cattle may not necessarily be kept on the farm for the entire grazing period, and only a portion of planted acreage may be utilized at a particular point in the season.

For the purpose of making decisions regarding the length of time stocker cattle should be owned, the grazing period is divided into three subperiods. Division of the grazing season in this manner also provides a means of representing the forage resource as a flow resource rather than a stock that can be used at any point in the season. Subperiod 1 comprises the first half of the fall-winter grazing period and runs from November 10 through January 10. The second subperiod consists of the second half of the fall-winter grazing season and runs from January 11 through March 14. March 15 through May 14 constitutes the third subperiod, which is often referred to as the grazeout period. If grazing occurs in the third subperiod, the wheat crop is assumed to be used exclusively for grazing. No livestock- grain interactions are incorporated from grazing in subperiods 1 and 2. That is, grain yields are not affected by grazing prior to jointing.

In the process of grazing stocker cattle over the various subperiods, stocker cattle can gain different live weight, depending upon forage availability. Based on these different weight gains, three sets of stocker activities are included in each subperiod: high-, medium-, and low-gain activities. Because of differences in potential weight gains, stockers having the same initial weight (450 pounds) may be characterized by one of three different weights at the end of subperiod 1. As the grazing continues in subperiod 2, three alternative levels of gain are again available. Because of the assumption that stocker cattle can transfer from one gain category to another between subperiods, nine stocker cattle activities are included for subperiod 2, each characterized by a different ending weight. In subperiod 3 (grazeout), these nine beginning weights of stockers would combine with the three gain categories to provide a total of 27 categories of livestock activities, each with a different end live weight.

At the end of each subperiod, stocker cattle can be retained into the next grazing period or sold. Additional cattle can also be purchased at the beginning of each grazing subperiod. The potential weight to be gained and the effect on return from both stocker and grain enterprises all influence the decision of whether to sell or keep an animal for a certain period of time. The producer possesses the flexibility to change stocking density at the beginning of any subperiod by selling or purchasing additional stockers. The categories of livestock activities and their marketing options are shown graphically in the schematic flow chart in Figure 4.1.

In addition to the base stocker activities, a set of activities was also included which provided supplemental feed to stocker cattle grazing wheat pasture. Energy supplementation of stocker cattle during the fall-winter grazing season has been shown to be a viable alternative for producers in Oklahoma (Horn et al., 1992). Incorporation of a energy supplementation program can be used to extend available forage for longer periods of time or increase the number of cattle to be grazed. This activity differs from supplementation activities discussed earlier where supplement is fed to make up for inadequate forage supplies. All stockers are fed supplement to compensate for forage

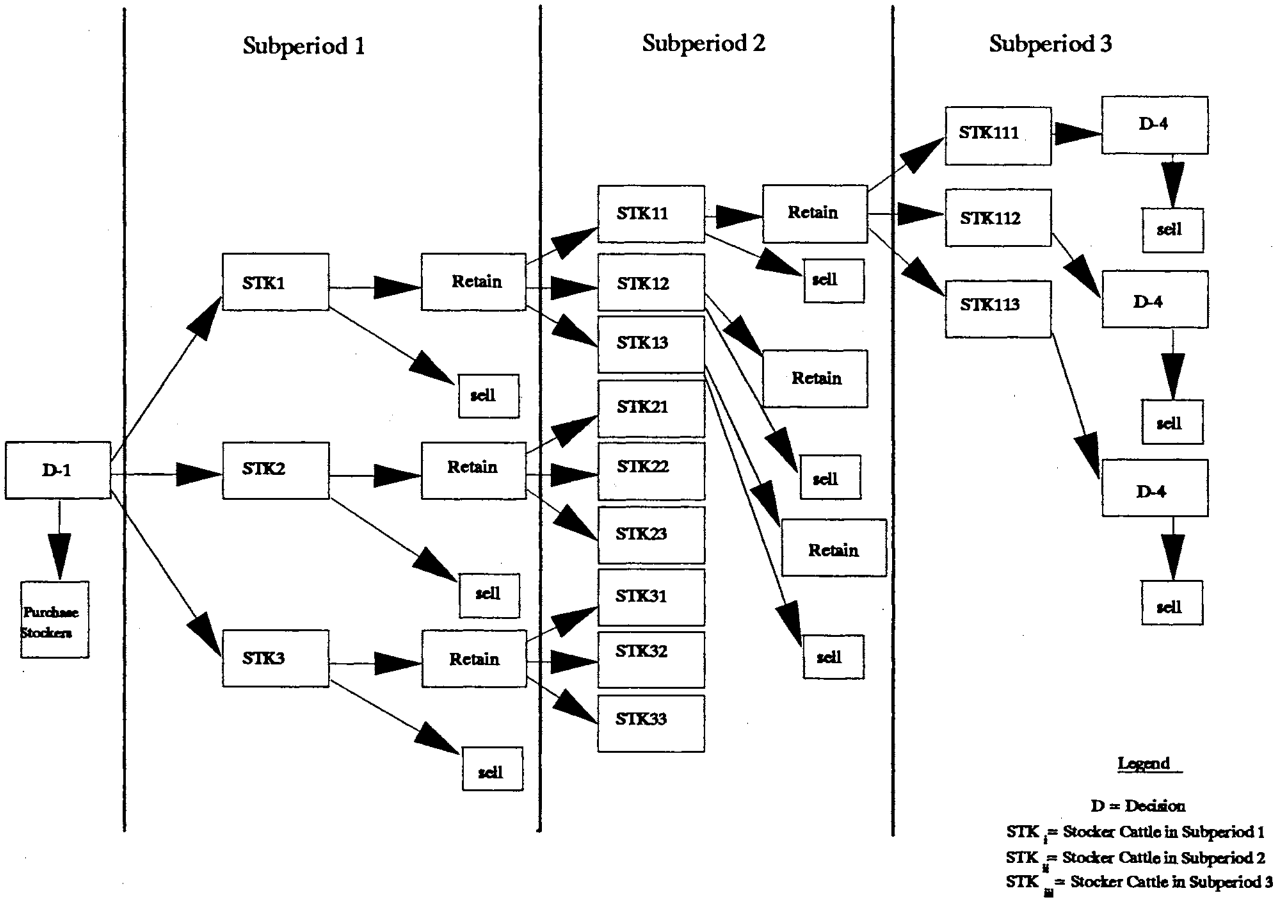

Figure 4.1. Flow Chart Showing Transfer of Stockers Across Subperiods and Decision Alternatives Available to the Producer.

deficits. In the supplemented stocker activity steers are supplemented daily to enhance performance.

Based upon three years of experimental data, a set of stocker activities was developed feeding a high-fiber energy supplement. These stocker activities will be referred to as "supplemented steers". The ration of the high-fiber energy supplement consists mainly of wheat middlings and soybean hulls. An average quantity of 4 pounds per day of the energy supplement can be fed over subperiod 1 and/or subperiod 2. The supplemented steers have a reduced forage requirement, in that supplement is substituted for a portion of the wheat pasture comprising the steer's diet. Therefore, use of supplementation has the added benefit in that the stocking density can be increased relative to the unsupplemented steer enterprise. As with unsupplemented steers, three alternative levels of gain for supplemented steers are included in the model. Thus, three supplemented steer activities are included in subperiod 1 and nine are included in subperiod 2. Steers are not supplemented in subperiod 3 (grazeout); however, these steers must be accounted for in the model separately from the unsupplemented steers because of their larger weight and different forage requirements and performance.

Estimation of Feed Requirements and Cattle Performance

Winter wheat pasture grazing is the main source of feed supply for the stocker cattle. Availability of feeds not only determines the size of stocker enterprise, but it also influences the composition of stockers in terms of age and body weight. The quantity and quality of forage affect the amount of feed intake. Thus, identifying the feed requirements for the various activities is an important consideration in developing optimal production plans.

In the organization of wheat-stocker production system, stockers with equal beginning weight (450 pounds) and the same chronological age were assumed to be placed on winter wheat pasture. Stockers were assumed to be placed on the wheat pasture at the beginning of any subperiod and removed from pasture at the end of any subsequent subperiod, depending on the weather and economic conditions. Unsupplemented stockers are dependent on wheat pasture for the entire period except that supplementary feeds are made available when there is a deficit. Supplemented stockers consume the supplemental energy ration and wheat forage.

National Research Council (1984) formulations were used to estimate energy requirements, intake levels, and weight gain for the stocker enterprises. Based upon forage quality data and animal weight, average daily intake was estimated for the subperiod. Energy for maintenance and gain was estimated from the intake, and average daily gain estimated based upon energy available for gain.

The amount of forage that stockers voluntarily consume was estimated using the following National Research Council equation:

$$VI = LWT^{0.75}(0.1493NE_m - 0.046NE_m^2 - 0.0196) \qquad (4.4)$$

where VI is the voluntary intake (kg/hd), LWT is the live weight of the animals (kg/hd), and NE_m is the net energy for maintenance (Mcal/kg). NE_m measures forage quality and was estimated based upon several years of data of wheat forage quality.

In determining energy requirements for animals, the National Research Council procedures estimated feed requirements for maintenance and gain separately. Net energy required for maintenance (NE_m) is the nutrition that is necessary for the animal to remain in a given, constant condition. According to Lofgreen and Garrett (1968), maintenance requirements (in Mcal/day) for stockers may be estimated as follows:

$$NE_{rm} = 0.077LWT^{0.75} \tag{4.5}$$

The net energy requirements for gain are estimated on a live weight basis. Live weight is defined as the weight of an animal after an overnight feed and water shrink (National Research Council, 1984). Dry matter available for gain is calculated as the portion of intake not used for maintenance. That is,

$$DM_{ag} = VI - NE_{rm}/NE_{m} \tag{6}$$

The equation to calculate net energy for growth for stockers on a liveweight basis is:

$$NE_{ag} = DM_{ag} * NE_{g} \tag{7}$$

As described earlier, the stockers may have different weight gains because of different levels of forage availability. Based on this assumption, stockers were divided into high, medium and low-gain categories. Furthermore, it was assumed that stockers can be transferred from one weight gain category to another weight gain category during the grazing period. For example, stockers having a low rate of gain in subperiod 1 may transfer to medium or high-gain activities in subperiod 2. The actual weight gain is estimated based upon the quantity of energy available for gain that is derived from forage intake. Stockers with a high gain potential consume greater amounts of forage than medium and low-gain category stockers. Live daily gain (LDG) in kg/day/head is calculated with the following National Research equation:

$$LDG = 13.91NE_{ag}{}^{0.9116}LWT^{-0.6837} \tag{4.8}$$

where NE_{ag} is the net energy available for weight gain (Mcal/day) and LWT is the live weight of the animal (kg/hd). The estimated weight gains for the base (unsupplemented) stocker activities in the fall-winter period were 1.95, 1.59 and 1.21 pounds per stocker per day for high, medium and low-gain categories, respectively. For the supplemented stockers, fall-winter gains were 2.20, 1.84 and 1.46 pounds per stocker per day, respectively. The weight gains for unsupplemented cattle increased to 2.25, 1.83, and 1.40 pounds per day in subperiod 3.

The NRC method yields a forage requirement of 18.14, 16.05 and 14.02 pounds of dry matter wheat forage to produce 1.95, 1.59 and 1.21 pounds of gain per day in unsupplemented stockers having an average feeding weight of approximately 571, 548 and 525 pounds, respectively in subperiod 1. The forage requirement to produce the same weight gains is different in subperiod 2 and subperiod 3 because of difference in the average feeding weight of the animals. Table 4.6 summarizes performance and feed requirements for alternative stocker production (unsupplemented) activities.

Forage requirements for the supplemented steers were adjusted to reflect the effect of the supplement on intake as well as weight gain. Based upon three years of experimental data, average daily gain was expected to be increased approximately 0.25 lb/day during the supplementation period (Horn et al., 1992; Horn et al., 1993). Based upon the estimated forage quality of the composite wheat forage and supplement diet, total daily intake was estimated. Intake requirements of wheat pasture were calculated as the difference between total intake and the quantity of supplement fed, assuming cattle selection favors the supplemental feed. Supplemented stocker activities are summarized in Table 4.7.

Forage Yield Deviations

Variability in the forage yield for each alternative wheat production activity is included in the deviation rows as the actual production in the three subperiods for each state of nature. The annual deviations are the difference between the actual production for that subperiod and the level of forage required in the same subperiod. The deviations

Table 4.6 Alternative Production Activities for Unsupplemented Stockers.

STOCKER ACTIVITY	PERIOD	DAYS HELD	WEIGHT GAIN/DAY	BEGINNING WEIGHT	AVERAGE WEIGHT	ENDING WEIGHT	FORAGE REQ/DAY	TOTAL REQUIRED
STK1	11/10-1/10	62	1.95	450.00	510.56	571.11	18.14	1125.00
STK2	11/10-1/10	62	1.59	450.00	499.14	548.28	16.05	995.00
STK3	11/10-1/10	62	1.21	450.00	487.45	524.91	14.02	869.00
STK11	1/11-3/15	63	1.95	571.11	632.64	694.18	21.30	1342.00
STK12	1/11-3/15	63	1.59	571.11	621.04	670.97	18.91	1191.00
STK13	1/11-3/15	63	1.21	571.11	609.17	647.23	16.57	1044.00
STK21	1/11-3/15	63	1.95	548.28	609.81	671.34	20.72	1306.00
STK22	1/11-3/15	63	1.59	548.28	598.21	648.14	18.38	1158.00
STK23	1/11-3/15	63	1.21	548.28	586.33	624.39	16.10	1014.00
STK31	1/11-3/15	63	1.95	524.91	586.44	647.97	20.13	1268.00
STK32	1/11-3/15	63	1.59	524.91	574.84	624.77	17.84	1124.00
STK33	1/11-3/15	63	1.21	524.91	562.96	601.02	15.61	984.00
STK111	3/16-5/14	60	1.95	694.18	752.78	811.38	24.27	1456.00
STK112	3/16-5/14	60	1.59	694.18	741.73	789.28	21.60	1296.00
STK113	3/16-5/14	60	1.21	694.18	730.42	766.67	18.98	1139.00
STK121	3/16-5/14	60	1.95	670.97	729.57	788.18	23.71	1422.00
STK122	3/16-5/14	60	1.59	670.97	718.53	766.08	21.09	1266.00
STK123	3/16-5/14	60	1.21	670.97	707.22	743.46	18.53	1112.00
STK131	3/16-5/14	60	1.95	647.23	705.83	764.43	23.13	1388.00
STK132	3/16-5/14	60	1.59	647.23	694.78	742.33	20.57	1234.00
STK133	3/16-5/14	60	1.21	647.23	683.47	719.72	18.06	1084.00
STK211	3/16-5/14	60	1.95	671.34	729.94	788.55	23.72	1423.00
STK212	3/16-5/14	60	1.59	671.34	718.89	766.45	21.10	1266.00
STK213	3/16-5/14	60	1.21	671.34	707.59	743.83	18.54	1112.00
STK221	3/16-5/14	60	1.95	648.14	706.74	765.34	23.15	1389.00
STK222	3/16-5/14	60	1.59	648.14	695.69	743.24	20.59	1235.00
STK223	3/16-5/14	60	1.21	648.14	684.38	720.63	18.08	1085.00
STK231	3/16-5/14	60	1.95	624.39	682.99	741.60	22.56	1354.00
STK232	3/16-5/14	60	1.59	624.39	671.94	719.50	20.06	1204.00
STK233	3/16-5/14	60	1.21	624.39	660.64	696.88	17.60	1056.00
STK311	3/16-5/14	60	1.95	647.97	706.57	765.18	23.14	1389.00
STK312	3/16-5/14	60	1.59	647.97	695.53	743.08	20.58	1235.00
STK313	3/16-5/14	60	1.21	647.97	684.22	720.46	18.07	1084.00
STK321	3/16-5/14	60	1.95	624.77	683.37	741.97	22.57	1354.00
STK322	3/16-5/14	60	1.59	624.77	672.32	719.87	20.07	1204.00
STK323	3/16-5/14	60	1.21	624.77	661.01	697.26	17.61	1057.00
STK331	3/16-5/14	60	1.95	601.02	659.63	718.23	21.98	1319.00
STK332	3/16-5/14	60	1.59	601.02	648.58	696.13	19.53	1172.00
STK333	3/16-5/14	60	1.21	601.02	637.27	673.51	17.14	1028.00

Table 4.7 Alternative Production Activities for Supplemented Stockers.

STOCKER ACTIVITY	PERIOD	DAYS HELD	GAIN	BEGINNING WEIGHT	AVERAGE WEIGHT	ENDING WEIGHT	FORAGE REQ/DAY	TOTAL REQUIRED	SUPPL1	SUPPL2
STK1	11/10-1/10	62	2.20	450.00	518.31	586.61	13.21	819.00	212.09	0
STK2	11/10-1/10	62	1.84	450.00	506.89	563.78	11.72	727.00	207.42	0
STK3	11/10-1/10	62	1.46	450.00	495.20	540.41	9.38	582.00	202.64	0
STK11	1/11-3/15	63	2.20	586.61	656.02	725.43	15.40	970.00	0	272.77
STK12	1/11-3/15	63	1.84	586.61	644.42	702.22	13.70	863.00	0	267.95
STK13	1/11-3/15	63	1.46	586.61	632.54	678.48	12.03	758.00	0	263.01
STK21	1/11-3/15	63	2.20	563.78	633.18	702.59	15.05	948.00	0	263.28
STK22	1/11-3/15	63	1.84	563.78	621.58	679.39	13.38	843.00	0	258.45
STK23	1/11-3/15	63	1.46	563.78	609.71	655.64	11.75	740.00	0	253.52
STK31	1/11-3/15	63	2.20	540.41	609.81	679.22	14.72	928.00	0	253.56
STK32	1/11-3/15	63	1.84	540.41	598.21	656.02	13.05	822.00	0	248.74
STK33	1/11-3/15	63	1.46	540.41	586.34	632.27	11.45	722.00	0	243.80
STK111	3/16-5/14	60	2.20	725.43	783.93	842.43	25.02	1501.00	0	0
STK112	3/16-5/14	60	1.84	725.43	773.13	820.83	22.28	1337.00	0	0
STK113	3/16-5/14	60	1.46	725.43	761.73	798.03	19.59	1175.00	0	0
STK121	3/16-5/14	60	2.20	702.22	760.72	819.22	24.46	1468.00	0	0
STK122	3/16-5/14	60	1.84	702.22	749.92	797.62	21.78	1307.00	0	0
STK123	3/16-5/14	60	1.46	702.22	738.52	774.82	19.14	1148.00	0	0
STK131	3/16-5/14	60	2.20	678.48	736.98	795.48	23.89	1433.00	0	0
STK132	3/16-5/14	60	1.84	678.48	726.18	773.88	21.26	1276.00	0	0
STK133	3/16-5/14	60	1.46	678.48	714.78	751.08	18.68	1121.00	0	0
STK211	3/16-5/14	60	2.20	702.59	761.09	819.59	24.47	1468.00	0	0
STK212	3/16-5/14	60	1.84	702.59	750.29	797.99	21.79	1307.00	0	0
STK213	3/16-5/14	60	1.46	702.59	738.89	775.19	19.15	1149.00	0	0
STK221	3/16-5/14	60	2.20	679.39	737.89	796.39	23.91	1435.00	0	0
STK222	3/16-5/14	60	1.84	679.39	727.09	774.79	21.28	1277.00	0	0
STK223	3/16-5/14	60	1.46	679.39	715.69	751.99	18.69	1122.00	0	0
STK231	3/16-5/14	60	2.20	655.64	714.14	772.64	23.33	1400.00	0	0
STK232	3/16-5/14	60	1.84	655.64	703.34	751.04	20.76	1245.00	0	0

Table 4.7 (Continued)

STK233	3/16-5/14	60	1.46	655.64	691.94	728.24	18.23	1094.00	0	0
STK311	3/16-5/14	60	2.20	670.22	737.72	796.22	23.91	1434.00	0	0
STK312	3/16-5/14	60	1.84	670.22	726.92	774.62	21.28	1277.00	0	0
STK313	3/16-5/14	60	1.46	670.22	715.52	751.82	18.69	1121.00	0	0
STK321	3/16-5/14	60	2.20	656.02	714.52	773.02	23.34	1400.00	0	0
STK322	3/16-5/14	60	1.84	656.02	703.72	751.42	20.77	1246.00	0	0
STK323	3/16-5/14	60	1.46	656.02	692.32	728.62	18.23	1094.00	0	0
STK331	3/16-5/14	60	2.20	632.27	690.77	749.27	22.75	1365.00	0	0
STK332	3/16-5/14	60	1.84	632.27	679.97	727.67	20.24	1214.00	0	0
STK333	3/16-5/14	60	1.46	632.27	668.54	704.74	20.13	1065.00	0	0

represent excess or shortage in forage supply over the various states of nature, and are entered in the risk portion of the model as a principal source of production risk.

To allocate a monetary value to these deviations, supplemental feed purchasing activities were included in the model. Supplement is purchased when a negative forage supply deviation is estimated. That is, the annual forage supply value is below the forage requirement for that subperiod. A supplement ration was developed which provided equivalent energy to the steer's diet assuming forage is not limiting.

Economic Data

Economic data comprises the cost and return aspects of an enterprise. Enterprise budgets can be used to obtain the economic data of an enterprise. In enterprise budgeting, the physical and financial plan must be outlined. The physical plan is a schematic presentation of the requirements of inputs and the corresponding output, whereas the financial plan contains the estimated cost and return aspects of the plan.

Wheat Production Costs and Revenues

The expenditures that are influenced by the producer constitute the operating cost of production. These costs are also called variable costs and are useful in making production decisions. Fixed costs are not important in making production decisions in the short-run because the producer will bear them whether production is undertaken or not. Enterprise budgets prepared by the Oklahoma Cooperative Extension Service were used as the principal source of information in the estimation of the cost of wheat production. Table 4.8 shows per-acre input requirements and costs incurred in wheat production. It was not necessary to outline unique budgets for each variety because of

Table 4.8 Costs of Wheat Production.

Operating Inputs	Units	Prices	Quantity	Value
Wheat Seed	BU	5.00	1	5.00
Fertilizer	CWT	10.50	1	10.50
Nitrogen(N)	LBS	0.17	65	11.05
Insecticide	ACRE	4.50	0.5	2.25
Miscellaneous	ACRE	2.00	1	2.00
Annual Operating Capital	DOL	0.13	28.37	3.69
Labor Charges	HR	4.65	3.09	14.37
Machinery,Fuel,Lube,Repair	ACRE			26.73

Total Operating Cost				75.59

the assumption that input requirements were the same for all varieties. Geographical, weather and other differences which might cause differences in input applications across years were not considered.

Wheat prices used in the model are Oklahoma seasonal average prices. To adjust prices to a 1993 basis, the implicit price deflator for gross domestic product was employed. The index numbers for 1984 to 1993 were divided into their associated 1993 index to obtain the adjustment factor. Nominal and real wheat prices are presented in Table 4.9. The average of the real prices ($3.23/bu) is used to estimate wheat revenues in the objective function, while each of the individual annual prices is used to estimate annual net return deviations from sale of wheat.

Stocker Production Costs and Revenues

Revenues from the stocker enterprises were estimated as the product of the cattle price and the projected sale weight. Sale weight was adjusted downward to account for death loss. A death loss of 2 percent was assumed.

Livestock prices used in the model are the average monthly prices received at the Oklahoma City stockyards over the nine year period. Prices reported for 400-500 pound steer calves in November were used to represent the cost of 450 pound calves. Monthly prices for steers in January, March, and May were used to estimate the sale value of steers at the end of each of the three subperiods. Steer prices are reported in 100 pound increments (i.e., 400-500, 500-600, 600-700, and 700-800 pounds). The prices corresponding to each weight category are assumed to reflect the value of an animal with a weight equal to the midpoint of the category. Linear interpolation is used to assign values to weights between these midpoints. The GNP price deflator was used to convert

Table 4.9 Nominal and Real Wheat Prices

Year	Average Price	PPI	Adjusted Price
1984	3.36	80	4.20
1985	2.91	75	3.88
1986	2.28	74	3.08
1987	2.46	81	3.04
1988	3.57	92	3.88
1989	3.79	92	4.12
1990	2.57	99	2.60
1991	2.85	99	2.88
1992	3.20	98	3.27
1993	3.36	100	3.36

the nominal prices to a 1993 basis.

The cost associated with the stocker enterprise portion of a wheat grazing system is a function of stocking density, the length of the grazing season, prices of various services and inputs, and the amount of supplemental feed provided to stockers.

The largest cost incurred in the stocker enterprise is the purchase of stocker calves at the beginning of the wheat grazing season. This cost was calculated as the product of beginning stocker weight (lb/hd) and beginning stocker price ($/lb). The beginning stocker weight was assumed constant at 450 pounds.

Veterinary costs include expenses incurred for the routine processing of newly arrived cattle, sick pen costs, and routine vet calls. Total veterinary and medical costs per stocker are $9.00/hd., of which $4.67 is used for processing the animal on arrival. Sick costs are $12.00 per stocker, and it was assumed that 25 percent of the animals will be treated. Thus, a cost of $3.00 per stocker is included in the budgets. The remaining $1.33 of the $9.00 may be attributed to routine vet calls. A vet call will cost $30.00 and it was assumed that 4.4 percent of the calves will require a vet call (Rawlins and Bernardo, 1988).

The stocker production cost also includes the purchase cost of supplemental hay and supplemental feed for use during conditioning and in periods of unfavorable wheat growth conditions. Hay costs were held constant at $0.03/lb and supplemental feed costs were $0.07/lb.

Salt and mineral costs represent a small component of stocker production costs. A requirement of 0.25 lb/hd/day of salt and mineral was estimated to be used for stocker cattle. The salt and mineral costs associated with the wheat grazing system model were calculated as the product of the salt and mineral requirement and its per-unit cost

($.15/lb).

A custom charge of $0.35 per cwt was used for hauling cattle to and from the sale barn. A 60 mile haul at $3.00 per mile with a 393 cwt truck pay weight was assumed in deriving the $0.35 per cwt cost. A marketing charge of $1.72/cwt was applied to all cattle sold in the model. This cost is based on current estimates of marketing charges paid at Oklahoma auctions (Walker et al., 1986). Marketing charges for purchased calves were reflected in the purchase price.

In determining labor cost, all labor in excess of that supplied by the owner-operator was assumed to be hired. Labor costs for the stocker enterprise were divided into machinery and equipment labor and livestock labor. Machinery and equipment labor costs encompassed labor which involved the utilization of machinery and equipment to provide supplemental feed to stockers during conditioning and low wheat forage production periods. Machinery and equipment labor costs were estimated as a function of the amount of supplemental feed handled during the conditioning period and grazing season. Machinery and equipment labor costs were estimated as $.011 per pound of supplement fed (Roddy, 1989).

Livestock labor costs were considered to be those costs involving the routine inspection and supervision of the stockers while utilizing the wheat pasture. The livestock labor requirement was estimated as 0.011 hr/day. A $5.00/hour livestock labor cost was assumed.

Machinery and equipment fuel, lubrication and repair costs were estimated based on the amount of supplements handled. These costs per head for fall/winter grazing season was assumed to be $9.86 (Oklahoma Cooperative Extension Service, 1993).

Interest expense is the other major component of stocker production costs.

Producers were assumed to borrow the amount of operating capital necessary to finance the original stocker purchase at the beginning of the grazing season. Interest expense was also charged on all purchased inputs. The interest rate was held constant at 11 percent.

Baseline Stocker Enterprise Budgets

Differences in weight gain assumptions across subperiods can produce an extremely large set of possible wheat stocker enterprises. However, to provide some reference point, a small set of enterprise budgets corresponding to the high-gain assumptions were prepared. Estimates of costs and returns were made on a per-head basis. Since the study includes supplemented and unsupplemented programs, the enterprise budgets include fall/winter and grazeout stocker enterprise budgets for both supplemented and unsupplemented programs.

Tables 4.10, 4.11, 4.12 and 4.13 show the baseline stocker enterprise budgets. Those items designated with an asterisk are variable costs which change across enterprises depending upon the assumed weight gain. The quantity of supplemental feed will also vary depending upon estimated forage availability in a particular year.

Model Coefficients for Stocker Enterprises

Because stocker production is represented in the model by 2-month subperiods, separate stocker activities are not included for each stocker enterprise. Also, to allow for possibilities of selling or retaining stockers after each subperiod, production costs and revenues must be isolated in the objective function. Objective function coefficients for each subperiod reflect the operating costs incurred during that subperiod. Sale activities

Table 4.10 Baseline Enterprise Budget for Fall-Winter Unsupplemented Stockers.

	UNIT	PRICE	QUANTITY	VALUE
LIVESTOCK RECEIPTS:				
Stockers	cwt	82.50	6.94	572.55
Total Receipts				572.55
OPERATING INPUTS:				
Stocker Calves	cwt	98.00	4.5	441.00
Supplemental Feed	lb	0.07	0	0.00
Supplemental Hay	lb	0.03	200	6.00
Salt & Mineral	lb	0.15	33.75	5.06
Freight	cwt	0.35	6.94	2.43
Marketing	cwt	1.72	6.94	11.94
Vet-Med Expenses	hd	9.00	1	9.00
Mach. & Equip. Costs	hd	7.96	1	7.96
Interest Expense	dol	0.11	162.86	17.91
Labor	hr	5.00	1.27	6.35
Beef Checkoff	dol	1.00	1	1.00
Misc.	dol	0.00	1	0.00
Total Operating Costs				508.65
RETURN ABOVE OPERATING COSTS ($/HD)				63.90

Table 4.11 Baseline Enterprise Budget for Fall-Winter Supplemented Stockers.

	UNIT	PRICE	QUANTITY	VALUE
LIVESTOCK RECEIPTS:				
Stockers	cwt	81.00	7.25	587.25
Total Receipts				587.25
OPERATING INPUTS:				
Stocker Calves	cwt	98.00	4.5	441.00
Supplemental Feed	lb	0.07	384	26.88
Supplemental Hay	lb	0.03	200	6.00
Salt & Mineral	lb	0.15	33.75	5.06
Freight	cwt	0.35	7.25	2.54
Marketing	cwt	1.72	7.251	2.47
Vet-Med Expenses	hd	9.00	1	9.00
Mach.& Equip. Costs	hd	9.86	1	9.86
Interest Expense	dol	0.11	172.85	19.01
Labor	hr	5.00	1.58	7.90
Beef Checkoff	dol	1.00	1	1.00
Misc.	dol	0.00	1	0.00
Total Operating Costs				540.72
RETURN ABOVE OPERATING COSTS ($/HD)				46.53

Table 4.12 Baseline Enterprise Budget for Graze-out Unsupplemented Stockers.

	UNIT	PRICE	QUANTITY	VALUE
LIVESTOCK RECEIPTS:				
Stockers	cwt	76.00	8.22	624.72
Total Receipts				624.72
OPERATING INPUTS:				
Stocker Calves	cwt	98.00	4.5	441.00
Supplemental Feed	lb	0.07	0	0.00
Supplemental Hay	lb	0.03	200	6.00
Salt & Mineral	lb	0.15	48.75	7.31
Freight	cwt	0.35	8.22	2.88
Marketing	cwt	1.72	8.22	14.14
Vet-Med Expenses	hd	11.00	1	11.00
Mach.& Equip. Costs	hd	9.96	1	9.96
Interest Expense	dol	0.11	244.24	26.87
Labor	hr	5.00	1.77	8.85
Beef Checkoff	dol	1.00	1	1.00
Misc.	dol	0.00	1	0.00
Total Operating Costs				529.00
RETURN ABOVE OPERATING COSTS($/HD)				95.72

Table 4.13 Baseline Enterprise Budget for Graze-out Supplemented Stockers.

	UNIT	PRICE	QUANTITY	VALUE
LIVESTOCK RECEIPTS:				
Stockers	cwt	75.00	8.42	631.50
Total Receipts				631.50
OPERATING INPUTS:				
Stocker Calves	cwt	98.00	4.5	441.00
Supplemental Feed	lb	0.07	384	26.88
Supplemental Hay	lb	0.03	200	6.00
Salt & Mineral	lb	0.15	48.75	7.31
Freight	cwt	0.35	8.42	2.95
Marketing	cwt	1.72	8.42	14.48
Vet-Med Expenses	hd	11.00	1	11.00
Mach.& Equip. Costs	hd	11.36	1	11.36
Interest Expense	dol	0.11	258.77	28.46
Labor	hr	5.00	2.03	10.15
Beef Checkoff	dol	1.00	1	1.00
Misc.	dol	0.00	1	0.00
Total Operating Costs				560.60
RETURN ABOVE OPERATING COSTS ($/HD)				70.90

are included for each activity, and the objective function coefficient reflects the gross receipts earned from the sale of the steer. Thus, net returns from the sale of a steer purchased in November and grazed through the grazeout period would be estimated as the sum of the objective function coefficients for the sale activity and the three subperiods (negative operating costs).

Government Programs

Modelling the government commodity programs poses some difficult methodological problems, since the structure of the commodity programs has changed over time. This is a particularly difficult problem given that the risk programming model uses time series data to account for price risk. In general, there are two methodological choices: (i) consider the government program provisions as fixed over the time horizon of the analysis, or (ii) consider the government program provisions as varying and account for these changes when estimating the annual returns associated with program participation. The most significant problem with the first method is that commodity prices are linked to program provisions; however, this interaction will not be captured in the model. For example, larger set-aside percentages are usually prevalent when wheat supplies are abundant, and hence, grain prices are likely to be low. On the other hand, the model was developed to represent the current planning environment faced by producers; one can then argue that the commodity provisions should be held constant at current levels. Thus, the former alternative was selected and current program specifications were treated as if they had been in effect over the entire time period.

The 1992 Government Commodity Program Worksheet (Anderson et al., 1992) was used to estimate per-acre revenues from program participation. The model is structured to accommodate three program alternatives: regular program participation, 0-92 participation, or no participation. To be eligible for deficiency payments, a producer must agree to set-aside a pre-determined proportion of the farm's base acreage. Producers have been permitted to produce wheat for forage on this acreage as long as it is not harvested for grain and grazed beyond a specific date. In addition, another portion of the base acres (mandatory flex-acres) is not eligible for deficiency payments but may be used for production of alternative crops, grazeout, or grain production without deficiency payments.

In addition to the regular program provisions described above, the 0/92 option is also available to producers. Under this program, producers are allowed to devote all or a portion of wheat base acres to conserving uses (typically grazeout acreage) and receive 92 percent of the deficiency payments they would have received under the regular program. Base acres allocated to the 0/92 program can be seeded to wheat and grazed through June 1. The model was constructed so that any portion of the wheat acreage base may be allocated to the 0/92 program.

Program parameters used in the model include the target price, set-aside percentage, flex-acres percentage, and loan rate. A program yield of 30 bu/ac, the average across the nine sites and twelve varieties (see Table 4.1), was used as the program yield. These program parameters reflect the provisions for the 1992-93 production year. Using these parameters and the 5-month and 12-month US average prices for each of the nine years, deficiency payments were estimated for each year of the time horizon.

CHAPTER V

RESULTS AND ANALYSIS

There are several factors that influence the decisions of how to organize wheat production. The dual use of wheat plants for grain and forage production and the introduction of commodity policy complicates the decisions. The possibility of grazing wheat pasture, participating in government wheat commodity programs, and the price differentials for wheat and cattle requires one to examine farm organizations and returns for several alternative scenarios.

The Target-MOTAD model developed using the observed wheat production data (experimental wheat variety trial data) was applied to five scenarios. In the baseline scenario, all production alternatives are available and prices reflect averages over the nine-year period. The second scenario employs the same economic data, but does not allow for the opportunity of leasing the wheat pasture. The third scenario eliminates all livestock activities to identify diversification opportunities for producers interested in grain production only. The final two scenarios consider the impact of changes in the wheat-cattle price ratios on the optimal farm organization.

The Target-MOTAD model developed using the simulated wheat production data is then applied to the baseline and "no grazing" scenarios. Differences in the optimal strategies used to meet the risk constraints in the two models are compared.

Application of Target-MOTAD Model Using Observed Wheat Production Data

Baseline Scenario

Table 5.1 reports the Target-MOTAD solutions for the baseline scenario for a target income of \$20,000. Wheat enterprises are summarized in the top of Table 5.1, followed by a summary of the livestock enterprises. The expected value of deviations below the target income (λ) was parametrically varied to obtain efficient farm plans for alternative risk preferences. A unique farm plan is associated with each λ value.

Table 5.1 shows that each farm plan contains a combination of wheat and stocker cattle enterprises; however, enterprises used at higher risk levels differ significantly from those at lower values of λ. When λ equals \$10,000,the optimal solution is equivalent to the profit maximizing solution. Production of the varieties Karl and Thunderbird and supplemented stockers comprise the optimal farm plan. The majority of the stockers are grazed until the end of fall-winter season, while the remaining cattle are retained through the end of the grazeout period. Karl is used for the dual purpose of grain and forage production. When grazing of Karl terminates at the end of the fall/winter season, cattle numbers decrease to levels such that only forage produced by Thunderbird is sufficient to meet the nutritional requirements through the end of the grazeout season. Only acreage designated for commodity program set-aside purposes is grazed out.

Small changes in the wheat varieties occur as farm plans are adjusted to meet reductions in the acceptable level of risk. The dominant variety, Karl, ranks first in grain production and fourth, fifth, and second in producing forage during the first, second, and third subperiods, respectively. Thunderbird ranks third, seventh and fifth

Table 5.1 Target-MOTAD Solution for the Baseline Scenario, Target Income=$20,000.

Farm Plan	A1	A2	A3	A4	A5	A6	A7
Expected Income Dev. ($)	10000	8000	6000	4000	3000	2500	2000
Expected Return ($)	75651	75308	74280	72032	66978	64409	61840
Wheat Variety				Acres			
Karl	808	808	808	808	668	580	492
Thunderbird-Go	42	42	42	0	0	0	0
Karl-Go	0	0	0	19	0	0	0
Arapahoe-Go	0	0	0	11	0	0	0
Abilene	0	0	0	0	139	227	315
Stocker Cattle				Head			
Subperiod 1:							
High Gain, Suppl.	759	672	408	0	0	0	0
High Gain, Unsuppl.	0	62	254	540	433	376	318
Subperiod 2:							
High Gain, Suppl.	759	672	408	0	0	0	0
High Gain, Unsuppl.	0	62	254	540	433	376	318
Graze-out:							
High Gain, Suppl.	70	70	70	0	0	0	0
High Gain, Unsuppl.	0	0	0	51	0	0	0
				Stocking Density (SD)			
Subperiod 1:							
SD (Hd/Acre)	0.89	0.86	0.78	0.64	0.54	0.47	0.39
Subperiod 2:							
SD (Hd/Acre)	0.89	0.86	0.78	0.64	0.54	0.47	0.39
Graze-out:							
SD (Hd/Acre)	1.67	1.67	1.67	1.67	1.70	0	0

Go = graze-out acreage, not harvested for grain in producing forage during the three subperiods (see Tables 4.1, 4.2, 4.3 and 4.4). The optimal set of wheat enterprises does not change as λ is reduced to \$8,000 and again to \$6,000. Reductions in the acceptable level of risk are met entirely by adjustments in the stocker enterprises. This result illustrates the dominance of Karl in the optimal farm plans. In the wheat production data used in this analysis, Karl is an outstanding grain and forage producer, and it is not characterized by large levels of production risk. Therefore, expected net returns can be maintained at higher levels by adjusting stocker activities rather than wheat production. As λ is decreased below \$6,000, both wheat and stocker enterprise combinations change. New varieties of wheat begin entering the optimal solution. For instance, Karl and Arapahoe varieties for forage production replace Thunderbird on the grazeout acreage in Plan A4. Also, as the risk levels decrease further, Abilene (grain and forage) starts entering the optimal solution and is produced along with Karl. Further parameterization of λ decreases the acreage allocated to Karl and increases the acreage of planted to Abilene. Abilene ranks fifth in average grain production and ninth, ninth and fourth in producing forage during the first, second, and third subperiods, respectively. The variety is characterized by relatively stable low levels of fall-winter forage production. Because stocker numbers are significantly lower and to meet the risk constraints, high levels of forage production are no longer necessary.

The livestock component of the farm plans are also sensitive to changes in risk-return levels. As the risk levels decrease, two principal changes occur. First, non-supplemented stockers start entering the optimal solution. Second, the total number of stockers grazed is reduced. Supplementation of wheat stockers is a risk increasing activity because it allows for increases in the number of head grazed.[1] As more livestock are grazed, the producer is exposed to increased production risk since the probability of a forage deficit in any one year is increased. Price risk is also increased since the impact of unfavorable livestock price movements will increase due to the presence of more cattle. At low risk-return levels (λ = \$4,000 or below), only non-supplemented stockers are grazed during the fall-winter season. In addition, all steers are sold at the conclusion of subperiod 2; grazeout steers are not produced in Plans A5 through A7.

Stocking densities in the first three solutions (Plans A1 through A3) are much higher than those normally employed by wheat-stocker producers. This result may reflect the combined effect of several factors. First, the stockers are supplemented which results in a lower forage requirement and higher stocking densities. Second, and more importantly, lower observed stocking densities may reflect risk averse behavior on the part of producers. Stocking densities associated with Plans A4 and A5 are more consistent with observed producer behavior. The stocking densities during the grazeout are greater than those of the stocking densities during the fall-winter season. These differences in stocking densities may be attributed to increases in forage yields in the grazeout period and are consistent with producer behavior.

To assess the sensitivity of the solutions to changes in the target level of income, the baseline scenario was run for a target income of \$0. Optimal farm plans for alternative values of λ are reported in Table 5.2. Karl (grain and forage) is used for the

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[1] "Supplemented stockers" refers to an activity where steers are fed an energy supplement to enhance performance and increase stocking density. Increases in income variability due to a greater number of stockers grazed makes this a risk-increasing activity.

Table 5.2 Target-MOTAD Solution for the Baseline Scenario,Target Income=$0.

Farm Plan	B1	B2	B3	B4	B5	B6
Expected Income Dev. ($)	4000	3000	2500	2000	1500	1000
Expected Return ($)	75651	75596	75443	75223	74919	74614
Wheat Variety	Acres					
Karl	808	808	808	808	808	808
Thunderbird-Go	42	0	0	0	0	0
Karl-Go	0	42	42	42	42	42
Stocker Cattle	Head					
Subperiod 1:						
High Gain, Suppl.	759	746	707	651	572	494
High Gain, Unsuppl.	0	8	37	78	135	191
Subperiod 2:						
High Gain, Suppl.	759	746	707	651	572	494
High Gain, Unsuppl.	0	8	37	78	135	191
Graze-out:						
High Gain, Suppl.	70	70	70	70	70	70
High Gain, Unsuppl.	0	0	0	0	0	0
	Stocking Density (SD)					
Subperiod 1:						
SD (Hd/Acre)	0.89	0.88	0.88	0.86	0.83	0.81
Subperiod 2:						
SD (Hd/Acre)	0.89	0.88	0.88	0.86	0.83	0.81
Graze-out:						
SD (Hd/Acre)	1.67	1.67	1.67	1.67	1.67	1.67

same acreage of land (808 acres) over the entire range of λ. Only the variety used for grazeout acreage changes as the risk level is reduced. As in the previous solutions, Thunderbird enters the optimal solution at higher risk levels, and is replaced by Karl at lower risk-return levels. The lower target income provides a less restrictive risk constraint than that used in Table 5.1. As a result, no changes in the variety planted for both fall-winter grazing and grain production is required. Therefore, the use of variety diversification as a risk management strategy has only limited application under this risk specification.

As in Table 5.1, the livestock component at higher risk levels for the target income of $0 includes only supplemented stockers. However, as λ is decreased, supplemented stockers are gradually replaced with unsupplemented stockers. At lower risk levels, both supplemented and non-supplemented stockers enter the optimal solution. Thus, specification of a lower target income allows supplemented stockers to remain in the optimal farm plan at all risk levels. Also, grazeout steers are produced in each of the optimal farm plans. Stocking densities are much less sensitive to changes in λ when a target income of $0 is employed. Under the $20,000 target income, stocking densities are reduced 56 percent to meet reductions in λ. In this case, only a 9 percent decrease in stocking density occurs.

The efficient farm plans from the baseline scenario are traced out graphically in Figure 5.1. Points on the frontier are risk efficient in that they represent farm enterprise combinations, each having minimum risk (expected deviation below the target income) for each specified level of expected return (Schurle and Erven, 1979). Farm plans corresponding to the labeled points on the frontiers are detailed in Tables 5.1 and 5.2.

The frontier for the target income of $20,000 indicates some potential for risk

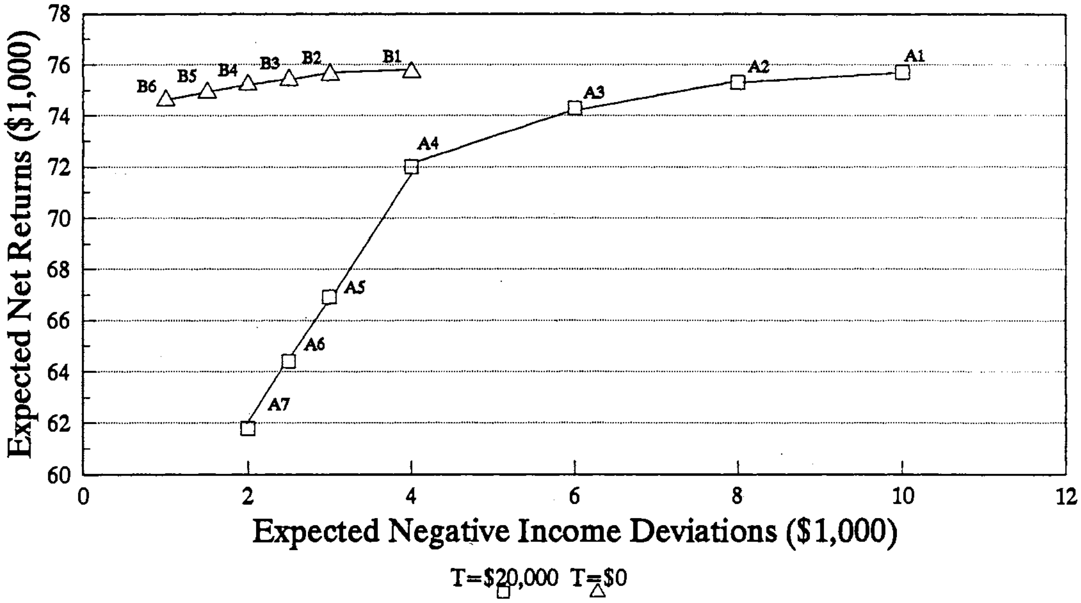

Figure 5.1. E-A Frontier for Baseline Scenario with Target Incomes of $20,000 and $0.

reduction without large reductions in expected net returns. Between points A1 and A3 the frontier is relatively flat, indicating that a decrease in risk is accompanied by a small decrease in expected net return. However, risk-return tradeoffs become much more significant as income deviations are reduced below $6,000. Between points A4 and A7, the frontier is virtually a straight line, indicating that the expected return decreases at a constant rate as risk is decreased. Expected net returns decrease significantly as the number of head of stockers is reduced to meet the incremental reductions in risk.

The frontier derived for a target income of $0 indicates significantly different risk-return tradeoffs. The profit maximizing solution occurs at $\lambda = \$4,000$ and only small reductions in expected net returns occur as λ is decreased to $1,000. The frontier for a target income of $20,000 lies below that of the frontier for a target income of $0 and is steeper, showing larger decreases in expected income as risk is decreased.

Base Scenario (Without Karl)

The results presented in Tables 5.1 and 5.2 are clearly dominated by the Karl wheat production activities. Karl is characterized by large grain and forage yields in the experimental data and does not display a large degree of production risk (as measured by deviations below the expected yields). To better illustrate the impacts of changes in enterprise combinations on both return and risk, the Karl production activities are excluded from the model. Table 5.3 reports Target-MOTAD solutions for the baseline scenario for a target income of $20,000 when activities using the Karl variety are excluded from the model.

When Karl is excluded from consideration, Pioneer 2180 dominates the profit maximizing farm plan. Pioneer 2180 ranks tenth in grain production, but ranks second

Table 5.3 Target-MOTAD Solution for the Baseline Scenario Without Karl Activities, Target Income = $20,000.

Farm Plan	C1	C2	C3	C4	C5	C6	C7
Expected Income Dev. ($)	15000	10000	8000	6000	4000	3000	2000
Expected Return ($)	66823	65705	64920	63842	62730	62070	59469
Wheat Variety				-------------------------Acres-------------------------			
Arapahoe	125	107	194	295	343	149	0
Thunderbird-Go	42	42	42	42	42	42	0
Pioneer 2180	469	0	0	0	0	0	0
AGSECO 7846	213	700	600	389	151	0	0
Abilene	0	0	12	123	251	426	620
Thunderbird	0	0	0	0	60	231	0
Pioneer 2157-Go	0	0	0	0	0	0	29
Mesa	0	0	0	0	0	0	157
Arapahoe-Go	0	0	0	0	0	0	12
Abilene-Rent	0	0	0	0	0	0	29
Stocker Cattle				-------------------------Head-------------------------			
Subperiod 1:							
High Gain, Suppl.	781	532	367	207	70	70	0
High Gain, Unsuppl.	0	75	185	286	383	417	437
Subperiod 2:							
High Gain, Suppl.	781	532	367	207	70	70	0
High Gain, Unsuppl.	0	75	185	286	383	417	437
Graze-out:							
High Gain, Suppl.	70	70	70	70	70	70	0
High Gain, Unsuppl.	0	0	0	0	0	0	62
				----------------Stocking Density (SD)----------------			
Subperiod 1:							
SD (Hd/Acre)	0.92	0.80	0.65	0.58	0.53	0.57	0.52
Subperiod 2:							
SD (Hd/Acre)	0.92	0.80	0.65	0.58	0.53	0.57	0.52
Graze-out:							
SD (Hd/Acre)	1.67	1.67	1.67	1.67	1.67	1.67	1.51

and first in forage production levels in subperiods 1 and 2, respectively. Because of the absence of a dominant grain producing variety, it appears that forage production becomes more important in determining the optimal wheat enterprise combinations. Acreage allocated to grazeout is planted to the Thunderbird variety in the profit maximizing plan.

As λ is reduced, Arapahoe begins to enter the risk efficient farm plans. Arapahoe may be characterized as a high grain producer (ranking second in grain production) and a low forage producer (ranking eleventh and twelfth in forage production in subperiods 1 and 2, respectively). Further reductions in risk-return levels are met by the introduction of AGSECO 7846 into the optimal solution. The acreage allocated to AGSECO 7846 increases, as Pioneer 2180 and Arapahoe acreage is reduced. Eventually, the share of AGSECO 7846 decreases and Thunderbird enters the optimal farm plans. At the lower risk-return levels, the risk efficient farm plans also include renting wheat pasture. This acreage is still harvested for grain, but the fall-winter grazing rights are leased. Acreage to be rented is planted to high grain producing varieties since the owner-operator derives no benefit from high forage production. The entrance of these rental activities into the farm plans indicates that although the rental rate ($16/acre) is less than the expected net return obtained from grazing owned stockers on one acre of land, income risk may be reduced by adopting such a strategy. At lower risk-return levels Pioneer 2157 and Arapahoe are planted for grazeout forage production, and Mesa and Abilene are used for grain production and fall-winter grazing (Table 5.3).

Clearly, the exclusion of Karl significantly increases the diversification opportunities available from producing different wheat varieties. Seven different wheat varieties are employed in meeting the incremental reductions in risk. Optimal farm plans involve the use of as many as five different wheat production activities, as opposed to a maximum of three varieties in the solutions reported in Table 5.1.

The livestock activities shown in Table 5.3 resemble those in Table 5.1. In the profit maximizing plan, supplemented stockers are grazed through the end of the fall-winter period and a small number are retained through the grazeout season. The number of steers grazed in the profit maximizing plan is somewhat higher, reflecting the higher forage production levels of Pioneer 2180. As the risk-return levels decrease, the farm plan includes the grazing of a combination of supplemented stockers through the end of the grazeout season and non-supplemented stockers through the fall-winter season. At still lower risk-return levels (λ = $2,000) only non-supplemented stockers enter the optimal solution. Stocking densities are generally higher than those reported in Table 5.1. Again, this result reflects the greater importance of forage production in determining optimal enterprise combinations.

The efficient farm plans shown in Table 5.3 are traced out graphically in Figure 5.2. The E-A frontier differs significantly from the frontier presented in Figure 5.1 for a target income of $20,000. First; the frontier is considerably lower than the E-A frontier derived when Karl was included as a production activity. Net returns associated with the profit maximizing solution are over $9,000 lower as a result of excluding the Karl variety. Risk-return tradeoffs are also less pronounced, illustrating the increased potential for diversification when the dominant variety is excluded. In the baseline solution, larger reductions in expected net returns occur in conjunction with risk reductions because Karl acreage had to be substituted out of the optimal plan to meet reductions in λ.

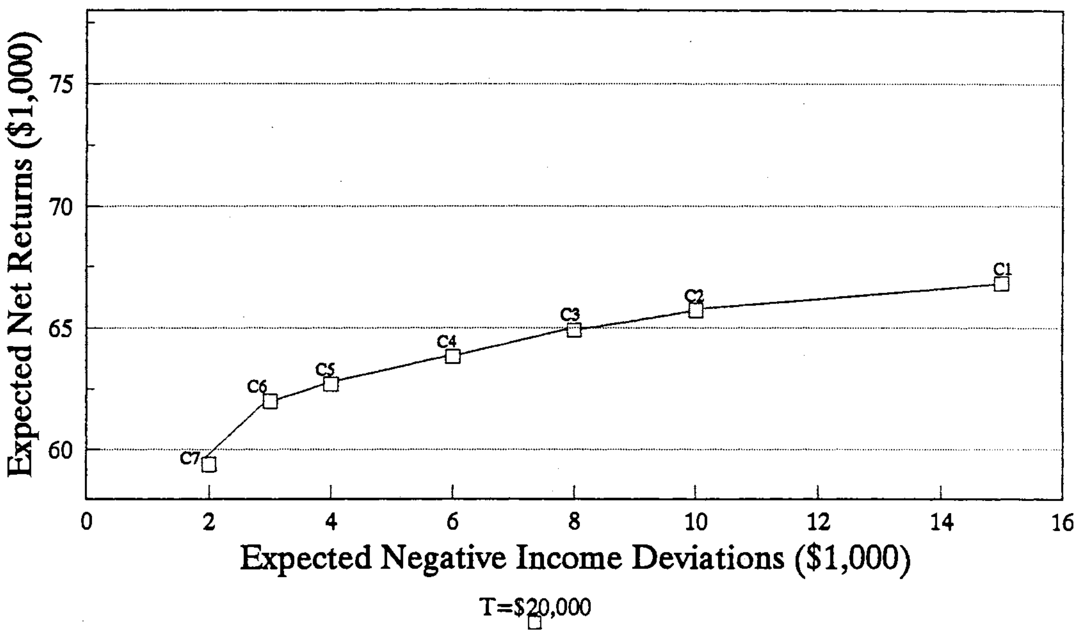

Figure 5.2. E-A Frontier for Baseline Scenario Without Karl, Target Income = $20,000.

"No Rent" Scenario

An important strategy that may be used to meet the risk constraints in the baseline scenario is to lease the grazing rights to the fall-winter wheat pasture. This practice allows the producer to obtain income from grazing without incurring additional risk, and is particularly useful in meeting risk constraints when very low λ values are imposed. However, some producers might not be willing to adopt this practice. By eliminating the pasture rental activities, one can evaluate diversification opportunities strictly from the perspective of enterprise selection.

The farm plans for the "no rent" scenario are reported for a target income of $20,000 in Table 5.4. Again, to more fully evaluate diversification opportunities, Karl activities are eliminated from consideration. Optimal farm plans are identical to the baseline solution (without Karl) for λ values greater than $2,500. These plans did not employ the pasture rental activities in the baseline, and thus, the omission of the rental activities has no effect. Several farm plans were derived at low λ values to fully assess variety diversification opportunities in the absence of the leasing alternative.

Farm plans at low risk levels (λ = $2,500 and below) employ a larger number of cultivars than the baseline plans. As many as four varieties enter the farm plans at low λ values. AGSECO 7846 and Pioneer 2180 are planted for fall-winter grazing and grain production, while Pioneer 2180 and Arapahoe are planted on acreage allocated to grazeout. Reductions in λ below $2,500 are met by reallocating acres among these four activities. Despite elimination of the pasture lease activities, the risk constraints can still be met without idling acreage. Diversification of varieties is shown to be an alternative risk management strategy, in lieu of leasing the wheat pasture grazing rights.

Table 5.4 Target-MOTAD Solution for the " No Rent " Scenario, Target Income = $20,000.

Farm Plan	D1	D2	D3	D4	D5	D6	D7	D8
Expected Return Dev. ($)	10000	8000	6000	4000	3000	2500	2000	1500
Expected Return ($)	65705	64920	63842	62730	62070	60591	57409	53611
Wheat Variety	-------------------------Acres--------------------------							
Arapahoe	107	194	295	343	149	0	0	0
Thunderbird-Go	42	42	42	42	42	0	0	0
AGSECO 7846	700	600	389	151	0	104	0	0
Abilene	0	12	123	251	426	654	547	437
Thunderbird	0	0	0	60	231	49	0	0
Pioneer 2157-Go	0	0	0	0	0	15	5	0
Mesa	0	0	0	0	0	0	261	371
Arapahoe-Go	0	0	0	0	0	27	37	0
Stocker Cattle	-------------------------Head--------------------------							
Subperiod 1:								
High Gain, Suppl.	532	367	207	70	70	0	0	0
High Gain, Unsuppl.	75	185	286	383	417	459	420	391
Subperiod 2:								
High Gain, Suppl.	532	367	207	70	70	0	0	0
High Gain, Unsuppl.	75	185	286	383	417	459	420	391
Graze-out:								
High Gain, Suppl.	70	70	70	70	70	0	0	0
High Gain, Unsuppl.	0	0	0	0	0	64	62	0
	----------------Stocking Density (SD)----------------							
Subperiod 1:								
SD (Hd/Acre)	0.80	0.65	0.58	0.53	0.57	0.54	0.52	0.46
Subperiod 2:								
SD (Hd/Acre)	0.80	0.65	0.58	0.53	0.57	0.54	0.52	0.46
Graze-out:								
SD (Hd/Acre)	1.67	1.67	1.67	1.67	1.67	1.67	1.51	0.00

The efficient farm plans shown in Table 5.4 are presented graphically in Figure 5.3. For comparison purposes, the E-A frontier for the baseline solution is also presented. Between points D1 and D6 the two frontiers are identical since pasture lease activities do not enter the optimal farm plans. At λ = $2,500 and below, the frontiers derived for the "no rent" scenario are below those for the baseline, reflecting the higher cost of achieving risk reductions in the absence of leasing grazing rights. In the baseline scenario, reductions in λ can be achieved with small reductions in expected net returns by substituting the lease activities into the farm plan. Income losses associated with these risk reductions are more significant when the pasture lease alternative is not available. Differences between the two frontiers widen as λ is decreased.

"No Grazing" Scenario

Only about one-half of Oklahoma's wheat acreage is grazed annually. Thus, an important question is whether variety diversification is a useful risk management tool for producers who do not employ livestock grazing. To assess this issue, the model was run excluding all livestock activities. Only income from grain production was considered in the analysis.

Farm plans for a target income of $20,000 are reported in Table 5.5. When Karl was included in the model, the Target-MOTAD solutions for the "no grazing" scenario were dominated by this variety. Thus, the model was run without wheat production activities using the Karl variety to better assess diversification potential from planting alternative varieties. In this case, Arapahoe and AGSECO 7846 dominate the farm plans at all risk levels. All available acreage is planted to Arapahoe in the profit maximizing plan. As the risk levels decrease, AGSECO 7846 begins to enter the optimal solutions.

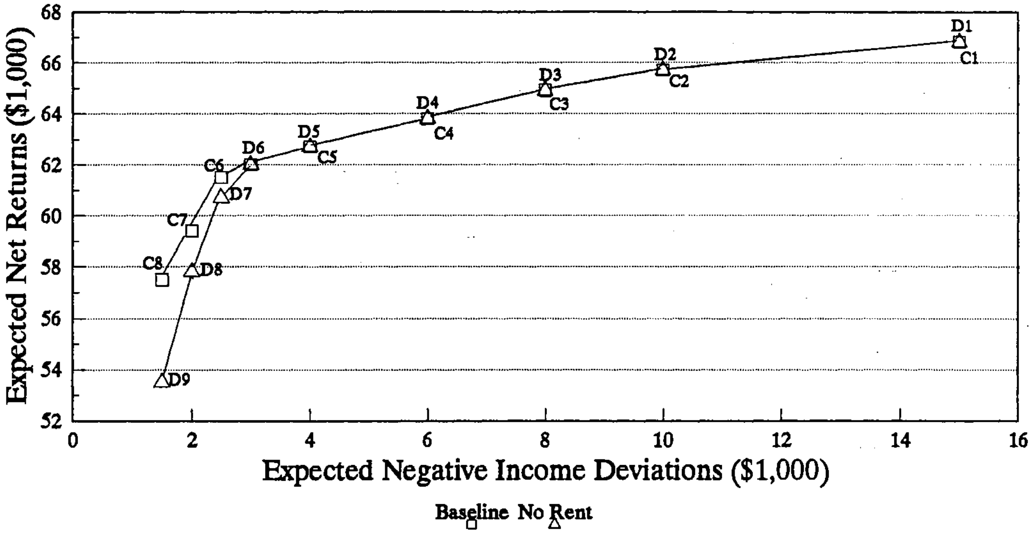

Figure 5.3. E-A Frontier For "No Rent" Scenario, Target Income = $20,000.

Table 5.5 Target-MOTAD Solution for "No Grazing " Scenario, Target Income = $20,000.

Farm Plan	E1	E2	E3	E4	E5
Expected Income Dev.	6000	4000	3000	2000	1500
Expected Income ($)	39693	39693	37951	33117	27187
Wheat Variety		--------------------Acres--------------------			
Arapahoe	808	800	473	95	136
AGSECO 7846	0	8	334	606	350

Both cultivars remain in the farm plans at the lower risk levels; however, at lower λ values, some acreage in addition to the required set-aside acreage is idled. Risk constraints cannot be met by planting additional varieties, and idling land must be used to achieve risk reductions. Clearly, variety diversification has limited potential as a risk management tool in the absence of wheat pasture grazing.

The efficient farm plans shown in Table 5.5 are presented graphically in Figure 5.4. The frontier lies significantly below those derived for the baseline scenario due to the absence of income from wheat pasture grazing. Expected net returns at the profit maximizing solution are over \$28,000 less than when grazing activities are included. The frontier increases at a decreasing rate at the lower risk-return levels and as the risk-return levels increase, the frontier tends to become flatter, and finally becomes a horizontal line. Relatively large reductions in expected income are required to achieve decreases in risk, particularly below values of λ = \$3,000. Risk reductions are met by idling land in this range of the E-A Frontier.

Price Sensitivity Analysis

In conducting the price sensitivity analysis, the prices of both wheat and cattle were considered. Solutions included in the price sensitivity analysis include "high cattle and low wheat", as well as "low cattle and high wheat" price scenarios. Both price scenarios are considered for a target income of \$20,000, and production activities using Karl are not considered.

In calculating "low" wheat prices for the sensitivity analysis, the average of the three lowest wheat prices (in real terms) for the nine year period was estimated, and the percentage below the objective function value (the nine-year average) was determined.

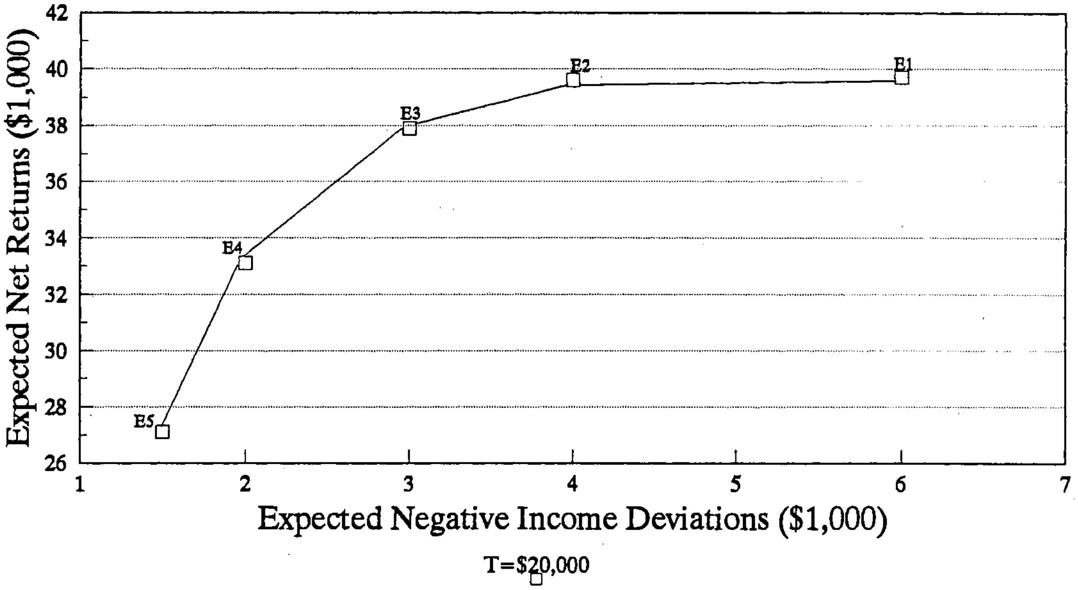

Figure 5.4. E-A Frontier For "No Grazing" Scenario, Target Income = $20,000.

The average of the three lowest prices was 18 percent below the nine-year average. To obtain the vector of wheat prices for the net return deviation rows, all individual year wheat prices used in the base scenario were multiplied by 0.82. The objective function value was scaled down by the same factor. Similarly, to calculate the "high" wheat prices for the sensitivity analysis, the average of the three highest was estimated, and the percentage used to scale up the prices was estimated as 14 percent. To obtain the high wheat prices for the sensitivity analysis, the individual year and average wheat prices were multiplied by 1.14.

Since profitability of stocker enterprises is dependent upon the spread between sale price and the purchase price of the calf, cattle prices cannot simply be scaled to develop alternative price scenarios. Instead, stocker net returns were considered in developing the price series for the sensitivity analysis. To calculate the "low" cattle net returns for the sensitivity analysis, the average of the three lowest net returns in the nine-year period was estimated. Next, the percentage needed to be applied to the stocker revenues to achieve these "low" net returns was estimated. To obtain the "low" cattle net returns, all stocker enterprise revenues used in the baseline scenario were multiplied by 0.925. To develop the "high" cattle net return scenario, the average of the three highest net returns was taken and the percent of the objective function values was determined. To obtain the high cattle net returns for the sensitivity analysis, all stocker revenues in the base scenario were multiplied by 1.075.

Alternative combinations of these transformed prices and net returns were used to develop the alternative price scenarios. That is, the "high cattle" and "low wheat" prices were combined to form one price scenario, and the "low cattle" and "high wheat" prices formed the other. These two scenarios provide the extremes in the wheat-cattle price ratios that producers might face in a given year. Risk efficient plans for each scenario were estimated for different risk levels at a target income of $20,000.

High Cattle and Low Wheat Price Scenario

Table 5.6 shows the Target-MOTAD solutions for the "high cattle" and "low wheat" price scenario for a target income of $20,000. As in the baseline solution (Table 5.3), Pioneer 2180 for grain and forage production dominates the farm plans at higher risk levels. The set-aside acreage, which can be used for any purpose except wheat grain production, is also planted to Pioneer 2180 in the profit maximizing plan. As λ is reduced, the Thunderbird variety enters the risk efficient farm plans. At lower risk-return levels, an increasing number of acres are planted to AGSECO 7846 for grain and forage production. Thunderbird and Arapahoe varieties are employed in the production of grazeout acres.

Wheat variety selection is shown to be responsive to the price conditions facing producers. Both Thunderbird and Pioneer 2180 take on increased importance relative to the baseline price scenario. These varieties both rank high in terms of average fall-winter forage production. The increased importance of these high forage producing wheat varieties in the optimal solutions reflects the increase in the profitability of stocker cattle relative to grain production.

In general, the livestock component of the optimal farm plans includes a larger number of cattle than the solutions reported in Table 5.3. Stocking densities range between .15 and .32 hd/ac above those reported in the comparable baseline solution. In addition, supplemented stockers remain in the optimal farm plans over the entire range of the parameterized risk value. Only at the low risk levels (Plans F6 and F7) are non-

Table 5.6 Target-MOTAD Solution for "High Cattle " and " Low Wheat " Price Scenario, Target Income = $20,000.

Farm Plan	F1	F2	F3	F4	F5	F6	F7
Expected Income Dev. ($)	6000	4000	3000	2500	2000	1500	1000
Expected Return ($)	99045	97781	94817	90841	86864	82640	78011
Wheat Variety				Acres			
Pioneer 2180	808	722	522	319	116	9	0
Pioneer 2180-Go	42	0	0	0	0	0	0
Thunderbird	0	85	28	28	28	28	28
Thunderbird-Go	0	42	22	22	22	22	22
Arapahoe-Go	0	0	19	19	19	19	19
AGSECO 7846	0	0	15	265	516	706	808
Stocker Cattle				Head			
Subperiod 1:							
High Gain, Suppl.	913	892	851	780	709	564	330
High Gain, Unsuppl.	0	0	0	0	0	71	228
Subperiod 2:							
High Gain,Suppl.	913	892	851	780	709	564	330
High Gain,Unsuppl.	0	0	0	0	0	71	228
Graze-out:							
High Gain, Suppl.	61	70	69	69	69	69	69
High Gain, Unsuppl.	0	0	0	0	0	0	0
				Stocking Density (SD)			
Subperiod 1:							
SD (Hd/Acre)	1.07	1.05	1.00	0.92	0.84	0.75	0.66
Subperiod 2:							
SD (Hd/Acre)	1.07	1.05	1.00	0.92	0.84	0.75	0.66
Graze-out:							
SD (Hd/Acre)	1.45	1.67	1.68	1.68	1.68	1.68	1.68

supplemented stockers combined with supplemented stockers in the livestock production plan. The high cattle returns provide an additional incentive to supplement stockers. Supplementation may be used to maximize livestock gain from the available forage base.

The frontier depicting the efficient farm plans shown in Table 5.6 is presented in Figure 5.5. The profit maximizing solution occurs at $\lambda = 6{,}000$. This value is significantly lower than in the baseline because the probability of negative income deviations is lowered due to improved cattle profitability. Some potential for risk reduction exists without large decreases in expected net returns at higher values of λ. However, below $\lambda = \$3{,}000$ the E-A frontier is virtually linear, indicating constant reductions in expected net returns for incremental reductions in λ. In this range of the frontier, reductions in λ must be met by decreases in stocker numbers. As a result, significant losses in expected returns are incurred to meet risk reductions.

Low Cattle and High Wheat Price Scenario Without Karl

Table 5.7 shows the Target-MOTAD solutions for the "low cattle" and "high wheat" price scenario. The acreage committed to grain production is dominated by Arapahoe at higher risk-return levels and by AGSECO 7846 at lower risk-return levels. The set-aside acreage is planted to Thunderbird at higher risk-return levels. However, no grazeout acreage enters the optimal solutions at lower risk-return levels ($\lambda = \$6{,}000$ and below). This result implies that strongly risk averse producers facing these price relationships prefer that the set-aside acreage be idled rather than used for spring livestock grazing. Also, the acreage allotted for grain and forage production is decreasing at low risk levels.

As in the previous price scenario, variety selection is shown to be sensitive to

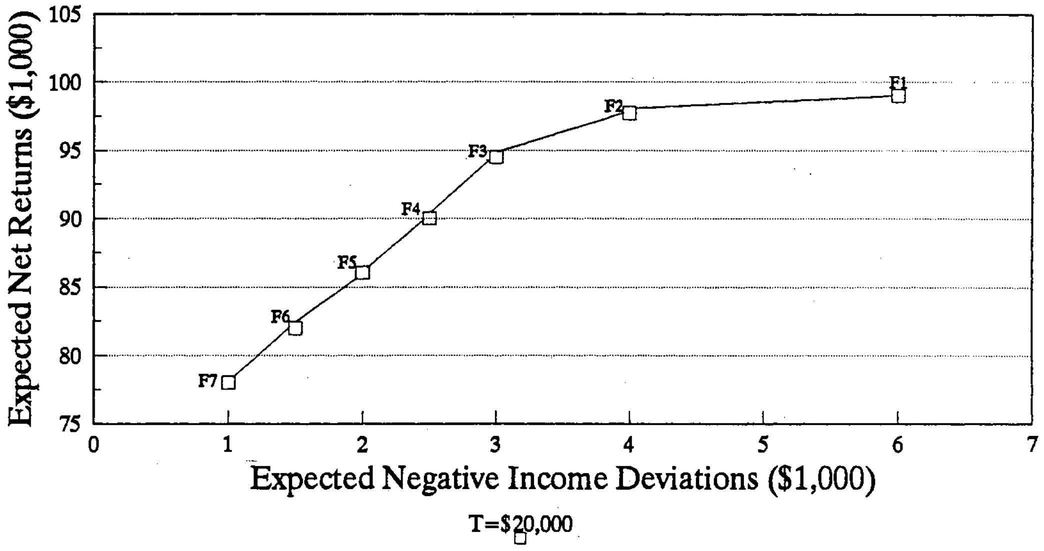

Figure 5.5 E-A Frontier For "High Cattle-Low Wheat" Price Scenario, Target Income = $20,000.

Table 5.7 Target-MOTAD Solution for " Low Cattle " and " High Wheat " Price Scenario, Target Income = $20,000.

Farm Plan	G1	G2	G3	G4	G5	G6	G7	G8
Expected Income Dev.	10000	8000	6000	4000	3000	2500	2000	1000
Expected Return ($)	62105	61963	60368	57501	53271	48637	41740	26118
Wheat Variety	-----------------------Acres-----------------------							
Arapahoe	808	808	808	808	151	0	0	0
Thunderbird-Go	42	42	0	0	0	0	0	0
AGSECO 7846	0	0	0	0	656	730	589	319
Stocker Cattle	-----------------------Head-----------------------							
Subperiod 1:								
High Gain, Suppl.	0	0	0	0	0	0	0	0
High Gain, Unsuppl.	386	361	256	70	59	53	43	0
Subperiod 2:								
High Gain, Suppl.	0	0	0	0	0	0	0	0
High Gain, Unsuppl.	386	361	256	70	59	53	43	0
Graze-out:								
High Gain, Suppl.	0	0	0	0	0	0	0	0
High Gain, Unsuppl.	70	70	0	0	0	0	0	0
	---------------Stocking Density (SD)---------------							
Subperiod 1:								
SD (Hd/Acre)	0.45	0.42	0.32	0.09	0.07	0.07	0.07	0
Subperiod 2:								
SD (Hd/Acre)	0.45	0.42	0.32	0.09	0.07	0.07	0.07	0
Graze-out:								
SD (Hd/Acre)	1.67	1.67	0	0	0	0	0	0

price movements. When price movements favor grain production to cattle, only Arapahoe and AGSECO are used for grain production. Both of the varieties are high grain producers in the experimental data. Forage production is not an important consideration in variety selection because of the relatively low stocking densities used.

The livestock component of the farm plans includes only non-supplemented stockers. The low value of cattle gain does not justify additional expenditure associated with supplementing stocker cattle. Relatively low numbers of these stockers are included in the farm plans across all of the risk levels considered. In the profit maximizing plan, the stocking density is less than half of the density employed in the baseline scenario (Table 5.3). No livestock activities are included in the farm plan at the lowest risk level (λ = \$1,000). The implication is that the producer is not willing to take the risk of stocker production at the prevailing net returns per head.

The efficient farm plans shown in Table 5.7 are traced out graphically in Figure 5.6. Large reductions in expected net returns accompany incremental reductions in risk over a wide range of the E-A frontier. Between Plans G4 and G8, the frontier indicates poor risk-return tradeoff opportunities. At higher risk levels (above λ = \$6,000) the slope declines and large reductions in risk are attainable with only small changes in net returns.

Application of Target-MOTAD Model Using Simulated Data

Due to possible limitations of formulating the Target-MOTAD model using the observed (experimental variety trial) wheat production data, the farm-level model was reconstructed using simulated production data and applied to two scenarios. In the base scenario for the simulated data, as for the field data, all production alternatives are

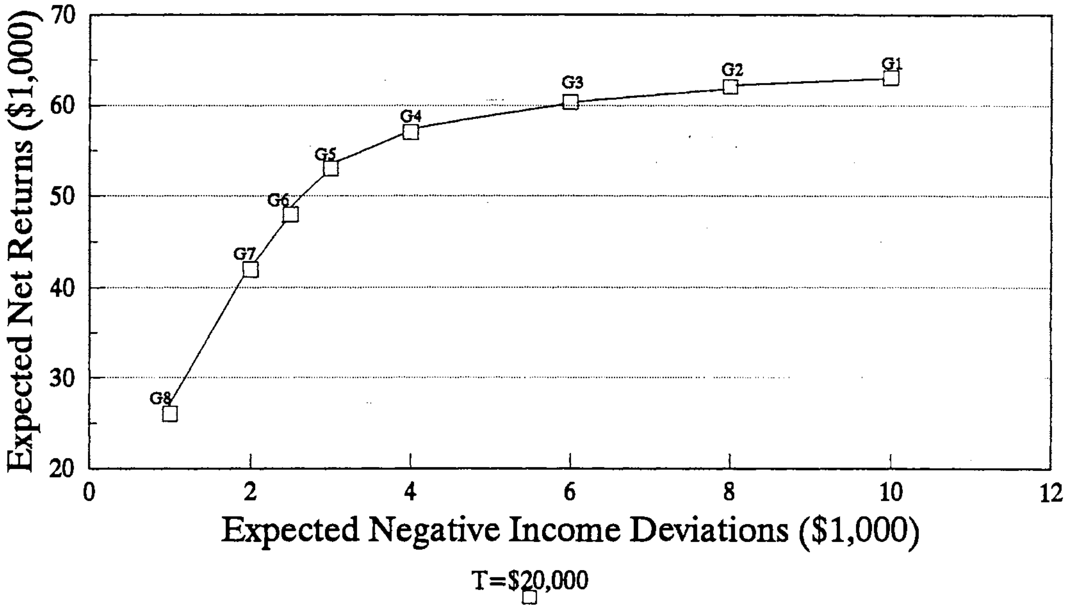

Figure 5.6. E-A Frontier For "Low Cattle-High Wheat" Price Scenario,
Target Income = $20,000.

available and prices and yields reflect the 12 years of the simulation period. The second scenario eliminates all livestock activities to identify diversification opportunities for producers interested in grain production only.

The CERES-Wheat model was calibrated to estimate grain yield and forage production data for the range of the available cultivars used in the analysis of the field data. Grain yield and forage production data were simulated using historical weather data over a 12-year period. In addition to differing by variety or projected use (grain or forage), the wheat activities also differ by planting date. Earliest, early and traditional planting dates are the three alternatives considered when producing for grain plus forage and/or forage only. The Target-MOTAD model was reformulated using these data to evaluate alternative cultivars. This model allows one to expand the number of production alternatives represented in the model, as well as possibly improve the specification of production risk.

Baseline Scenario

Table 5.8 reports the baseline solutions of the Target-MOTAD model developed using simulated wheat production data for target income of $20,000. Wheat enterprises are summarized in the top of Table 5.8, followed by a summary of the livestock enterprises.

Although the specific farm plans differ from those reported in Table 5.4, the general strategies used to meet reductions in risk levels resemble those derived using the experimental data. In the profit maximizing solution, a single variety (TAM W-101) is planted on all 850 acres of the representative farm. Expected forage and grain yields from this variety are high in the simulated data, but both forage and grain yields are also

Table 5.8 Target-MOTAD Solutions for the Baseline Scenario Using Simulated Wheat Production Data, Target Income = $20,000.

Farm Plans	H1	H2	H3	H4	H5	H6	H7
Expected Income Dev.	25000	15000	10000	8000	6000	4000	3000
Expected Return ($)	97479	94635	90609	88797	86715	72697	61743
Wheat Variety				-Acres-			
Karl							
-Earliest Plt.Dt.	0	311	210	0	0	0	0
-Early Plt.Dt.0	112	200	267	301	0	0	
-Traditional Plt.Dt.	0	0	0	104	60	412	493
Tam W-101							
-Traditional Plt.Dt.	497	136	81	41	0	0	0
-Traditional Plt.Dt.,Go.	370	0	0	0	0	0	0
Mesa							
-Traditional Plt.Dt.,Go.	0	288	172	103	69	0	0
Pioneer 2180							
-Early Plt. Dt.	0	0	0	333	418	0	0
-Traditional Plt. Dt.	0	0	0	0	0	391	112
-Traditional Plt.Dt.,Go	0	0	172	0	0	0	0
Thunderbird							
-Early Plt.Dt.	0	0	0	0	0	0	89
-Early Plt.Dt., Go	0	0	0	0	0	47	0
Pioneer 2157							
-Traditional Plt.Dt., Go	0	0	0	0	0	0	52
Stocker Cattle				-Head-			
Subperiod 1:							
High Gain, Suppl.	957	584	406	321	46	0	0
High Gain, Unsuppl.	0	259	383	451	645	425	273
Subperiod 2:							
High Gain, Suppl.	957	584	406	321	46	0	0
High Gain, Unsuppl.	0	259	383	451	645	425	273
Subperiod 3:							
High Gain, Suppl	957	584	406	321	46	0	0
High Gain, Unsuppl.	0	259	127	0	167	135	98
				-Stocking Density (SD)-			
Subperiod 1:							
SD (Hd/Acre)	1.10	1.00	0.94	0.91	0.81	0.50	0.36
Subperiod 2:							
SD (Hd/Acre)	1.10	1.00	0.94	0.91	0.81	0.50	0.36
Subperiod 3:							
SD (Hd/Acre)	1.10	1.00	0.64	0.38	0.20	0.16	0.13

characterized by a high degree of yield variability. As a result, the TAM W-101 activities are quickly substituted out of the optimal solutions as λ is reduced. As risk is reduced, Karl and Pioneer 2180 enter the solution for use in fall-winter grazing and grain production. Mesa and Pioneer 2180 replace TAM W-101 for use on grazeout acreage. AGSECO 7846 and Thunderbird enter the risk efficient plans at lower levels of λ. With the exception of TAM W-101, all of these varieties were employed in one or more of the risk efficient plans derived for the baseline scenario using experimental data (Tables 5.1 through 5.3).

The solutions reported in Table 5.8 also indicate that planting date can be employed by producers as a diversification tool, in a manner similar to varieties. For the two most dominant varieties in the optimal farm plans, Karl and Pioneer 2180, wheat production activities using all three simulated planting dates are employed. At higher risk levels, Karl is planted using the earliest planting date to take advantage of potential early fall forage. This strategy increases production risk since there exists a larger possibility of crop failure than if a later planting date was used. As the acceptable level of risk is decreased, Karl production activities using a later planting date begin entering the solution, and at λ values of \$4,000 or less only the traditional planting date is employed. In this case, fall forage production is not a priority because much lower stocking densities are employed.

Changes in the livestock enterprises in response to incremental reductions in λ resemble those observed when experimental wheat production data are used. As in Table 5.3, only supplemented steers are grazed in the profit maximizing plan. The optimal stocking density is higher than when experimental data are used, reflecting the fact that simulated forage production levels are somewhat higher for most varieties than the experimental data. Another important difference in the solutions is that all of the steers are grazed out in the profit maximizing plan. When the observed data are used, only grazeout steers are allocated to the 5 percent mandatory set-aside acres. Differences between the simulated and experimental data are sufficient to change the relative profitability of using acreage for grazeout purposes rather than grain production. As λ is reduced, the stocking density is decreased and unsupplemented steers are substituted for supplemented steers. Larger reductions in stocking density are observed when simulated wheat production data are employed. In Table 5.1, the optimal stocking density is decreased to .54 ac/hd when $\lambda = \$3,000$. When simulated data are employed, the optimal stocking density at this risk level is .36 ac/hd. Additional reductions in steer numbers are required because other sources of risk are increased relative to the risk levels represented in the plans derived using the observed data. The percentage of steers held during the grazeout period is also decreased in association with decreases in risk levels.

The risk efficient farm plans reported in Table 5.8 are traced out graphically in Figure 5.7. For comparison, the E-A frontier derived from the baseline scenario using experimental data is also included. The frontier for the simulated data lies substantially above the frontier derived using the experimental data. At the profit maximizing solution, for example, expected returns are over $22,000 higher using the simulated data. Differences in net returns from the two models decrease as λ decreases. At a λ value of $6,000, the Target-MOTAD solution for the simulated data provides an expected return of $86,715, while use of the experimental data results in a return of $74,280. These differences can be mainly attributed to differences in the variability of the wheat forage and grain yields between the two data sources. Although expected net returns are

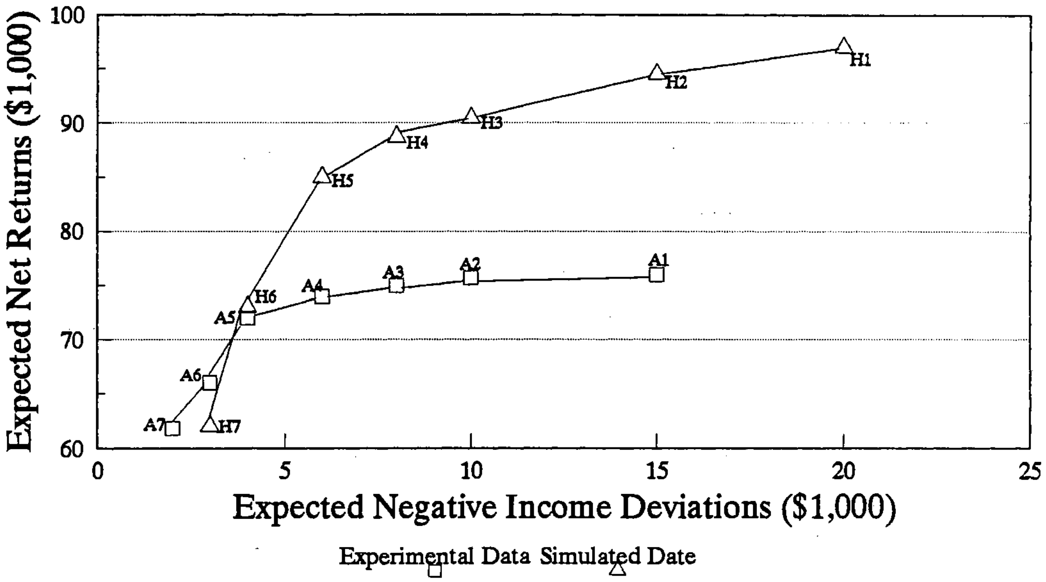

Figure 5.7. E-A Frontier For Baseline Scenario With Observed and Simulated Wheat Data, Target Income = $20,000.

much higher using the simulated data at high risk levels, net returns derived using simulated and experimental wheat production data are very similar at lower risk levels. In fact, net returns associated with λ values of $4,000 and $2,000, are nearly identical between the two solutions.

Comparison of the two E-A frontiers also indicates that the choice of wheat production data has very significant implications on risk-return tradeoffs. The frontier derived using experimental data indicates that substantial reductions in risk (from point A1 to A4) can be achieved with only negligible reductions in expected net returns. The frontier depicting optimal farm plans using the simulated data is much steeper over this range. Larger reductions in expected returns are required to meet the risk constraints. Both E-A frontiers indicate rather significant tradeoffs between risk and expected net returns below λ = $6,000.

"No Grazing" Scenario

Table 5.9 reports solutions when the Target-MOTAD model using simulation data is applied to a target income of $20,000 and no livestock grazing is permitted. This scenario helps identify variety diversification possibilities for those producers who want to engage in grain production only. At the highest value for λ (λ = $4,000), only Karl planted at the early date enters the optimal solution. The corresponding expected return ($48,460) is the profit maximizing income level. However, as the risk levels are reduced, other varieties as well as different planting dates enter the optimal solutions. At the lowest λ evaluated (λ = $1,500), Karl planted at the traditional date and Thunderbird planted at the early date enter the optimal solution. As when the experimental data were applied to the "no grazing" scenario, significant acreage must be

Table 5.9 Target-MOTAD Solutions for "No Grazing" Scenario Using Simulated Wheat Production Data, Target Income = $20,000.

Farm Plan	J1	J2	J3	J4
Expected Income Dev.	4000	3000	2000	1500
Expected Return ($)	45460	44626	39427	32451
Wheat Variety	-------------Acres-------------			
Karl				
-Early Plt.Dt.	808	766	503	0
-Traditional Plt.Dt.	0	0	0	105
AGSECO 7846				
-Traditional Plt.Dt.	0	25	0	0
Thunderbird				
-Early Plt.Dt.	0	0	105	250

idled to meet the risk constraint.

The efficient farm plans shown in Table 5.9, are presented graphically in Figure 5.8. As in the baseline scenario, the E-A frontier lies above the frontier derived using the experimental data. The frontier is steeper at the lower risk-return levels, but flattens as risk levels increase. Slopes of the two frontiers are similar indicating that the risk-return tradeoffs are not significantly affected by the use of simulated versus observed data.

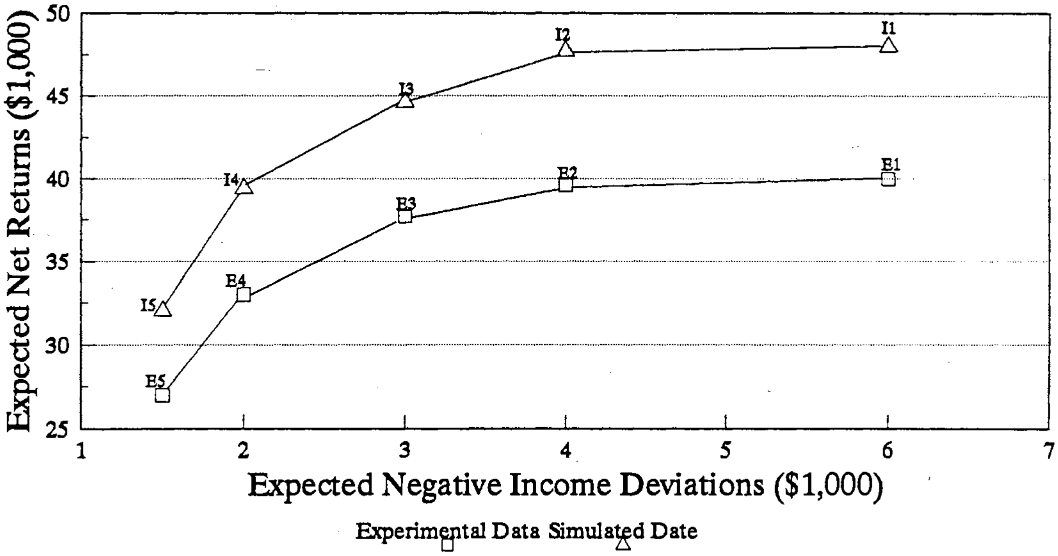

Figure 5.8. E-A Frontier For "No Grazing" Scenario With Observed and Simulated Wheat Data Target Income = $20,000.

CHAPTER VI

SUMMARY AND CONCLUSION

The production of wheat and stocker cattle grazing wheat pasture represents a unique and profitable production alternative available to the majority of Oklahoma agricultural producers. Together the two enterprises provide a significant economic contribution to the Oklahoma agricultural economy. The combined production of wheat and stocker cattle contributes over two-thirds of the total value of the agricultural products for the state.

Like most agricultural producers, wheat-stocker producers operate in an uncertain economic environment. Income instability results from production, marketing, and financial uncertainties. Wheat-stocker producers have several means to cope with risk. Marketing risk can be managed through the adoption of hedging strategies, forward contracting, and participating in government commodity programs. Means of reducing production risks include employing lower stocking densities, supplemental feeding of hay, and leasing pasture to cattle operators. A risk management strategy that has not been well studied involves selection of wheat varieties. Two risk management strategies involving the selection of wheat cultivars include introducing improved cultivars and diversifying by producing several wheat cultivars in the same production year.

Farmers employ the strategy of diversification to reduce extreme fluctuations in income. Diversification may be thought of in terms of producing several enterprises at the same time or employing different production practices within the same enterprise. The behavior of risk-averse producers is consistent with the strategy of diversification. By planting several varieties which differ in growth characteristics, producers may reduce the probability that a single environmental event may affect their entire wheat crop. Because wheat-stocker producers are concerned about both grain and forage production, one might expect greater diversification opportunities than if grain production were the sole objective.

The objective of this study was to evaluate potential diversification opportunities for wheat-stocker producers through cultivar selection. A farm-level model is developed which incorporates risk due to variability in yields and prices as decision constraints. The model is applied to identify efficient wheat-stocker production systems for commercial wheat producers in central Oklahoma characterized by alternative risk preferences.

Method of Analysis

A farm-level Target-MOTAD model was developed and applied to fulfill the objectives of the study. Activities in the model include wheat production activities and stocker grazing alternatives. The wheat production activities include the production of different varieties, which provide different combinations of grain and forage production. The stocker production activities utilize forage produced by the alternative wheat varieties.

The Target-MOTAD model accomplishes risk measurement in a linear programming model through linear approximation using the absolute value of expected negative deviations from the target return level (λ) as a measure of risk. The method uses a combination of target income (T) and λ in identifying a set of efficient farm plans. By solving the model parametrically for various values of λ, an E-A (expected income-absolute deviation) frontier may be derived. E-A frontiers were developed for several different production scenarios to analyze the effect of various production constraints on risk-income relationships. These solutions gave points of maximum expected net returns for specified levels of risk, given the normal technical restrictions of the linear programming model and additional risk constraints.

Four sources of risk are included in the Target-MOTAD model, including deviations in income from variability in wheat grain yields, income variability from wheat price deviations, income deviations from livestock price variability, and costs associated with variability in wheat forage production. Because forage production, forage quality, and animal forage requirements differ over time, the grazing season was divided into three subperiods. Forage balance rows are included for each subperiod and each state of nature to estimate forage deficits incurred in each state of nature. Forage deviations were then converted to a monetary value to estimate the effect of forage variability on income risk.

The data requirements for the model include grain yield and forage production data, cost and price information, and forage requirements and livestock gains. The Target-MOTAD model was formulated using both observed and simulated wheat production data. For the observed data, grain and forage yields were collected from a three-year wheat variety study conducted at various locations across central Oklahoma. For the simulated data, grain and forage yields were estimated by applying the CERES-Wheat crop simulation model. Wheat grain and forage yields were simulated for the 12 varieties using historical weather data over a 12 year period. Forage requirements and livestock gains were estimated from a combination of available experimental data and National Research Council net energy and intake relationships.

Twelve wheat varieties were included in the model for the production of grain and/or forage. The forage was used for the production of stocker cattle, and was specified in terms of dry matter produced in three subperiods. Separate wheat production activities were included for acres harvested for grain and for grazeout purposes. In addition, wheat production activities representing alternative planting dates are included in the model developed using simulated wheat production data.

Two types of stocker activities were included in the livestock component of the model. The unsupplemented stockers were limited to wheat pasture and supplemental hay when the supply of forage was in deficit. Supplemented stockers were provided an average of 4 pounds per day of the high-fiber energy supplement in addition to wheat forage and supplemental hay. Alternative stocker activities were also included to represent differences in weight gain by stockers during the three subperiods. The stockers were assumed to fall into either high, medium, or low weight gain categories. Marketing constraints were also included to allow the model to purchase stockers at the beginning of each subperiod or sell or retain stockers in the following subperiod.

Variable costs were charged to all production activities included in the model. For wheat selling activities Oklahoma seasonal average prices for nine years (1985-1993) adjusted to 1993 were used in estimating net return deviations. The average of the adjusted prices of the nine years was used in the objective function. For stocker purchasing and selling activities, average real prices for nine years (1985-1993) were used in the objective function, and prices observed in each year were used in the risk portion of the model.

Summary of Results

The Target-MOTAD model developed using the observed wheat production data (experimental variety trials) data was applied to five scenarios. In the baseline scenario, all production alternatives are available and prices reflect averages over the nine-year period. The second scenario employs the same economic data, but does not allow for the opportunity of leasing the wheat pasture. The third scenario eliminates all livestock activities to identify diversification opportunities for producers interested in grain production only. The final two scenarios consider the impact of changes in the wheat-cattle price ratios on the optimal farm organization. The model constructed using the simulated wheat production data is solved for the baseline and "no grazing" scenarios.

The optimal enterprise combinations depend on target income (T) and the limit on the expected value of deviations below the income (λ). A set of efficient farm plans was identified for the baseline scenario for target incomes of $0 and $20,000. Specifically, λ was parametrically varied between $15,000 and $1,000 to derive a set of risk efficient farm plans for each target income. The remaining scenarios were evaluated for a target income of $20,000 and a series of λ values.

Baseline Scenario

In the baseline scenario, all wheat varieties were allowed to enter the model. The optimal solutions of the model solved by parameterically varying λ for the target income of $20,000 indicated significant changes in enterprise combinations at various risk levels. Production of the variety Karl for fall-winter forage and grain production, the variety Thunderbird for grazeout, and supplemented stockers comprised the profit maximizing plan. Small changes in wheat varieties were employed in response to initial reductions in risk levels. Varieties characterized by relatively low but stable levels of fall-winter forage production enter the farm plans as the acceptable level of risk is further constrained.

The livestock component of the farm plans is particularly sensitive to changes in risk levels. As λ is decreased, two principal changes occur. First, non-supplemented stockers start entering the optimal solution. Second, the total number of stockers grazed is reduced. Energy supplementation of wheat stockers is a risk increasing activity because it allows for increases in the number of head grazed. As more livestock are grazed, the producer is exposed to increased production risk since the probability of a forage deficit in any one year is increased. Price risk is also increased since the impact of unfavorable livestock price movements will increase due to the presence of more cattle. At low risk-return levels, only non-supplemented stockers are grazed during the fall-winter season. In addition, all steers are sold at the conclusion of subperiod 2; grazeout steers are not produced.

To assess the sensitivity of the solutions to changes in the target level of income, the baseline scenario was run for a target income of $0. Over the entire range of λ, Karl is planted on all acreage allocated to fall-winter grazing and forage production (808 acres). Only the variety used for grazeout acreage changes as the risk level is reduced. Therefore, the use of variety diversification as a risk management strategy has only limited application under this risk specification.

The efficient farm plans can be graphed in expected net return - risk (expected deviations below the target income) space to form E-A frontiers. Points on the frontier are risk efficient in that they represent farm enterprise combinations, each having minimum risk. The frontier for the target income of \$20,000 indicates some potential for risk reduction without large reductions in expected net returns. Over the initial portion of the E-A frontier, the frontier is relatively flat, indicating that a large decreases in risk are accompanied by only small decreases in expected returns. However, risk-return tradeoffs become much more significant as income deviations are reduced below \$6,000. Expected net returns decrease significantly as the number of head of stockers is reduced to meet the incremental reductions in risk. The frontier derived for a target income of \$0 indicates significantly different risk-return tradeoffs. Only small reductions in expected net returns occur as λ is decreased.

Because of the Karl variety's high average grain and forage production levels in the observed data, the baseline solutions were dominated by Karl wheat production activities. To better assess the impacts of changes in wheat varieties' risk and expected returns, the baseline scenario was run omitting the activities using Karl. The exclusion of Karl significantly increases the use of variety diversification to meet risk constraints. Seven different wheat varieties are employed in meeting the incremental reductions in risk. Optimal farm plans involve the use of as many as five different wheat production activities, as opposed to a maximum of three varieties in the baseline solutions. Livestock production takes on a greater importance in the optimal farm plans because of the absence of a dominant grain producing variety.

"No Rent" Scenario

In the baseline scenario, risk constraints at low λ values were met by leasing the grazing rights to fall-winter wheat pasture. In this scenario, the lease option was omitted to evaluate risk management strategies strictly from the perspective of enterprise selection. Farm plans at low risk levels (λ = \$2,500 and below) employ a number of cultivars than the baseline plans. As many as four varieties enter the farm plans at low λ values. Despite elimination of the pasture lease activities, the risk constraints can still be met without idling acreage. Diversification of varieties is shown to be an alternative risk management strategy, in lieu of leasing the wheat pasture grazing rights.

"No Grazing" Scenario

The "no grazing" scenario was developed to assess variety diversification opportunities for wheat producers interested only in grain production. In this scenario, only two varieties enter the optimal farm plans as risk levels are lowered. When λ is decreased further, land is idled. Variety diversification has limited potential as a risk reducing strategy when wheat is produced only for grain.

The E-A frontier derived under this scenario lies significantly below the frontier for the baseline scenario due to the absence of income from wheat pasture grazing. Expected net returns at the profit maximizing solution are over \$28,000 less than when grazing activities are included. The frontier also indicates the presence of limited risk-return tradeoffs, since relatively large reductions in expected income are required to achieve decreases in risk, particularly below values of λ = \$3,000.

Price Sensitivity Analysis

In conducting the price sensitivity analysis, the prices of both wheat and cattle were considered. Solutions included in the price sensitivity analysis include "high cattle and low wheat", as well as "low cattle and high wheat" price scenarios.

Wheat variety selection is shown to be responsive to the price conditions facing producers. Under the "high cattle-low wheat" price scenario, high forage producing varieties enter the optimal solutions. Both Thunderbird and Pioneer 2180 take on increased importance relative to the baseline price scenario. These varieties both rank high in terms of average fall-winter forage production. The increased importance of these high forage producing wheat varieties in the optimal solutions reflects the increase in the relative profitability of stocker cattle relative to grain production. The livestock component of the optimal farm plans include a number of cattle than the baseline; stocking densities range between .15 and .32 hd/ac above those reported in the comparable baseline solution. In addition, supplemented stockers remain in the optimal farm plans over the entire range of the parameterized risk value. The high cattle returns provide additional incentive to supplement stockers.

Variety selection is shown to be sensitive to price movements when price movements favor grain production relative to cattle. Under the "low cattle" and "high wheat" scenario, only Arapahoe and AGSECO 7846 are used for the joint production of grain and fall-winter forage production in the risk efficient farm plans. Both of the varieties are high grain producers in the experimental data. Forage production is not an important consideration in variety selection because of the relatively low stocking densities used. The livestock component of the farm plans includes only non-supplemented stockers. The low value of cattle gain does not justify additional expenditure associated with supplementing stocker cattle.

Model Results Using Simulated Wheat Production Data

To investigate the sensitivity of the optimal farm plans to the wheat production data employed, the Target-MOTAD model was reformulated using the simulated wheat production data. Use of the simulated data provides an alternative specification of the production risk in the model. Both the baseline and "no grazing" scenarios were evaluated using the Target-MOTAD model developed with simulated wheat production data.

Although the specific farm plans differ from those derived using the observed data, the general strategies used to meet reductions in risk levels are very similar. In the profit maximizing solution, a single variety (TAM W-101) is planted on all 850 acres of the representative farm. Additional varieties are substituted into the plan as λ is reduced. With the exception of the TAM W-101, all of these varieties were employed in one or more of the risk efficient plans derived for the baseline scenario developed using the observed data. The solutions also indicate that planting date can be employed by producers as a diversification tool in a manner similar to varieties. At higher risk levels, earlier planting dates are employed to take advantage of potential early fall forage. As the acceptable level of risk is decreased, later planting dates are employed. In these cases, fall forage production is not a priority since lower stocking densities are used.

Changes in the livestock enterprises in response to incremental reductions in λ, resemble those recommended when observed wheat production data is used. Stocking densities are higher than when observed data is used, reflecting the fact that simulated forage production levels are somewhat higher for most varieties than the observed data. Another important difference between the solutions is that all of the steers grazed in the fall-winter period are grazed out in the profit maximizing plan. Differences between the simulated and experimental data are sufficient to change the relative profitability of using this acreage for grazeout purposes rather than grain production.

Comparison of E-A frontiers derived using simulated and observed wheat production data indicates that the choice of wheat production data has very significant implications on risk-return tradeoffs. The frontier derived using observed data indicates that substantial reductions in risk can be achieved with only negligible reductions in expected net returns. The E-A frontier from the simulated data is steeper indicating reductions in expected returns are required to meet the risk constraints.

Optimal farm plans derived when the Target-MOTAD model using simulated wheat production data was also applied to the "no grazing" scenario, are similar to those derived using observed data. At the highest value for λ, only Karl planted at the early date enters the optimal solution. However, as the risk levels are reduced, other varieties as well as different planting dates enter the optimal solutions. As when the observed data was applied to the "no grazing" scenario, significant acreage must be idled to meet the risk constraint.

General Findings

The Target-MOTAD model was used to evaluate expected income and risk under alternative production organizations. The model provided a wide range of farm plans under each production constraint that could be attractive to producers depending on their risk preferences.

Efficient farm organizations for wheat-stocker producers are shown to be sensitive to the producer's risk preferences. The derived E-A frontiers illustrate some ability for the wheat-stocker producer to reduce risk without severely reducing expected income. Diversification of wheat varieties is an important management strategy available to producers to manage risk. However, utilization of wheat varieties as a risk management tool requires coordination of management with the livestock component of the farm plan.

Profit maximizing producers will select high forage producing varieties to increase net returns derived from the stocker enterprise. To reduce risk, varieties which provide higher grain yields and/or a smaller, but more stable supply of forage may be substituted into the farm plan. Production risk is reduced as a result of lower variability in forage and grain yields, and price and production risk are also decreased due to reductions in the number of stockers grazed.

The specific results derived in this study are unique to central Oklahoma due to the site specificity of the data employed. However, the model formulation is representative in showing the relationship between risk and expected return in wheat-stocker production. In addition, the general risk reduction strategies derived from the model are applicable to wheat-stocker production settings in other regions.

The model was applied to decision making concerning wheat variety diversification and the use of the wheat pasture for grazing stocker cattle. The same model can be used to address problems associated with the production of other crops combined with other types and classes of livestock.

Limitations and Need for Further Research

Various difficulties were encountered in undertaking this study. These problems provide several opportunities for future research and can be summarized as follows:

1. Target-MOTAD model is essentially a static model in that a long-run plan of how the producer should organize wheat-stocker production is presented. As a result, it lacks a dynamic component allowing for the continuous transition from the present situation to the desired ultimate goal.

2. Forage yield data for some varieties for the grazeout season were unavailable

and necessitated estimation. Availability of more complete observed forage data for additional varieties, planting dates, and seeding rates, would improve the model specification.

3. Clipped forage measured in pounds of dry matter from experimental trials were used in this model. However, in the process of producing wheat-stocker production, stockers are grazed on wheat pasture but no adjustment was made when supply and demand balances were determined.

4. Stocker intake requirement assumptions were based upon the NRC technique and adjusted to take into account non-consumptive uses. Availability of actual data relating consumption to alternative live weight and weather conditions would improve the accuracy in determining the supply and demand balance for wheat forage.

5. Stocker performance assumptions were also based upon the NRC technique. Actual data relating cattle productivity to alternative levels of nutritional intake in a typical production setting would solidify the gain assumptions made.

6. Forage data employed in the model are specified in approximately two-month intervals. Each subperiod is represented using a given quality of forage, and this quality is held constant across all states of nature. However, during a sixty day interval fairly dramatic changes can occur in forage quality and thus a certain amount of nutritional misspecification is possible. Within a given subperiod, large differences in forage quality also occur across years.

7. Data of three years across three locations were used to represent nine states of nature for the wheat production data. The locations have geographical proximity, and hence, fall under similar environmental conditions. Nonetheless, some degree of bias is introduced in representing variability in grain and forage production, relative to using

historical data on a single site.

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VITA 2

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