The Economic Viability of Intensive Stocker Cattle Grazing Systems

By

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ABSTRACT

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The average annual net return (AAR) to land and other unallocated costs for land capable of producing 100 to 120 bu/acre corn was calculated for three grazing systems differing in grazing pressure and design and for a corn system with three yield levels at two prices. Production data from a Michigan State University stocker cattle grazing trial was used. Break-even thresholds between systems were calculated. Risk was included through the use of cumulative distributions and an expected benefit model. A corn system at 100 and 120 bu/acre resulted in a higher AAR than that of two stocking systems supporting two head/acre which was greater than the AAR of a corn system yielding 80 bu/acre. The two stocking systems had a higher AAR than the corn system at any yield level using a break-even price. Cumulative distributions explicitly showed the large negative returns possible with an inappropriately high stocking rate.

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LIST OF SYMBOLS

AAC_C	= $L_B + V_C + O_C$
AAC_S	= $V_S + (VC_S * H)$
AF	= Annuity factor
AOC	= Opportunity cost (ARR of next best alternative land use system
AVV	= Average annual return
C_a	= Other associated costs (e.g. veterinary costs, water costs,...)
C_f	= Total cost of supplemental feeds
C_h	= Total cost of harvesting hay and silage
C_n	= Total cost of nitrogen fertilizer
CARA	= Coefficient of absolute risk aversion
CF^{corn}	= Cash flow in 1989 dollars ($/acre)
CF_t^{cattle}	= Cash flow in 1989 dollars ($/acre)
CF_t^{1989}	= Cash flow in period t in 1989 dollars ($/acre)
D	= Fraction of a year
DL	= Death loss
E(B)	= Expected Benefit
E(ARR)	= Expected annual average return
H	= Number of head
I	= Interest on feeder cattle
L_B	= Labor cost
N	= Number of years
O_C	= Other ownership costs (e.g. building depreciation, maintenance and interest)
P_{corn}	= Market price of corn ($/bu)
P_P	= Purchase price of cattle ($/cwt)
P_S	= Sale price of cattle ($/cwt)
PV	= Present value
$PV_{N=10}^{1989}$	= Present value of system operated for N years in 1989 dollars
r	= Real interest rate
t	= Year in which cash flow appears
V	= Overall value of meat and hay/silage produced
V_S	= Cash flow associated with the stocker operation (e.g. poloxalene)
V_C	= Other variable costs (e.g. seed, fertilizer)
VAR_{ARR}	= Variance of average annual return
W_P	= Sale weight of cattle (cwt)
W_S	= Purchase weight of cattle (cwt)
Y_{corn}	= Yield of corn (bu/acre)

Chapter 1 Introduction

1.1 Background

The Michigan beef cattle industry leadership believes Michigan has the potential to double the number of cattle fed to 600,000 per year (Weinstock, 1990). This suggestion is based upon the fact that Michigan's share of fed beef production in the corn belt and in the U.S. has increased over the past decade (Black, 1990), suggesting a comparative advantage in fed beef for Michigan.

A key to achieving this objective is to increase the sizes of Michigan cow/calf and stocker sectors. The Michigan share of the US cow/calf production has been constant over the decade of the 1980's. National cow-calf production declined over the decade of the 1980's and Michigan shared equally in the decline. A target was set to obtain half of the increased feeder supply that would be needed from Michigan cow/calf and stocker operations and the remainder from purchases outside the state.

The identification of alternative production and marketing systems that increase the profitability and/or reduce the risk of the cow/calf and stocker sectors in the beef cattle industry would help achieve this goal. Stocker grazing operations on land currently in row crop production (e.g.

corn, soybeans and wheat) is an alternative that is being explored.

1.2 Factors Influencing Adjustments in the Row Crop and Beef Industry that Suggest the Economic Potential for Stocker Operations

Significant changes in Michigan beef cattle production systems and in the prices faced by beef cattle farmers have occurred over the last two decades. These include: (1) a reduction in the "inflation adjusted" prices received for calves, relative to previous decades in the post World War II era, an increase in feed grain and soybean prices during the 1970's followed by a decrease in the 1980's and changes in the relative prices of inputs, with increases in the relative prices of energy intensive inputs; (2) an increase in knowledge about grazing systems; (3) changes in the technology available, particularly fencing technology and (4) changes in USDA price and income support programs, particularly increased flexibility under the 1990 Farm Bill.

1.2.1 Macro Adjustments and Changes in "Inflation Adjusted" Prices Paid and Received by Participants in the Beef Cattle Industry

Adjustments at the national level and resultant changes in prices, resulted in cattle producers exploring alternative production methods. Beef cattle production nationally, while exhibiting cycles, experienced growth throughout much of the twentieth century, peaking in 1974. In late 1973, fed beef prices fell sharply, resulting in sharp drops in feeder cattle prices. In 1974, oilseed and grain prices reached a record high post World War II level's, resulting in a transfer of land from forage production to grain and oilseed production and a reduction in the cow/calf herd (Black, 1990).

In the mid and late 1970's, there were large increases in energy prices and the rate of inflation became a major problem. The inflation adjusted prices of transportation inputs and fertilizer increased and the nominal interest rate reached record highs in the late 1970's, although real interest rates were low or negative as a result of the rate of inflation. The demand for beef appears to have fallen continuously since the late 1970's (Hilker, 1991). The result has been lower inflation adjusted fed cattle and calf prices. The increases in feed grain, wheat and oilseed prices in the 1970's increased the profitability of using pasture land for grain and oilseed production and reduced the profitability of using the land for cow-calf and stocker production. The extensive margin in crop production was pushed outward.

By the late 1980's national beef cattle production had been reduced to 75 percent of peak levels, increasing fed and feeder calf prices to the point where adequate profits could be realized to maintain the size of the cow herd. Also, grain and oilseed prices were significantly lower over most of the 1980's relative to the 1970's.

Lower calf prices change the utilization of pasture land. When calf prices are high, producers tend to maximize income from pasture by holding additional cows on pasture; calves are sent to feedlots at an earlier age. Relatively, less pasture is used for stocker operations. When calf prices are lower, the reverse is true.

1.2.2 Technology Available to Stocker and Cow-Calf Growers

New technological developments affect the beef cattle industry by making potential stocker system profits more volatile. Improvements in grazing and fencing technology have increased interest in intensively managed grazing of stocker cattle as one alternative land use.

New electric fencing technology provides a reasonable alternative to permanent fencing. The relatively low cost of electric fencing allows more flexibility in management of pasture and movement of livestock.

1.2.3 1990 USDA Farm Bill

The 1990 Farm Bill allows more flexibility in the use of base acres for non-program crops than previous farm bills (Hilker, 1991). Flex acres which had previously been restricted to program crops can now be in other uses, such as grazing. This new legislation will have a wide array of implications for the beef cattle industry, including cattle supply and profitability.

1.3 Description of the Michigan Beef Cattle Industry

There are three major types of Michigan beef cattle farms: cow-calf, stocker and feedlot operations. Cow-calf farms provide the stocker and feedlot farms with 400-550 pound calves; weight depends upon the frame size of the cows and bulls used, feedstuff quality and calving date. Calves may be overwintered, for sale as stockers or sold directly to feedlots. Feedlots purchase both calves and yearlings to be fed to market weight.

Stocker cattle farms, the focus of this study, are those in which cattle are on pasture over the spring, summer and/or fall months. The cattle are obtained either from a cow-calf enterprise on the farm (vertical integration of cattle production) or purchased. Calves or yearlings may be purchased in the winter or spring, placed on pasture in the summer and sold in early fall. Length of the pasture season depends on pasture type, climate and market conditions.

The type of pasture affects both the carrying capacity and the length of season for grazing. Grass pastures can be grazed from early April until snow or cold weather dictates removal of the cattle. Legume pastures, such as alfalfa, should not be grazed in late September in order to allow adequate root reserves to build up. Once the plant has had an adequate regrowth period and a hard frost has killed the available forage, it may be grazed.

Grazing systems are categorized into two types; continuous and rotational. Continuous systems allow cattle access to an entire pasture over the season. Continuous grazing is generally practiced on marginal land. This study is concerned with finding the optimal use of land with soils suitable for row crops. Therefore, continuous grazing will not be considered. In rotational grazing, cattle are moved at relatively short intervals, from one pasture to another[1]. After grazing, each section is allowed time for regrowth before being grazed again.

Conventional rotational grazing can be defined as grazing practiced with fewer than 8 separate pasture areas. The movement of animals is often on a fixed schedule. Intensive rotational grazing (including controlled grazing) involves more frequent moves of animals, based on pasture condition. Intensive grazing requires more pastures.

[1] Often, part of the first rotation is mechanically harvested and stored.

1.4 Objectives

The objective of this study[2] is to evaluate the economic viability of intensive stocker grazing as a land use alternative to corn, soybeans and wheat production. Economic viability is defined as generating the highest average annual net return to land (and other costs that are the same across systems) at an acceptable level of risk.

There are eight objectives of the study to accomplish this overall objective. They are:

(1) to define beef weight gain per acre and the yield and quality trajectory of alfalfa pastures within a grazing system over time as a function of management intensity. This will provide an objective function within which the management intensity of the grazing system will be an input, and revenue from beef production, the output. This objective will be met through future analysis when data becomes available (Schlegel, 1991).

(2) To identify variables and their values which influence the costs and returns for each system.

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[2] This thesis is a companion thesis to: Schlegel, M.L. 1991. Grazing Schemes for Direct Seeded Alfalfa Pastures. Department of Animal Science. Michigan State University.

(3) To estimate net cash flows from stocker production (for three grazing systems) on alfalfa pastures with varying degrees of management input and from corn production.

(4) To compare the average annual return to land for each of four systems. The four systems considered: (1) low stocking rate (13L) and (2) high stocking rate 13 paddock system (13H), a (2) low stocking rate 4 paddock system and a (4) 120 bushel/acre corn.

(5) To calculate break-even prices and yields to indicate the economic threshold at which systems are equivalent.

(6) To interpret the results from the analysis in light of various risk preferences and risk bearing capacities faced by Michigan cattle producers. How the trade-offs between profit and risk can impact the decision making process of various cattle producers facing the outlined options will be quantified. The implications of uncertainties in both corn and beef gross margins are considered.

(7) To provide the framework for the development of a computer model by which individual farm decision makers can assess the economic viability of various land use alternatives for a particular farm under particular risk preferences and risk bearing capacity.

(8) To specify avenues for future research.

1.5 Scope of the Study

A 40 acre plot is assumed to be capable of growing 100 to 120 bushel/acre corn. A farm manager has essentially three choices for using this land: cropping, grazing or leaving it idle (Figure 1.1). Although the USDA's CRP program may be an option, it will not be explored.

Growing crops on the land could include grains, oilseeds, legumes and nonlegumes, all of which could be used by a farmer to feed his cattle or sold directly. The first three alternatives generally necessitate the use of a feedlot or other concentrated confinement for the cattle. With confinement feeding come the costs of feeding the animals and hauling manure. Growing crops for a cash crop often requires incurring storage costs, machinery costs, and extensive planting and harvesting labor.

The other land use alternative is grazing[3]. Grazing systems generally take one of two distinct forms as described in section 1.3, continuous or rotational. Both types of grazing systems are seasonal, as plant growth is

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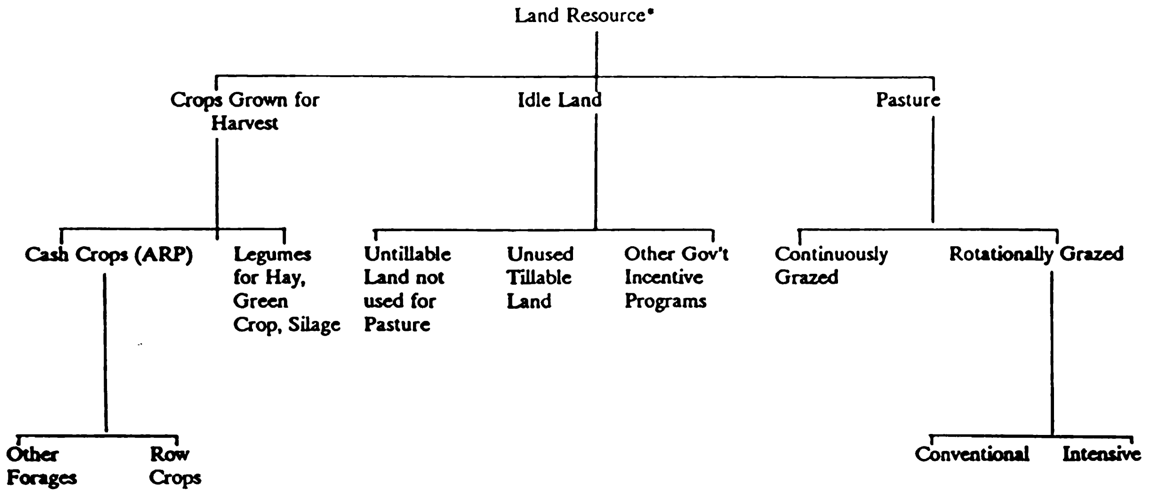
[3] Although such practices as grazing harvested corn fields maybe a common practice in some areas of the country and one such study is included in the literature review, only the grazing of alfalfa will be considered within the limited scope of this analysis.



* Land Resource Use is a function of operator's preference, demand (operator's market) for various crops, land quality and rotational scheme.

Figure 1.1 Hierarchy of Farm Operator's Land Resource Use Options limited by the seasonal environment. Both require a watering site or system. Both grazing systems may require less storage, less machinery, and perhaps lower labor costs than cropping the same land. Grazing systems limit consideration of crops over cropping for harvest systems. Supplemental feeding may be required under one/both system(s) depending upon forage type and availability and animal pressure[4].

Having reviewed the two alternatives for land use, corn production and grazing, as well as the two basic grazing system types, techniques to be used for comparison will be considered. The land is productive enough for row crops. Therefore, corn is considered the defender alternative land use and grazing systems for stocker cattle are considered the challengers. The method used in this thesis will be to compare corn production, rotational grazing and intensive grazing simultaneously.

While a great deal of thought can be given to an "optimal crop mix/rotation" for crop production and the legume mix for grazing which would maximize returns to the land, these ideas will be left for further research or will simply be discussed as management considerations. The budgets to be

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4 Breed, weight, desired gain, condition of the animal, sex and pregnancy are among the factors determining animal pressure.

used as comparison tools will be limited to including specific crop and pasture mixes.

Input will include data from a Michigan State University (MSU) campus grazing trial, MSU crop budgets, USDA price series and agricultural supply dealer expenditure estimates.

Net present value analysis will be used to adjust for time. While comparison of net return to land and other unallocated costs and break-even analysis for corn and beef production levels and prices will be used to compare various systems utilized in a beef stocker or corn production operation.

1.6 Organization of Thesis

Chapter two describes the biological basis for the economic model by reviewing past literature. Various trials are discussed. Past literature on various economic methodologies used to solve resource allocation and capital expenditure problems is discussed.

In chapter three, the economic framework to be used in the analysis are set forth. The land use alternatives to be considered are described including system definitions, assumptions and variables. The capital budgeting and break-even analysis methods to be used are described. The incorporation of risk into the analysis is discussed and a model is presented and its use justified.

In chapter four, Michigan State University grazing trial data is set presented. Using this data, budgets are developed for the alternative land use systems. Net present value and break-even thresholds are calculated using the capital budgeting and break-even analysis techniques set forth in chapter three. Risk considerations are incorporated as management options to minimize uncertainty. Cumulative distributions of net returns to each system are presented. Implications for decision makers with various levels of risk aversion and facing different constraints are discussed.

Chapter five summarizes the results of the analysis, their implications and the limitations of the study. Suggestions for further research are presented.

Chapter 2 Literature Review

2.1 Introduction

The use of past literature increases the data base and level of understanding from which components of an analysis are drawn, broadening applicability of the results. Agricultural studies depend upon a combination of biological systems and therefore, must draw upon a diverse survey of literature. To understand the characteristics of animal and plant systems, their interaction and how this interaction forms a system and compares with other biological systems, much material, covering many subjects, must be reviewed. Further incorporating the management and financial considerations involved in a business decision, makes it clear that one can only scratch the surface of the available literature in a project of this scope. Therefore, a very limited number of papers from which to assess our knowledge base, formulate ideas, systems and assumptions (parameters) must be selected.

This chapter is a review of such selected papers. Background information on how the evolution of grazing coincides with that of the beef industry and the macroeconomy is discussed. Literature on grazing systems follows, including a look at plant species, emphasizing alfalfa, the crop which acts as a challenger to corn in this thesis, and the management of pasture through plant and animal control. Logistics of the

development of an intensive grazing system follows. Variables to be included in an economic analysis are specified. Fencing, a considerable portion of the cost of grazing system development, is emphasized. A review of literature describing pasture systems and results of past research trials follows. Literature on the economics of grazing is discussed.
From this base of knowledge, the design, implementation and analysis of a specific rotational or intensive grazing system for stocker cattle on alfalfa is built. Grazing is then introduced as a challenger system to corn.

2.2 Background

2.2.1 Grazing

The original beef animal feeding system was pasturing. The use of pasture decreased over time due to the advent of automated feed harvesting systems (Bartlett, 1991). This automation slowly replaced pasture, much of which performed poorly as overgrazed and weedy continuously grazed pastures of low nutritional value and sparse regrowth (Rayburn, 1988).

Interest in grazing as a potential solution to relatively low profits in the beef industry has recently been renewed by advances in grazing and fencing technology. Fencing technology has become available to make 20 to 30 paddock intensive grazing systems practical (Bartlett, 1991), offering the potential to utilize maximum forage potential with low investment. Previously, fencing costs on such a system would have been prohibitively high.

2.2.2 Macroeconomic Shocks

Two major shocks to the beef industry in the 1970's caused producers to look for alternative production methods. At the beginning of the decade, there was an increase in grain prices contributing to a large reduction in the cow-calf herd. In the mid to late 1970's, the were large increases in real input costs including energy, transportation, fertilizer, and credit which could not easily be passed on to the consumer in the form of higher beef prices (Nation, 1985). Over this period, asset values (largely land holdings) and thus, borrowing capacity, remained constant or decreased. In the past 50 years, especially accelerated from 1960 to 1980, agriculture has faced increased technology and capitalization in buildings and equipment.

2.2.3 Implications of Macroeconomic Shocks

Due to the higher cost of traditional input use patterns and the trend towards highly capitalized production, a structural change, oriented towards cost reduction, may hold promising potential. Feed, depreciation and/or interest make up a large share of these overall beef production costs.

Rotational grazing may be used to cut feeding and associated costs by moving animals regularly to harvest their own feed efficiently. A rotational grazing system will potentially use less machinery and labor for cutting, drying, storing and feeding of animal feed and hauling manure, fewer chemicals and decrease risk while maintaining the beef gain per acre over either mechanically harvested or continuously grazed land.

Cow/calf herds are heavily grass based, but calves are weaned at 300 to 500 pounds. Attempts to increase weaning weights with higher quality grasses and increased cow weights have often increase costs substantially (Nation, 1985). Recently, producers began to look at intensive rotational grazing as a method by which to increase weaning weights and maintain or decrease grain supplementation and fuel costs.

Much resistance to intensive grazing exists due to the increased daily pasture management requirement. The traditional method of animal turnout still offers the greatest profit potential for a low management grazing system (Nation, 1985).

2.2.4 Pastureland

In past years, for many areas, no pressing economic need existed to use the abundant land efficiently. There existed a high land/animal ratio and a large grain surplus since World War II (Murphy, 1989).

In the Northeast region of the United States alone, there are approximately 10 million acres of permanent pastureland referred to as marginal land due to soil and site limitations that make tilling and row-cropping infeasible. In addition, there are 4 million acres in rotational pastures and other crops that produce below potential due to poor management (NE Research Program Steering Committee, 1976 in Murphy, 1989).

Gould (1989) inventoried Michigan's pastureland resources by county and estimated the number of ruminant animals grazing these lands, including dairy cow herds, beef cow herds and sheep flocks. An average of 2.9 acres of pastureland, ranging from 1.65 to 8.83 acres depending upon county, is available per estimated grazing animal unit in the lower peninsula. This large land/animal ratio implies a potential to increase the utilization of Michigan's pastureland (Gould, 1989).

The acres of pasture per animal unit is a function of degree of urbanization, soil fertility, land topography, percent of pasture acres wooded versus cleared, and relative advantage of animal versus cash cropping in the county. Counties with lower soil fertility have a lower carrying capacity per acre and thus, require more acres per animal (Gould, 1989).

In the upper peninsula, acres of pasture per grazing animal unit ranges from 2.68 to 9.24 by county, averaging 3.9. In Michigan, there is a total of approximately 1 million grazing acres and about 350,000 grazing animal units or 3.15 acres per

1 animal. Sixty-nine percent of grazing units are beef cow herds (Gould, 1989).

2.2.5 Intensive Rotational Grazing

Intensive rotational grazing has potential to increase the efficiency of pasture use in Michigan. Intensive grazing systems can be used with any class or species of animals, in any environment (wet/dry, hot/cold), or with any stocking rate. Although it may not be feasible due to social, cultural, or economic reasons, biologically, intensive grazing can be applied wherever plants grow.

An intensively managed grazing system can increase productivity per acre, resulting from both high quality pasture from intensive forage management and breeding selection for efficiency of forage utilization.

2.3 Grazing Systems

In this section, definitions of grazing systems are explored.

2.3.1 Continuous Grazing Systems

In continuous grazing, a pasture is continually grazed throughout the season. Carrying capacity is thus limited by the slowest plant growth period. Therefore, a conservative number of animals is grazed and/or supplemental feeding is necessary.

Continuous grazing, in combination with a fixed stocking rate, may result in overgrazing during slow plant growth period and/or undergrazing during fast plant growth period. Continuous grazing with a low stocking rate will result in forage waste due to undergrazing of the pasture and increased selectivity by the animals (Allen, 1985). The most palatable plants are frequently regrazed while competition from the undesirable species, which are allowed to mature and reproduce, increases. During this period, individual animal performance may be high while production per acre suffers. Management options to decrease forage selectivity include increasing the stocking rate, restricting grazing area, or conservation (Murphy, 1989).

Advantages to continuous grazing systems include lower capital costs and management demands and less stress to animals from movement and overcrowding (Wall, 1982 in Allen, 1985).

2.3.2 Rotational Grazing

In rotational grazing, the pastures are subdivided. Movement between areas is often on a fixed schedule (Bartlett, 1991) and determined by set fences.

Two types of rotational grazing systems, conventional and intensive systems differ by the number of grazing areas, the size of each grazing area, pasture grazing duration and rest period and daily stocking rate per acre.

2.3.3 Continuous Versus Rotational Grazing; Trial Results

Within the literature, there is no consistent advantage to either rotational or continuous grazing systems. Hubbard (1951), Rogler (1951) and Hull, et al. (1967) related weight gains under rotational and continuous grazing to stocking rate and animal type. Hull, et al. (1971) related the results of two grazing system types to number of paddocks.

Numerous studies have found that continuous grazing treatments result in higher production than rotational grazing (Campbell, 1961, Cooke, et al., 1965 and Blaser, et al., 1969 in Parsch and Loewer, 1987).

McMerkan and Walshe (1963) found that a rotational grazing system is more productive than continuous grazing system (in Parsch and Loewer, 1987).

Animal performance in rotational grazing systems have also been found to be greater than that of continuous grazing only in certain years (Walton and Bailey, 1981) and only during late summer months. One study found both systems to be equally productive during the early summer months (Lowensby, et al., 1973 in Parsch and Loewer, 1987).

2.3.4 Intensive Rotational Grazing

Voisin (1959, 1960) developed a type of rotational grazing designed to maximize pasture productivity through time control. The pasture is allowed to recover between grazings according to plant growth rate. This period is referred to as the pasture rest period (Hodgson, 1977).

A high stocking rate is used for a short period of time in a pasture composed of at least 8 paddocks. A variable movement schedule is often used (Bartlett, 1991).

This type of rotational grazing requires a greater management input than conventional rotational grazing. It is referred to by many names including intensive rotational grazing, intensive grazing management, short duration grazing, Savory grazing, controlled grazing management and Voisin grazing management (Murphy, 1989). For the purposes of this thesis, the term 'intensive grazing' will be used to describe this management intensive type of rotational grazing system.

Rayburn (1988) defines an intensive rotational grazing system in biological terms as one in which the stand is grazed to a height appropriate for the plant species survival and environmental conditions. Each grazing period is sufficiently short so grazing of regrowth within the same grazing period does not occur.

2.3.5 Pasture Design

The three types of grazing systems discussed have implications for pasture design. Continuous grazing systems require little time control and therefore require little pasture design. Rotational grazing requires paddock systems designed to define movement schemes and intensive rotational grazing systems incorporate an even stricter element of time control

Design of an intensive grazing system considers the characteristics and shape of the pasture available and may include existing resources such as a natural water source or an existing fence.

A circle design utilizing a central hub (Malechek and Dwyer (1983)), is one example of a pasture layout (Figure 2.1). In this system, the use of central hub minimizes animal stress and water damage development, in addition to facilitating animal handling.

2.3.6 Pasture Systems

In a conventional grazing trials, one pasture is grazed over the entire season and is evaluated as a separate entity. Pasture systems are comprised of several separate pastures which animals graze over the course of the season. The systems are designed using differences in pasture growth associated with different forages and management practices. For example, pastures comprised of early maturing species are

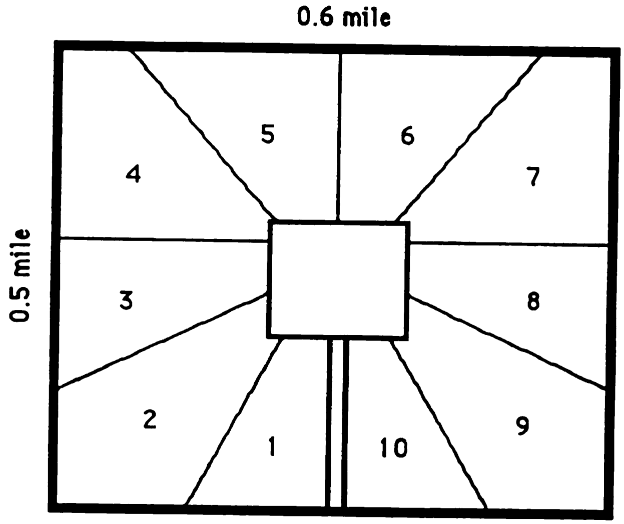


Figure 2.1 Intensive Grazing Design: Circle With a Central Hub

combined with those which grow late into the season to form a complete, extended pasture system. Production potential of the entire system for season long grazing is then evaluated.

Trials conducted on pasture systems have a season-long, multiple pasture dimension contrasted to the segmented approach of conventional single pasture grazing trials (Matches, et al., 1974).

Two benefits to a pasture system in grazing trials are increased degrees of freedom for statistical analysis and a decreased number of separate pastures required, as pastures can be used for more than one treatment. Two disadvantages of grazing multiple assignment tester animals in two or more separate pasture components are increased chance of error in animal assignments and that compensatory gain may mask the animal response to one specific forage or treatment.

2.4 Managing Pasture: Plants

Because management requirements vary from low with continuously grazed systems to high with intensive rotationally grazed systems, plant biology and its relationship to various management schemes must be thoroughly understood when designing a grazing system. An understanding of the biological principles of plants and animals facilitates pasture management.

2.4.1 Plant Biology

The growth cycle of the plant has important implications for pasture management. Once grazed, the leaf area of a plant begins with a stage of slow regrowth supplied with energy from the root reserves. Leaf area then increases rapidly through the later vegetative stages of growth, using energy supplied through photosynthesis. Here, plant growth rate is five to 20 times higher than in the first stage (Bartlett, 1991). Depending on plant species, the rate of dry matter production is greatest about the fourth week of growth and levels off during the third stage as the plant matures, reproduced and decays (Bartlett, 1991). Grazing during the late vegetative stage optimizes the use of this plant growth cycle.

Amount of fiber, energy and protein present as quality measures of a pasture are a function of days regrowth, forage type and time in season. Protein solubility is a function of forage type, month of sample and bulk height. Major mineral content is a function of forage type (Rayburn, 1988).

2.4.2. Plant Considerations in Grazing System Design

Intensive grazing works well because forage is harvested at its peak growth rate (Bartlett, 1991). Plants require an adequate regrowth (8 to 10 inches) period of 35 to 40 days in midsummer and 28 to 35 days in the spring and fall (Bartlett, 1991).

Land slope and orientation greatly influence the plant environment and forage growth. If a paddock is not homogeneous in slope, terrain and species mix, then over and under grazing may take place within the same field (Turner, et al., 1986).

2.4.3 Treatment Effects in Grazing

The literature indicates no consistent finding on the effect of grazing treatment on plant quality and quantity. Findings from research indicate the effect of grazing system on diet quality and quantity. Various plant communities were not affected by grazing treatment (Walker, et al., 1988 in Walker, et al., 1989). Diet quality varied seasonally as a function of availability of live herbage, but not of total herbage or grazing pressure. Lack of differences between diets was attributed to an absence of large variability in palatability among major forage species (Walker, et al., 1989). Grazing treatments on clay loam range sites did not effect botanical or nutrient composition of cattle diets (Heitschmidt, et al., 1987).

Any difference found in the nutrient composition of diets of fistulated steers grazing a 16 paddock system versus continuous grazing was attributed to pasture differences (Pitts and Bryant, 1987).

In Oregon, differences in sheep performance between rotationally grazed and continuously grazed pasture were attributable to differences in diet quality due to differences in available herbage between treatments (Sharrow, 1983).

Diet quality was found to be similar between the first and last day of grazing over various grazing systems (Walker, et al., 1989, Taylor, et al., 1980, Kirby and Parman, 1986, and Pitts and Bryant, 1987, in Walker, et al., 1989). Ralphs, et al. (1986) reported significant changes in diet quality and botanical composition of sheep and cattle diets within a three day grazing period. These changes were directly related to diversity of plant species available. The change in diet quality was simply a change in species intake as preferred species ran out.

2.4.4 Species Type

Species type within a pasture will effect grazing performance. Clover (1989) discusses the environmental impact of various forages. Of all crops, forages have the highest potential for removing environmental pollutants. Perennial plants provide nourishment to the soil, permanent protective cover from wind and water erosion and receive and eliminate waste. Non-perennial plants can only be eliminated by reversing the selective grazing habits of livestock.

Several studies have looked at the relationship between species type and pasture performance. In Alabama, high average daily gains and gains per acre have been produced on small grains (Anthony, et al., 1971 and Harris, et al., 1971 in Schmidt, et al., 1985) and fungus free tall fescue (Hoveland, et al., 1983) pastures with stocker cattle. Average daily gains on season perennial grass have been low (Hoveland, et al., 1971 in Schmidt, et al., 1985). *Serala* has been found to be productive in the warm season, but produces poor gains because it is high in tannin. *Au Lotan*, with a lower level of tannin, offers good potential (Schmidt, et al., 1985).

Cool season annuals represent pastures of most stocker-feeder operations in the South (Nation, 1985). Due to a high leaf/stem content, more than 2 pounds per day can be produced on these slow maturing plants. Growing conditions of cool season annuals vary greatly throughout the season. Therefore, practices such as put and take stocking, or using lightweight cattle in the spring and supplementing in the mid winter are often practiced.

Warm season grasses can provide efficient use of soil nutrients and have a stabilizing effect on the soil. Because they often have slow establishment, native warm season grasses cannot be used effectively as a sole pasture. When combined with cool season species, an effective pasture system can be formed.

Clover (1989) suggests coastal bermuda as a warm season grass, reed canary grass and tall fescue as cool season grasses and annual ryegrass for winter grazing.

Birdsfoot Trefoil requires a high grazing height encouraging selective grazing under an intensive system and leading to an increase of undesirable weeds and a lower productivity of desirable forages. Grasses which will work well under intensive management grazing systems include perennial ryegrass, orchardgrass, Kentucky Bluegrass, and Timothy (Murphy, 1989).

Grazing systems of soybeans, cowpeas, velvet bean in corn, lespedeza and sweet potato vines have been evaluated (Nation, 1989). In one study, grazing of sweet potatoe vines was valued at $14.82 per acre in terms of feed saved. The grazing of corn crop residues provides the opportunity for reducing stored feed needs in the corn belt region. Based on hybrid, growing conditions and grain yield, 2.3 to 2.9 tons of residue have been produced per acre.

Legume-grass mixtures provide a dense turf which reduces trampling damage and can produce high tonnages. The legumes in the mixture fix nitrogen for grass growth, resulting in low fertilization needs, are high in protein and contain the mineral needs of an animal. Legumes alone make poor sod and create a high bloat risk. Thirty to forty percent legume and sixty to seventy percent grass is recommended as the ideal pasture mixture Nation (1985). As other components of pasture composition, the amount of legume in a pasture can be controlled through grazing management (Bartlett, 1991). If more clover is desired, the grass should be defoliated frequently to allow sunlight in (Swayze, 1988 and Rayburn, 1988).

White clover often becomes the dominant legume in pastures under intensive management because it is favored by periodic low grazings that remove tall growing plants that would shade it (Murphy, 1989) and receives adequate regrowth time.

Therefore, seeding a high cost legume may not be justified.

2.5 Alfalfa

Grazing alfalfa represents the challenger system to row crops in this thesis. Gain per acre using alfalfa can exceed 1000 pounds while stand persistency is maintained (Clover, 1989) although other research has not indicated this potential (e.g. Schlegel, 1991).

2.5.1 Alfalfa as Pasture

Due to its high yields, high quality and perenniality, alfalfa has been used as a premium forage for hay and silage, and is used extensively in the ewe-lamb industry in New Zealand. Alfalfa has not been widely used as a grazing species in the United States. Due to its delicate stems, it cannot survive compacted soils and crown breakage (Coburn, 1906 in Allen, 1985).

A renewed emphasis on forage quality, the fact that alfalfa's growth pattern fits well into a controlled grazing program and offers a high quality nutrition in the hot, late summer months and alfalfa's strong drought tolerance have worked to spur an increased interest in the use of alfalfa for grazing.

Alfalfa is high in energy and protein. Its high rate of passage and low proportion of cell walls allows the rumen to empty quickly. Alfalfa allows large bites and thus, a fast rate of intake (Clover, 1989). It has been estimated that stocker cattle can eat enough for up to three pounds of growth per day in four hours (Dougherty and Absher, 1987).

Sustaining an alfalfa pasture requires a higher management input than other permanent grasslands, translating into higher variable labor hours or opportunity cost associated with management input.

Bloat can be a problem, increasing the risk of increased health costs and/or death loss. There is potential for erosion and treading damage unless grasses are present. This may lead to increased stand maintenance costs and/or lower stand productivity in future periods. Although alfalfa is productive on good soils, it is not productive on marginal lands. Alfalfa has a shorter growing season than some other pasture crops such as fescue (Dougherty and Absher, 1987).

2.5.2 Weed Control in Alfalfa

Although weeds in alfalfa will not greatly affect forage yield, because most weeds mature faster, quality will decrease. In the Midwest, weeds in an alfalfa stand tend to decrease both crude protein and energy (Hesterman and Kells, 1989). Cost/anticipated benefit figures can be estimated to determine the desired level of weed control.

2.5.3 Growth Cycle of Alfalfa and its Implications for Grazing

Several researchers have found that alfalfa survival and productivity is severely reduced with continuous grazing (Moore, et al., 1946, Barker, et al., 1957, Iversen, 1965, O'Connor, 1970, Peart, 1986, Brownlee, 1973, McKinney, 1974, and Southwood and Robards, 1975).

Rotational grazing acts as a tool by which to adapt to the growth cycle of alfalfa. Frequency of cutting is important in stand maintenance and for yield of alfalfa (Graber, 1972, Bryant and Blaser, 1964, Reyonds, 1971, Smith, 1972 and Janson, 1982, in Allen, 1985). Yield is a function of number and size of stems per acre. Number of stems is dependent on the physiological status of the crown and size is dependent on agronomic and environmental conditions (Dougherty and Absher, 1987).

Alfalfa for grazing should be planted and grown, including managing seeding, inoculation, fertilization, weed control and pest management, as appropriate with alfalfa for hay or silage (Dougherty and Absher, 1987). Additionally, theoretical nutrients from manure and urine should be ignored when forecasting available forage. Although grazing should mimic mowing to a large extend, the plants reaction to the animal an machinery are not the same (Vankeuren and Martin, 1972 in Allen, 1985).

Highest yields occur when alfalfa is cut at full bloom stage, although the highest nutrient yield occurs at one tenth bloom (Smith, 1972 in Allen, 1985). Cutting near maturity allows root reserves of carbohydrates to form, resulting in fast regrowth and strong plant vigor. Immature cutting results in stand losses (Graber et, al., 1927 and Grandfield, 1935, in Allen, 1985). Increasing the cutting height usually decreases dry matter yields of hay per acre over the season (Smith review, 1972 in Allen, 1985). Two to three weeks must be allowed for adequate carbohydrate storage, with maximum storage occurring at the full bloom stage (Granfield, 1935 and Smith, 1962 in Allen, 1985). Rest period recommendations for alfalfa are as follows; Vankeuren and Martin (1972) in Allen (1985): 35 to 42 days, Iversen (1967): 36 days, O'Connor (1970): 42 days, McKinney (1974): 38-39 days, Smallfield (1980): 42 days, Leach and Clements (1984): 40 days, and Dougherty and Absher (1987): 26-32 days. Smallfield (1980) found that a 21 day rest period for alfalfa increased dry matter yield, number of plants and root weight and greatly decreased weed content as a percent of pasture over a 42 day rest period.

The growth pattern of alfalfa dictates a fairly rigid form of rotational grazing to maintain a stand over time. Two main periods, a well defined grazing period followed by a well defined rest period, must be specified (Dougherty and Absher, 1987).

Alfalfa should be grazed as close as possible to the ground without damaging the crown (Dougherty and Absher, 1987). Clover (1989) recommends a two phase system, with low demanding animals following high demanding animals. Grazing should begin one week before the first cutting would occur. Alfalfa requires rotational grazing (Vankeuren and Martin, 1972 in Allen, 1985). The duration period of grazing is more important than the regrowth period (Leach, 1978, and Janson, 1982 in Allen, 1985) and can extend up to 14 days (Janson, 1982 in Allen, 1985). If it is cut or grazed too frequently, the population and size of plants decreases and the stand is weakened (Dougherty and Absher, 1987).

If the grazing period is too short or too long, selectivity will be high, thus increasing unpalatable weed species. An excessively long grazing period allows cattle to graze off or damage crown shoots, decreasing stem population and leading to weed or grass invasion. Alternative pasture should be available during excessively wet periods.

Three, nine and eighteen day grazing durations led to similar alfalfa yields and stem densities the following spring (O'Connor, 1970). A two to four day grazing period produced a higher eight month forage yield (base of 100%) than did a 15 day (86%) or 30 day (71%) grazing duration (Jason, 1973). Grazing durations between five and 20 days were found to provide similar forage production and stand persistence

(McKinney, 1974). After two years, alfalfa survival was lower and percent grass higher with a four day grazing duration versus a sixteen day duration (Leach and Clements, 1984).

Rest period was found to be influenced by the beginning of flowering, the presence of new crown shoots, lodging, infestation of alfalfa weevil or potato leaf hoppers and drought stress. Rest periods which are too short may decrease root reserves and crown bud primordia, thus lowering the potential of crown and taproot to stave off diseases and winter kill and promote grass growth. If a stand is grazed longer than 12 days, a decreased stem population and decreased subsequent yields, weak crowns and roots, decreased stand life, and weed or grass invasion may result (Dougherty and Absher, 1987).

Seasonal and environmental conditions affect alfalfa's response to grazing (Janson, 1982, in Allen, 1985) and thus, alfalfa grazing management must vary by season.

Rotational grazing drastically and quickly changes the structure and quality of the alfalfa sward. These changes are paralleled by drastic changes in the diet and therefore, productivity. This supports the follower grazer concept developed by Blaser, et al. (1969) at Virginia Tech, in which grazing management provides consistent quality of forage over time for a specific group of animals (Dougherty and Absher, 1987).

Alfalfa can be used as a season long pasture forage. Alfalfa is most persistent in the spring (Heinricks and Nielsen, 1976 in Allen, 1985) but this may be the worse time of year to graze alfalfa due to wet weather (Janson, 1982 in Allen, 1985). Native pastures can be grazed later, allowing a producer to carry cattle later into the summer.

Summer grazing of alfalfa can be used to provide a high quality forage during the hot, dry summer slump period. Grazing in the late summer can also be an effective way to harvest the forage during times when its difficult to get in the field to hay. With moderate moisture, plants may adapt but have fewer shoots and less growth (Leach, 1978 in Allen, 1985). Overgrazing drought stressed alfalfa may decrease the stand due to increased incidence of crown and root rot disease (Talbot, 1982 in Allen, 1985).

In the fall, alfalfa growth is slowed or stopped by either a series of light frosts or a killing frost. The forage quality obtained in the fall is excellent and grazing is often an effective method to harvest the forage, as weather conditions may make hay curing difficult. Fall grazing also decreases the severity of alfalfa weevil in the spring. Overgrazing the stand in the fall may remove crown buds which will decrease production in future years and does not leave an adequate growth to hold the snow cover. Cold resistance falls considerably when harvested less than four to six weeks before a killing frost. Late summer and fall harvest management are the keys for stand persistence in the following year (Smith, 1972 in Allen, 1985). Management needs vary by climate, with less severe climates offering the most flexibility.

2.5.4 Bloat Risk and Prevention

Grazing stands containing a high percentage of alfalfa increases the risk of bloat. Bloat susceptibility is related to the rate at which small feed particles leave the rumen. Methods used by producers to avoid bloat include waiting to graze until one third bloom stage, as the pre-bud stage alfalfa's large flat leaves may increase bloat risk, maintaining a constant rate of intake by cattle and turning cattle out when the alfalfa is dry and when the cattle have a full gut. Cattle should not be moved from poor to high quality alfalfa. Dandelions or quackgrass in the stand can decrease bloat risk (Thomas, 1989).

Poloxalene should be used in blocks, lick tanks, or mixed with supplemental feed (Rather and Dorrance, 1985). Bloat has been associated with a low Sodium (Na) and high Potassium (K) condition in the rumen, thus, mineral supplements rich in NaCl should be used.

Rather and Dorrance (1985) reported cattle lost from bloat due to grazing alfalfa on 19 of 30 farms studied. Producers blamed poor management for the death loss of cattle.

2.6 Managing Pasture; Animals

2.6.1 Animal Biology

In this section, a review of animal biology's implications for grazing system design will be explored. An animal's characteristics will affect its ability to utilize pasture. Species differ in their diet requirements, grazing patterns and social interactions. Breeds differ in their response to environmental conditions. The class and weight of an animal affect its need for quality and quantity of forage. Number of animals present affects the producers control over timing of pasture use, stress on undesirable plants and animal behavior (Smith, 1989).

2.6.2 Animal Considerations in System Design

Grazing behavior may vary among grazing treatments in intensive grazing systems as a function of differences in forage yield and presentation (Arnold and Dudzinski, 1978, in Walker, et al., 1989).

Animals have a large impact on plant growth. Over or undergrazing can be detrimental to pasture quality. In general, total forage production decreases over time, as the more palatable species are grazed before their maximum growth rate is reached. Overgrazing may cause the steers to eat the unpalatable and nonnutritious basal stems, limiting intake and may damage crowns.

Intensive grazing places a large number of animals in a small area. The hoof action of a large number of animals in a limited area tends to disperse manure and trample out broadleaf weeds. Trampling caused by animals looking for the best forage is also decreased. The rest period allows the trampled forages to regrow as the manure makes soil contact (Bartlett, 1991).

Animal behavior can be partially defined by a measure of grazing efficiency. Grazing efficiency is the % of available pasture actually consumed by the livestock. Fifty percent grazing efficiency under continuous grazing systems has been considered reasonable (Nation, 1985).

2.6.3 Timing of Movement

The response of a pasture to grazing management varies with the intensity of the system. Three tools by which to change the intensity of the grazing system are the timing of animal movement, the stocking rate and the number of paddocks in the system. Optimal pasture rest length is a function of vegetative growth rates and the nutritional requirements of the livestock present (Walker, 1989). Rayburn (1988) similarly found the optimal rest period to be a function of forage species and the characteristics of the animal grazing. Forage availability affects dry matter intake.

Wynn-Williams (1982) defines grazing duration as the length of time livestock graze an area at any one time before being moved, to allow uninterrupted regrowth. A longer regrowth period means greater forage availability, but may also mean higher fiber and lower energy and protein as species mature (Rayburn, 1988). Rayburn (1988) describes two methods of controlling availability of forage. The forage allocation method looks at the amount of dry matter available at the beginning of the grazing period. This is the easiest to quantify and can be easily compared to the nutritional requirement of the herd. The forage residual method looks at the amount of residual remaining at the end of the grazing period. These measurements are more difficult to make, but it allows better control when grazing clovers. Smith (1989) recommends moving the cattle after 40 to 50% of the forage is consumed in cases where dry matter cannot be easily estimated.

Variables to consider in time control grazing application include the growth rate of the plant, the number of pastures available, and the stocking rate per acre over time.

If the grazing period in one paddock is long, the rumen micro-flora must continually adjust to a changing diet causing weight loss (Figure 2.2) and lower revenues (Smith, 1989).

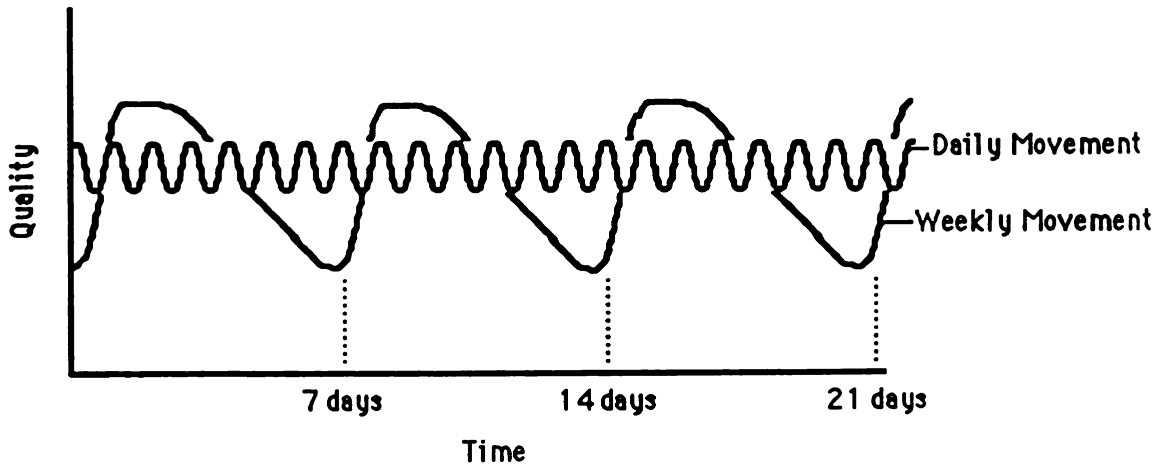


Figure 2.2 Quality of Intake as a Function of Time

Moving the animals frequently allows for manure and urine to be deposited evenly, decreases trampling damage and decreases non grazing social interaction. The stand comes back better and intake increases.

2.6.4 Stocking Rate

In Kentucky, alfalfa stands are stocked at 3 to 5 head per acre for the first year and higher in later years if the capital is available (Dougherty, et al., 1987). The Cooperative Extension Service of other states often recommends 4 to 6 head per acre. This stocking rate then increases according to the production of alfalfa, managerial skill and availability of capital. Due to the seasonal growth pattern of alfalfa, in which growth decreases over the season, carrying capacity decreases throughout the season.

Cowlishaw (1969) analyzed numerous grazing trials with three or more stocking rates and found that the average daily gain of cattle or sheep decreased linearly as stocking rate increased. Others have found the relationship between stocking rate and gain per acre was invariably curvilinear (Mott, 1960, and Riewe, 1961, in Marten and Jordan, 1972).

There are two methods to stock a grazing system, put and take or fixed stocking rates. Put and take stocking uses variable animal stocking rates during the season according to the carrying capacity of the pasture (Mott and Lucas, 1952). Fixed stocking rate uses the same stocking rate all season. Stocking rate can be defined at the number of animals per unit of land (Mott, 1960). Grazing pressure can be defined as the number of animals per unit of available forage. Carrying capacity is the stocking rate at optimal grazing pressure (Mott, 1960).

The put and take stocking rate is preferred by many researchers in the United States (Mott, 1960, Marten and Donker, 1968, Burns, et al., 1970, Matches, 1970, Mott and Lucas, 1952, in Matches, et al., 1974). Matches, et al. (1974) describe the harvesting of excess forage for hay of silage or stockpiling for winter grazing as one practical put and take stocking procedure.

Testers and grazers or puts and takes are the two groups of cattle used in a put and take system. Testers remain for the whole season and their performance is tested as an estimate of forage quality. Grazers are added and removed to apply an appropriate grazing pressure. In a fixed system, all animals are testers (Matches, 1970, in Matches, et al., 1974).

Loewer, et al. (1987) state that set stocking rates should be used in arid or semi arid conditions, after plants have gone to seed, and when attempting to introduce more desirable plants. They can be used when one desires high individual performance using a light stocking rate, when reproduction schedules require it and when the pasture growth rate is very fast.

The stocking rate can be estimated from the yields of the second, third and fourth cutting indicated on the farm record, the required level of intake (3% of body weight at 50% utilization) and the length of the grazing period. Stocking rate should not be based on the first cutting (Doughterty and Absher, 1987). A high stocking rate will increase uniformity of pasture distribution and utilization (Smith, 1989).

For many systems, the use of two groups of cattle should be considered. The stocking rate of the late summer and fall should be 25 to 50% less than the first group. With each group, the heavier stockers should be sold as they reach market weight.

In a continuously grazed pasture, stocking rate must be high enough so that the forage is held to a mean height of 12 to 18 inches. This can be very difficult to maintain, as the growth rate slows over the season. With rotational grazing, grazing should to start at approximately 12 to 15 inches and continue to 5 to 6 inches (Gerrish and Davis, 1988).

2.6.5 Number of Paddocks

The number of paddocks is a key variable in defining a grazing system. Factors affecting the appropriate number of paddocks include length of rest period required, nutritional requirements of the cattle and stimulation of forage intake with fresh feed.

2.6.6 Conception

Artificial insemination (A.I.) efficiency is sometimes low with heifers on pasture as heat checking and breeding are difficult (Zartman and Shoemaker, 1989). Research was performed at an intensive grazing site at the Ohio Ag. and Research Development Centers Branch station of Mahoning County Farm. The use of superovulation resulted in a 100% conception rate for 13 heifers on pasture in 8 weeks during a droughty June and July in 1988. This indicates that pastured heifers can be bred artificially with great success and reasonable labor and demonstrates the capacity to schedule heifer breeding on pasture (Zartman and Shoemaker, 1989).

2.6.7 Management Practices

For grazing steers and non replacement heifers, several management practices need consideration. Implants are advantageous (Garner and Cornell, 1988). A properly designed implant program can increase growth rate by 10% (Wyatt, 1985). Implanting success is measured by feed efficiency, rate of gain, carcass parameters and presence of side effects. When grazing, these are not practically measured. Pounds of beef per acre, any adverse side effects and ease of application are thus used to indicate the appropriateness of implantation (Wyatt, 1985).

Parasite control should be practiced. Shade is important, especially for infected fescue pastures. Without proper shade, body temperature may rise, affecting growth, milk production and breeding efficiency in cows. Fescue toxicity symptoms from endophytic fungus include poor gains, reduced intake, heat intolerance, rough haircoat, agalactia (absence of mammary gland development) and fescue foot (Garner and Cornell, 1988).

The profitability of raising a beef animal is a function of growth rate and efficiency of feed utilization, which are functions of genetic composition, disease status, absence of internal and external parasites, nutrition and sexual status (Wyatt, 1985).

2.6.8 Ration Formulation Considerations For Animals on Pasture

Rayburn (1988) describes the optimal balance between pasture use and supplemental feeding on pasture as a function of the animal's biological cycle, the animal's response to supplemental feed, the value of animal product sold, pasture availability and value, supplemental feed availability and value and the overhead cost of the farm business.

For sheep and cattle, the dry matter intake of grass decreases 0.5 kg for each additional kg of dry matter of concentrates fed (Ag. Research Council, 1980). Therefore, a substitution rate of concentrate for grass of 0.5 kg should be used as a rule of thumb when incorporating pasture into a ration. For forages of less than 80% dry matter and with metabolizable energy less than 11MJ, such as many hay or silage diets, a substitution rate of 1 to 1 with grass should be used.

Insufficient pasture may cause animal performance to suffer and excessive pasture may cause non-grazed feed to be wasted (Rayburn, 1988). For unsupplemented animal pasture, allocation affects the rate of production and efficiency of pasture utilization. If pasturing a beef cow, excess pasture can make her overfat and cause calving difficulties. Insufficient pasture may make it difficult for the calve to reach market weight by the end of the grazing season (Rayburn, 1988).

2.7 Implementation of an Intensive Grazing System

In order for intensive grazing systems to compete with row crops on comparable land, good management procedures must be followed during the planning, implementation and control stages.

Murphy (1988) compares learning to manage an intensive grazing system to learning to ride a bicycle. The task should be approached to accomplish the job, rather than perfectly execute every detail. Specifics are then worked out during the implementation period.

2.7.1 Land Improvement From Grazing

Swayzes, 1988, recommends the following to a producer interested in implementing an intensive grazing system: begin by taking a soil test, adding lime and phosphorous as needed, and stocking livestock heavily to clear land of tall growing plants and to apply concentrated manure. Overtime, grazing will encourage the formation of a thin sod of low growing grasses and clover. The soil is tested and fertilized as needed to favor clover in 2 to 3 years. Productivity increases in the land will be accelerated by replanting or oversowing the land.

Kyburg (1989) recommends beginning by experimentation, slowly developing marginal land for grazing.

Stocking rates will continue to increase with land productivity. Swayze (1981) recommends beginning with 100% portable fence to allow maximum flexibility. Permanent fence can then be slowly added.

2.7.2 Grazing Resources and Basic Considerations

An inventory of the basic resources available is taken during the planning stage. Goals are set. Resource needs stem from present and future system expectations and include the size and number of pastures available, quality and quantity of forages, soils, topography and unique characteristics of the land. The physical inventory also includes capital, its condition and liquidity, life expectancy and worth. Livestock should be inventoried. The breeds, sex, age, stock flow, calving season, mean weaning weights, percent calves weaned and major livestock programs such as artificial insemination on the farm must be recognized and their implications to the systems success, understood. The financial situation, including borrowing ability and employee and management hours available, skills, and preferences are inventoried.

Objectives and production and performance targets are set. Feed budgets are planned to meet performance goals. Herd management and cash flow is discussed. Implementation of a grazing system requires capital management. Within three to four years after the initiation of grazing, carrying capacity of the land will increase, increasing capital demands with the purchase of additional cattle (Swaynes, 1988). Risks are considered. An iterative implementation process is developed, with feedback initiating changes in the systems implementational tactics.

Designing and implementing a grazing system includes planning and flexibility. Swayze (1981) stresses the importance of animal containment, animal nutrition, feed ration balancing, plant growth management, vegetation types and soil productivity.

Animal feed requirements, available pasture and the feasibility of mechanically harvesting should be considered. Winter feeding methods influencing the starting weight and fleshiness of the animal and marketing options must also be considered (Clark, 1988).

2.8 Fencing

One major capital cost which must be considered throughout the grazing system design stage is fencing.

2.8.1 History of Fencing Systems

Barbed wire fence was introduced in the mid-1800's, and by the 1870's, the open range was a thing of the past (Steger, 1986).

Initially, producers faced two basic decisions; how much acreage to allocate to grazing versus cash crops and the most effective stocking rate with which to use this land. Around the mid 1950's, the issue of time control was added and with it, the concept of intensive grazing (Steger, 1986).

Intensive grazing offers improved forage response to grazing. Fencing is used to sub-divide the pasture. The objective is to use fencing to best utilize the plant resources available, while providing adequate rest periods for regrowth (Turner, et al., 1986). Because the use of intensive grazing has been limited and often practiced without the necessary management control, animal performance suffered.

Animal Performance began to show improvement through better forage management made possible by incorporating electric fence as a tool in pasture management. High tensile wire fencing was introduced to the United States from Australia and New Zealand (Selders and Mcaninch, 1987). Electric fencing offered an alternative to the traditional barbed wire and woven fences, with animal performance more than paying off the cost of installing and maintaining the fence (Steger, 1986).

Fencing technology is now based on a high power fence charger which powers a fence working as a physiological barrier (Steger, 1987). Intensive grazing requires a large amount of fencing. Therefore, fencing must be inexpensive. The new technology in chargers allows minimal fencing to provide maximum control. This keeps costs lower by using a high amperage to maintain a high voltage, even under heavy ground conditions. In addition, this fence is safe because the charge period is short. Polywire fencing with step-in posts is also available. High tensile permanent fence is lower in cost than conventional fence, requires less maintenance, is easier to operate and is cheaper than machinery (Bartlett, 1991).

2.8.2 Fencing Systems for Grazing

This section looks at fencing systems and how they work. The advantages and disadvantages of high tensile electric fencing and other types of fencing most commonly associated with intensive grazing are considered.

The main objective in the use of fencing in any grazing system is animal control. Animals will cross the fence for three basic reasons: curiosity, to be with other animals, and to get available food or water. Variables which need to be considered prior to the construction of a fencing system include costs, the distance to an available power source and water and the duration of the system (i.e., is this site to be permanent, semi-permanent, or temporary?).

Other considerations include terrain slope, erosion, rockiness, and obstructions (e.g., is the land impractical for cash crop farming because it can't be adequately reached by the appropriate machinery). The homogeneity of the land is an important variable. Animals change grazing behavior with forage availability over time. A nonhomogeneous field can be overgrazed in some spots and undergrazed in others. The proper type and placement of fencing can help alleviate these problems.

Portable fencing such as polywire or flexnet allows the same unit of fence to be used in many locations within one season. Although costs per foot is higher, a great deal less yardage is needed (Swayze, 1988). A portable internal fence with minimal permanent fence will decrease fencing costs and facilitate conservation machine harvest.

Fence and labor costs for installation and maintenance will vary greatly depending on existing fence, materials available, topography and type of system (Murphy, 1989). Permanent fence can offer a high quality, long lasting fence which is low in maintenance and over the life of the fence, is often lower in cost. A general rule is that very small operators should use 100% portable power fence and large operations should use permanent fencing or a combination of permanent and temporary fencing (Swayze, 1988). As a farm matures, permanent fence can replace temporary fencing (Bartlett, 1991).

Advantages to the use of high tensile electric fencing as compared to conventional fencing (woven or barbed wire) are economics, effectiveness, flexibility and ease of use (Malechek and Dwyer, 1983).

High tensile wire is economical. It is reasonably inexpensive to construct, requires fewer posts, is durable and has less visual impact on the landscape than conventional fencing. Ease of construction allows producers to build their own fence, saving valuable labor expense (Gallagher, 1988). Ease of maintenance saves both material and labor costs (Selders, 1987). Decreased maintenance costs may result from a decrease in fence damage due to animals, snow and fallen trees. High tensile wire fencing can be constructed for $600 to $1000 per mile (Malechek and Dwyer, 1983). Through proper use, this fencing acts as a tool to increase forage quality, decrease use of supplemental feed, increase efficiency of labor and equipment and better control vegetation to offset operating costs such as herbicides for weed control.

High tensile wire is effective. Through a uniform charge, it provides good livestock control, predator control and offers protection to newly seeded areas and increased water shed protection. It is safe for livestock and causes minimal damage to the hide. This effectiveness is due to the high voltage and low impedance which provides a safe, short pulse, allowing the animal to easily back off (Malechek and Dwyer, 1983).

High tensile fence is flexible. Spider fence (semi-permanent) allows for ease of frequent movement between paddocks, a practice which can lead to increased forage quality and production (Selders, 1987). High tensile fence can be subject to low temperature contraction with out losing elasticity, while still maintaining flexibility. It is flexible enough to bend, wrap up, form, tie in knots or clamp with crimping sleeves or by hand. This high elastic limit decreases common stretch or sag problems that are found in conventional fencing (Selders, 1987).

High Tensile wire is easy to handle and can be easily adapted to specific needs (Malechek and Dwyer, 1983). Portable polytape allows rapid set-up and take down. Long distances may be strung from a single charger.

The disadvantages of high tensile fencing include wire tension problems in extreme temperatures, power failures, the cost of electricity, and the need for special equipment such as a crimper and a tightener. By assessing the costs associated with these advantages and disadvantages, the economic viability of high tensile electric fencing for a particular operation can be assessed.

2.8.3 Economics of Fencing

Cost benefit analysis can be used to chose a fencing system. The benefits derived from an undertaking must be greater than or equal to the costs incurred. This usually involves only tangible costs and benefits (those which can be assigned a dollar figure). From there, a decision maker can incorporate intangibles, such as personal preference and safety concerns, to finalize their decision. The cost of preparing the site and future expansion or other land use plans must be considered in a economic analysis.

Benefits of utilizing high tensile fencing can be realized by increased revenue or reduced costs over conventional fencing. The cost of high tensile electric fencing is usually 30-50% of conventional fencing (Steger, 1986 and 1987). For example, a four wire fence on flat pasture costs approximately half as much as a comparable barbed wire fence and one third as much as a net wire fence. Costs for high-tensile fencing drop rapidly when fencing flat terrain (Gallagher, 1988).

Extensive plant management made possible by the use of semi-permanent and temporary fencing through intensive time controlled grazing, potentially decreasing supplemental feed costs by increasing the forage quality. In addition, increased plant management capabilities allow the manipulation of vegetation to offset expenses like weed control. Vehicle expenses are saved because cattle are in a concentrated location.

Increased revenue can be realized through increased weight gain per animal and/or a higher stocking rate per acre. Thus, a higher return per acre grazed can be made possible by more management control. For example, "Graze More Beef" demonstrations resulted in gains per acre 600 to 650 lbs higher than that realized in traditional continuous grazing at low stocking rates (Turner, et al., 1986). Other benefits which have been realized include increased conception rate and calf weaning weights.

Economic costs of high tensile fencing can occur as increased costs or decreased returns over general conventional fencing. Increased costs with a high tensile electric fence include an electrical charge not realized with nonelectrical fencing and special tools.

2.8.4 Fence Construction

Many variables are explicitly considered to design a fencing system. Actual fencing construction requires a design of the fencing system layout, acquisition of the necessary materials and tools and an understanding of construction principles and techniques.

The design and layout of an intensive grazing system involves many steps. Initially, pasture boundaries must be defined. The first attempt of designing a grazing system should always be on paper. Producers should make use of 3 maps (soil capacity, aerial photograph and topographical map) to organize logical boundaries for fields (Turner, et al., 1986).

Shading opportunities should be considered in the design of the system for milk cows, but is not generally necessary for other species. Shade will encourage manure deposit in one central area, depriving other areas of natural fertilizer (Bartlett, 1991).

Existing fence should be considered, but not limit the best use of the land's resources (Turner, et al., 1986). Fixed resources on the farm (acreage, soil type, slope, rockiness), semi-fixed resources (water supply, existing fences, and grass base) and variable resources (forage type, temporary fences, cattle numbers) and factors such as seasonal use patterns, economics, and opportunity cost of land are included (Turner, 1986).

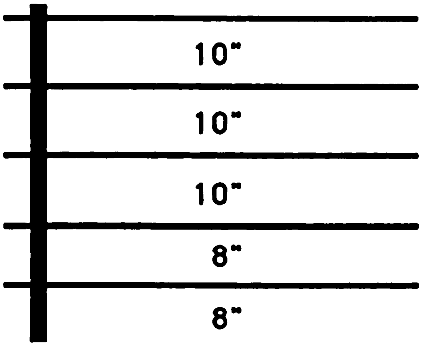
The location and shape of the field is a logical beginning point to design a system. Animal movement must be considered. The fencing design must facilitate easy movement of cattle to decrease animal stress and increase performance. A pie-shaped arrangement has two distinct disadvantages over a rectangular system: a mud hole may develop at the watering site and it is more difficult to make semi-homogeneous paddocks that following land contours with this arrangement.

A choice must be made between electric or conventional fencing such as wooden or woven fences. Existing fencing at the grazing site will alter the cost structure of the alternative fencing systems. When grazing is considered on under or unutilized land, rate of return to the fencing system is often used as an economic indicator of the projects feasibility.

A mixture of temporary and permanent fencing can be used in the system. There are management and other considerations in addition to those of cost and longevity. The use of temporary fences is a good labor saver. Temporary and portable fence increase management effectiveness or ease the use of tillage equipment. If an electric wire fence is used, the type and number of wires must be chosen. Guidelines are available on the number of wires to use by species (Figure 2.3).

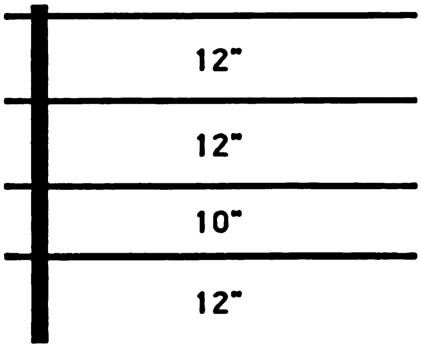
Water access and availability may be a capital consideration in the formation of a grazing site. Location of the watering tank or access to a natural water source can greatly influence the cost of the system. A watering site should include good drainage and enough space for watering, but not so much as to encourage loitering. As a result of proper fence design, cattle should come to the site only to drink water, which always must be in adequate supply (Steger, 1986). Because its more difficult to use a separate water supply for each paddock, a central watering source is often recommended. Water direct from a pond or spring may hamper disease control (Turner, et al., 1986).

Five Wire Cattle Fence
(46", five wire)

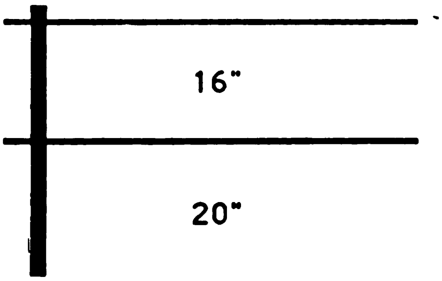


(6 foot fiberglass rod with soft spacings)

Four Wire Cattle/Horse Fence
(46", four wire)

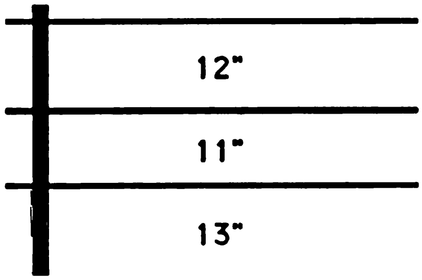


Two Wire Beef/Dairy w/o Calves
(36", two wires)



(also suggested is two wire, 17" and 37")

Two Wire Beef/Dairy with Calves
(36", three wires)



Hard to Hold Cattle
Permanent 17", 26", 37"
Portable 11", 26-26", 34-38"

Figure 2.3 Number of Wires for Animal Control

For sheep or a small number of cattle, water can be hauled with a pickup or water wagon. Another option is black plastic hose laid on or just below the surface. This option is inexpensive and effective and the line does not have to be water proved as the grazing season does not coincide with long or extreme periods of freezing weather (Bartlett, 1991).

The materials and tools used in the construction and use of an electric fencing system make up additional costs. An energizer is a vital component of an electric fencing system. Energizers vary by type of power source requirement (battery, solar, or plug in) and by capacity (size of capacitor), which determines how far the charge can be transmitted.

An energizer is chosen based on the length of the fence, vegetation present, type of animal and power available (Steger, 1987). Each amp of capacity will effectively power one mile of fence. For control of stocker cattle, voltage may be as low as 2000 to 2500 volts and a low impedance, properly grounded, fence charger should be used. Grounding is often the limiting factor of efficiency. Existing ground rods for power or telephones should not be used as grounding for the fence. Energizers vary widely in cost. An energizer emitting a short pulse will limit total energy, protecting posts and wires.

Wire type must also be chosen. Overpower wire is costly and not necessary for livestock control. A commonly used wire is twelve and one-half gauge high tensile triple galvanized wire, which will last about 20 years. Tumbleweed electric fences allow the size of the grazing area to be easily adjusted for rainfall and growing conditions (Nation, 1985).

Posts have a basic function of holding up the wire. The best and most trouble free post to use is a self-insulating round fiberglass post (Steger, 1987). The other alternatives are steel posts, which can ground the intended hot wire, and structural tubing and wooden posts, which have a higher labor requirement, but if treated, can often be used without insulators.

The post-insulator combination used is a major factor in appearance and effectiveness of the electric fence system. It works best to use free running wires so animal pressure will not break the fence. Using insulators on all posts and wires offers two benefits: the location of the ground or hot wires can be easily changed and the efficiency of the energizer increases. High quality insulators should be used for a good fence. End insulators such as porcelain donuts or insulators made from high strain plastic work well. Soft plastic insulators are more easily cut by wires.

When using an electric fencing system, the costs of protection from electric shock include a voltmeter, insulators, lightening protection and insulation. Other items which may need to be purchased include: staples, wire splicers (sleeves), mechanical fasteners or wire knots, spinning jenny (wire dispenser), nicopress tool (crimping tool) and a chain removable tool with clamps to grasp the smooth wire for stretching. A voltmeter, lightening diverter, flood gate controller, voltage splice protector, and cut off switches may also need to be purchased. These costs are important to consider when comparing land use alternatives.

An All terrain vehicle (ATV) can be used for building fence, stringing temporary wires, opening gates, checking pasture and other pasture chores. An ATV may be more economical and mobile that a tractor or a pickup (Bartlett, 1991).

2.9 Grazing Models

Research on grazing can be a time consuming and expensive task. The results of a study are often applied to numerous practical problems of a varying degree of similarity to the conditions present in the actual study. The specific nature of a particular grazing study may make inferences to a wide range of on farm situations inappropriate, creating a need to formulate a method to shorten the gap between research and its applicability to the farm situation. Grazing models were developed for this purpose.

2.9.1 Grazing Models

One such model, GRAZE, was developed to relate beef animal performance to environment, management practices and selective grazing of pastures (Loewer, et al., 1987). In this model, daily measures of pasture quality and availability are maintained. Measures of animals physiological weight and age are computed at fifteen minute intervals. Using these measures, body composition, efficiency of growth and feed utilization are then determined. Rotational grazing systems are then evaluated using time of grazing and/or availability of dry matter as a basis for animal movement.

In this model, the pasture is divided into various subdivisions throughout each day. These subdivisions represent conceptual differences in herbage quality and mass associated with selective grazing. The number and size of these subdivisions vary with environment and forage removal. These subdivisions are reevaluated and ranked each day depending on plant growth, composition, and quantity of dry matter removed previously. Dry matter is removed, beginning with the highest ranking area. This logic continues until the animal reaches its intake maximum.

In this model, the dry matter intake rate is a function of the physiological age of the animal and plant quality and availability (Figure 2.4). Plant quality and availability is a function of new, old or dead plant particles present.

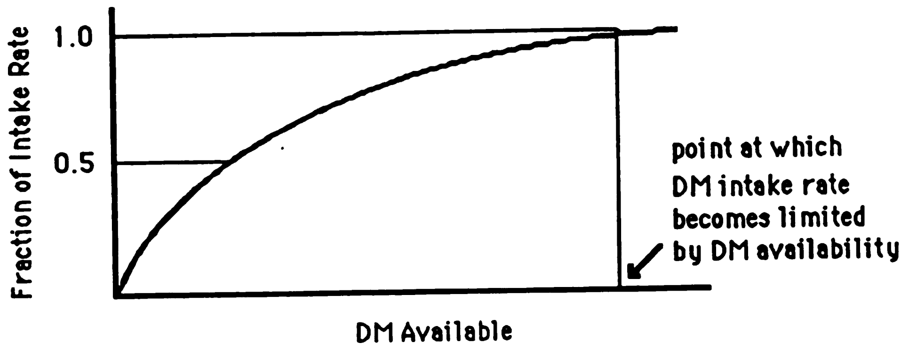


Figure 2.4 Intake Rate as A Function of DM

The rate of ingestion is a weighted average of the portion of the plant consumed and its potential intake rate. The potential intake rate may decrease by forage availability (Loewer, et al., 1987).

GROWIT is a model which simulates plant growth and composition on a daily basis as a function of the minimum and maximum daily temperatures, rainfall, forage removal rates, fertilization data and crop parameters. Each plant is categorized as new, old, dead or unavailable for grazing. Each plant is further described in terms of cell content, potentially digestible cell wall or indigestible cell wall material (Loewer, et al., 1987).

Another model, the Farm Advisory Model, was formulated to evaluate grassland management decisions on beef and sheep farms in the United Kingdom (Dowle and Doyle, 1988). The model is used to assess the implications of altering fertilization, stocking rates, feeding schemes and grazing management. This model evaluates the likely practical and economic consequences of changes in grazing and conservation management. Within the model, four submodels are present. These include grass growth, stock feeding management, integration of conservation and grazing and a measure of biological and economical efficiency.

The grassland is partitioned between grazing and conservation by maximizing the conservation cut subject to meeting the sufficient grass intake to meet animal requirements at all times. Hay and silage losses of 25 percent are assumed.

This model is used to rapidly assess the likely implications of a given change in a grazing system on both grass utilization and profits. There are many such changes which can be evaluated including the alteration of site characteristics, increasing grass area, improving sward composition, changing sward composition and improving drainage. The implication of changing levels and timing of fertilizer application and conservation cuts, and the value of concentrate feeding can also be evaluated.

2.9.2 Grazing Model Accuracy

The validity of grazing models depends upon their ability to predict actuality. The validity of the Farm Advisory Model was tested.

In order to validate the Farm Advisory Model, its prediction results were compared with the observed results of 40 farms in Great Britain (Meat and Livestock Commission of Great Britain). The model underpredicted stocking rates and overpredicted number of conservation cuts. Most of the farms took either no or one conservation cut. The predicted yields were larger than actual for the first cut and smaller than actual for the second cut. Four farms took silage cuts. The yield of these cuts was generally less than that predicted. This lower actual yield may be due to higher than predicted stocking rates implemented on these farms.

The difference between predicted and actual stocking rates and quantities of silage could be quite large. This is consistent with the idea that most farms are not exploiting livestock to their full potential. In the model, increased annual rainfall and fertilization rates was correlated with higher stocking rates and profits (Dowle and Doyle, 1988).

The dynamic aspects of both plant and animal growth, environmental influences, the definition of plant and animal maturity and accurate measures of forage quality make it difficult to model beef-forage systems (Loewer, et al., 1987). Attempts to overcome these difficulties increase through modeling efforts put forth by the research community.

2.10 Grazing Research/Survey Findings

Much research has been done in the area of grazing. In this section, a few studies from each of several areas, including grazing system treatment effects, economic findings in grazing research, research on alfalfa, grazing systems for dairy cattle and forage and grazing demonstrations will be discussed.

2.10.1 Grazing System Treatment Effects

Allen (1985) reported on two randomized block design trials comparing different rotational grazing systems. In the first trial, angus cows, calves and yearlings were grazed on a tall fescue, red clover and white clover mixture consisting of two systems.

In system one, yearling steers grazed up to 50% of the available forage in each paddock prior to the cows. Calves creep fed with the steers. Hay was harvested in 45% of this pasture. In system two, cows continuously grazed on 55% of the total area, with the remaining area grazed by calves and steers and cut for hay.

In both systems, yearlings were removed in early August. Calves continued to creep feed and were weaned in October. In early November, cows grazed stockpiled fescue from the second pasture to meet their additional nutrient requirements. Weanlings were wintered on adjacent stockpiled fescue at a rate of one acre per calf. The pasture was stocked with six cow/calf pairs and the steers grazed excess forage on a put and take system. Stocking rate was increased by one cow in the rotational system during the first week. No supplemental feeding was practiced until December.

Cows in the three paddock continuous system maintained a higher body weight than those under the rotational system. Yearlings gains were higher in the continuous system, while calf performance was similar for both systems. In the first year, more hay was harvested from the rotationally grazed system. Total gain per acre was 405 lbs and 415 lbs, for the rotational and continuous systems, respectively.

In the second trial, a ten paddock system was compared to a one paddock continuous system over two replicates, with crossbred stocker steers grazing orchard grass and red clover. The grazing season was from May 9 to September 26. Excessive hay was harvested. Stocking rate began at two head per acre and was adjusted for forage availability, resulting in a stocking rate of one head per acre by August. No steers grazed from July 6 to August 9 due to hot weather. Paddock movement in the rotationally grazed system was determined by forage availability and did not allow for grazing of regrowth. In the continuous system, the paddock was divided into two sections prior to first cutting to allow excess forage to be cut. Individual animal average daily gains and gains per acre were higher for the continuous system. Total gain per acre was 345 lbs and 421 lbs for the rotational and continuous systems, respectively.

It was concluded that individual animal performance was greater in continuous grazing systems over those utilizing rotational grazing. No short term advantage was found for rotationally grazed systems, although inputs of fence, watering supplies, shade and labor were higher for the rotational systems. This is in agreement with Missouri research (Whittier, et al., 1987 in Allen, 1985) which found no advantage to rotationally grazing fescue based pastures, and no advantages to increasing number of paddocks for season long grazing. No botanical composition differences were found between the systems after one year.

Walker, et al. (1989) hypothesized that overall diet quality would be lower in a rotationally grazed treatment than in a moderately stocked, continuously grazed treatment as a result of grazing pressure, although individual cow performance would not be affected.

An experiment was designed to examine the affect of a rotational grazing system at two stocking rates on quantity and botanical composition of cattle diets, harvest efficiency, animal behavior, watershed conditions, livestock performance and profit margins.

The pasture consisted of short and mid grasses, Japanese brome and honey mesquite. The continuous system was a single, 248 ha pasture stocked at 6.2 ha per cow per year. The rotationally grazed system had 14 paddocks with a mean size of 33 ha. Data was collected from two 27 ha paddocks and one 30 ha paddock. Stocking rates varied from 3.7 to 5.2 ha per cow per year. The 30 ha paddock was grazed for two to five days. The 27 ha paddocks were grazed for 18 hours to two days, resulting in a pasture rest of 30 to 65 days. Calf weights increased from 200 to 450 kg over the trial. Individual cow weight gains in the two systems were similar. Rotational grazing did not lower the quality of the pasture.

Morrow, et al. (1986) hypothesized that intensive grazing would result in a higher percent use of the forage available, decreasing selectivity and thus the overall quality of diet as a function of paddock movement. Hereford cows nursing Gelbvieh-sired calves, born from late February to early April, were grazed on three forage management systems utilizing cool season grasses and legumes. The low system was an orchardgrass pasture stocked at 2.67 acres per cow/calf unit on a three paddock rotation. The medium system was a orchardgrass and red clover pasture stocked at 2.00 acres per cow/calf unit on a six paddock rotation. The high system was a pasture of bromegrass interseeded with alfalfa or birdsfoot trefoil or fertilized with nitrogen stocked at 1.33 acres per cow/calf unit on a 12 paddock rotation. The results are summarized in Table 2.1.

Table 2.1 Morrow, et al. (1988) Experimental Results

System	1986		1987	
	lb/calf	lb/acre	lb/calf	lb/acre
Low	266	100	285	107
Medium	262	131	306	153
High	248	186	308	232
Days on Pasture	153		140	

In 1986, the high system had 86% more gain than the low system, although individual animal performance was less. In 1987, the high system had a higher individual animal performance and gain per acre than the low system. The need to monitor forage quality and availability in a high input system in order to produce high calf gains was stressed.

Matches, et al. (1974) reported on three grazing trials, including one conventional and two pasture systems held in Missouri to look at two practical experimental designs for grazing systems. The objectives of the study were to consider different forages and management practices for grazing.

The trials were held on two farms. On the Bradford farm, 1.2 ha pastures of tall fescue, orchard grass and crown vetch were grazed for 217 days by polled Hereford heifers of mean beginning weight of 227 kg. Eight tenths ha pastures of cool season forages including tall fescue, orchardgrass, and smooth bromegrass and pastures of warm season forages including bluestem and switch grass (1.2 ha) and pearl millet (0.8 ha) were grazed by Holstein heifers of mean starting weight of 334 kg.

The trial's pastures consisted of separate pastures of cool and warm season forages, with nine pasture systems being formed from three warm season and three cool season pastures. The warm season and cool season pastures were grazed in two and three paddock rotations, respectively.

Significant differences existed for gain per hectare and average daily gain among treatments in the separate pasture trials, while there was little difference shown among pasture systems with season-long grazing. The highest average daily gain per ha and per animal occurred on the fescue all season system at Southwest center site. High animal performance was attributed to a uniform diet throughout the season. The large differences found between individual forages was lost when pastures were integrated into pasture systems for season-long grazing. Integration resulted in differences one half to one third of that found in conventional trials. Precision between separate pastures and pasture systems was found to be comparable.

Heitschmidt, et al. (1982) compared intensive grazing with continuous grazing. Weight gain per head was the same for both systems. The stocking rate in the intensive grazing system was twice that of the continuous system. Thus, gains per acre for the intensive system were twice that of the continuous system. Total forage production was good in both systems and potentially higher in the intensive system.

Malechek and Dwyer (1983) compared animal production of intensive grazing systems with that of conventional systems in Utah. Animal behavior, nutrition, forage use, plant community change, watershed impacts, on site economics and universal applicability were evaluated. A 210 acre pasture of crested wheatgrass was arranged in a ten paddock wagon wheel design. Grazing began in April, with cattle in each paddock for approximately three days per cycle for two cycles. The major limitation of this system was the shortage of early spring forage which limited cattle numbers to those that could be economically fed expensive hay in the winter and early spring.

Clark, et al. (1988) reported on Hereford cross yearlings grazing grass and grass-legume fields at the Elora research station in 1986 and 1987. The objectives of the study were to evaluate the profitability of an intensively managed pasture as compared to cash crops on productive land, to look at the effects of pasture as a component of a cash crop rotation on soil health and to compare currently recommended and exotic forages for integrated pest management.

Clark, et al. (1988) hypothesized: (1) smaller paddocks and more frequent moves would permit higher stocking rates and thus, higher gain per acre and (2) a grass-legume pasture would produce more beef profits than grass plus nitrogen fertilizer.

In each year, a control group was fed good quality alfalfa silage and a feed high in bypass protein while four treatments were conducted on three acre plots. The two forage types, grass and grass-legume swards, were each run on two rotational schemes, a four paddock system and a 12 paddock system. The four paddock system consisted of four, 0.75 acre paddocks each grazed six to 12 days per rotation. The 12 paddock system had 12 paddocks (0.25 acres), each grazed two to four days per rotation. In each, the regrowth period was 20-25 days in the spring and 30 to 40 days in midseason and the fall.

The range in gains for individual steers was between 358 and 370 lbs over all systems. The control group gained 365 lbs per head in 1987. The highest gains were in the grass-legume mixture in the four paddock system and were greater than 400 lbs per steer in 1986 and 1987. Gains per acre were 25 % higher in 1987 (718 lbs/acre) than in 1986 (575 lbs/acre) due to the use of short keeper steers in May and June of 1987. Gain approached 800 lbs per acre in the four and 12 paddock systems in 1987.

Over two years, the per animal gains were greater in the grass-legume mixture and were more pronounced in the four paddock system (14%) than in the 12 paddock system (4%). This may be due to damage caused by regrazing of young, high quality orchardgrass in the four paddock system. There was 18% more gain from a grass-legume stand per acre (25% and 12% on four and 12 paddock systems, respectively) than on a grass stand. Gains per acre in both systems were almost the same, while stocking rate varied. Mean pounds per acre over 1986 and 1987 were 563 and 622 pounds per acre in the grass system, four and 12 paddock systems, respectively and were 702 and 698 pounds per acre in the grass-legume pasture, four and 12 paddocks systems, respectively.

2.10.2 Economic Findings in Grazing Research

Parsch and Loewer (1987) used GRAZE, a beef-forage grazing simulator, to evaluate strict rotational grazing as a management strategy. GRAZE simulated grazing of 226 kg. steer calves on Bermudagrass in a continuous grazing system versus nine rotationally grazed systems. The use of ten different weather scenarios for each system looked at the risk sensitivity of each system. Market sensitivity was not addressed.

The systems were then ranked by stochastic dominance. Returns per hectare are equal to gross returns minus costs and are predicted from animal weight. Net returns from calves measures return to overhead labor, overhead capital, land and management. Costs include purchase of steer calves, costs associated with buying, selling, and transportation of cattle, vet costs, fencing, herding labor, and interest on operating capital.

In this white-box model, beef-forage production is simulated as a function of environment and management. Grazing animals maximize digestible dry matter intake rate as a function of weight-age of animal and forage quality and availability. Steers were stocked at seven head per acre from June 1 to October 4 and were not supplemented. Rotational systems were defined by number of paddocks, number of days each paddock was grazed and stocking density.

Expected returns were highest in the continuously grazed system, although risk considerations may cause a producer to choose one of the rotationally grazed systems. Strategy formulation will vary according to several factors, including the risk preference of the producer. An increase in the number of paddocks and grazing period decreased gain and net return per acre. Sufficient rainfall increased gains and net returns in pastures with longer grazing periods and more paddocks.

Rotational grazing performed poorly under poor weather, decreasing gain and net return as the number of paddocks and grazing period increased. Gains were 621 kg per ha for the continuously grazed system and averaged 558 kg per ha for the rotationally grazed systems. Continuous grazing surpassed rotational grazing in economic performance in eight years out of ten.

Leung and Smith (1984) analyzed the profitability of conversion from a continuous grazing system to an intensive grazing system on a predominately Kikuyu grass pasture. The intensive grazing system consisted of 28 paddocks arranged in a wagon wheel design with a center hub. Mean rotation duration was 28 days and ranged from 16 to 34 days, depending on growth rate of grass and forage availability. Weaned steers, with an average starting weight of 450 lbs, were used.

Partial budgeting was used to evaluate the change from a continuous to an intensive rotational grazing system. Costs and revenues that varied between systems included labor, veterinarian expenses, mineral supplement and water associated with a larger herd in addition to cost of construction of the grazing cell and change in returns from beef gain. Beef production per acre was 250 pounds in the continuous and 725 lbs in the intensive grazing system. On 358 acres, this resulted in an additional profit for the intensive grazing system of $26,000 per year or $72 per acre over the continuous system, indicating an economic potential for intensive grazing to increase profits. The intensive grazing system requires a large additional cash outlay. Careful cash flow planning and intensive managerial demands are essential in an intensive system. A holistic or systems approach should be used to coordinate an intensive grazing system with the other enterprises of the range, including time and subject management.

Clark, et al. (1988) performed research on profitable pasture management in response to a need for methods to increase profit margins in beef production.

2.10.3 Alfalfa and Other Forages

Rather and Dorrance (1935) report the results of a survey of 35 Michigan farms which regularly used alfalfa for pasture. The farms had an average history of over ten years grazing alfalfa. Thirty of the farmers preferred grazing alfalfa to sweet clover while only two preferred sweet clover. Reasons stated include greater carrying capacity, the longer stand persistence, higher palatability and a longer grazing season with alfalfa pastures. The lack of persistence of second year sweet clover after July 15 was also cited.

Alfalfa was also compared with grass pastures (old and newly seeded) in 1932. Most permanent grass pastures in Michigan were primarily Kentucky bluegrass with either white clover on good soils or Canada bluegrass on poor soils. Alfalfa was found to be more productive as a pasture crop in the spring and summer and exhibits greater growth and productivity in the hot summer months than grass.

Alfalfa was seeded on a sandy loam soil in Augusta, MI in 1929 to look at carrying capacity and suitability of alfalfa pasture for dairy cows and grazing influence on pasture compared to haying. Findings indicated that the number of animals must be large enough to prevent plants from maturing to a point of low palatability with continuous grazing.

Grazing was discontinued on September 1 to allow a full store of root reserves to develop. Close mowing or grazing of alfalfa is injurious to the alfalfa plant during this period.

Oliver (mid 1970's (from Nation, 1985)) reported on stocking rate of highly nitrated coastal bermudagrass in Northwest Louisiana. An initial stocking rate of 2,000 lbs per acre of yearling weight produced the best gain per acre. A lower stocking rate allowed the growth of mature forage and a higher stocking rate limited forage availability. Best gains occurred when the grass was kept at one to three inches in height, although this required intensive management as the rainfall in the south is highly variable.

In contrast to baled harvest, alfalfa yields increased over the season. Several management implications were formed from the results of the trial. Rotation schedules must meet the normal growth curves of plants, approximately 34 to 36 days for alfalfa throughout season and 21 to 28 days for grass. The rotation schedule for grass varies throughout the season. For alfalfa, stocking rate of cattle should be heavier in the first rotation and then decrease throughout season. A shorter grazing period in each area will allow plants to recover better, increasing carrying capacity. Grazing of weed species enhances legume and grass population growth. With daily rotations, special attention must be given to timing of movement, as cattle will stand idle waiting to be moved. It is recommended that cross fencing be used if cattle are on a given strip for less than five days. If grazing periods of greater than five days are allowed, pasture will experience regrowth and thus a back fence should be used. The high tensile fencing and portable fencing with low impedance energizers are the most economical and practical.

Allen (1985) studied alfalfa management for hay and pasture with both spring and summer grazing. Sheep grazed an established stand of alfalfa with herbicides applied in the second and third years. Mean stocking rate for the heavy and light stocked systems was 73 and 53 sheep/ha in the first year and 39 and 34 sheep/ha in the second year. Sheep were spring grazed during two years beginning on April 6, when alfalfa was 13 cm in height. Sheep were grazed for zero, two, four and six weeks at a light (leaf area index (LAI) of 1.0) and heavy (LAI of 0.5) grazing pressure. The residual effects of grazing on the hay harvest were measured in the third year with no grazing. Hay was cut at six weeks after April 6 at the late bud stage. Regrowth was harvested on all systems at one tenth bud stage.

Light grazing pressure had little effect on the stand or its future production. High grazing pressure, especially for the six week period, reduced plant density and yield. Weeds increased with grazing, but were decreased using herbicides after the third season cuttings. Grazing, especially at high pressure, decreased nutrient value of the stand. The stand quickly recovered when grazing was discontinued. Grazed stands reached the cutting stage at a similar time to ungrazed stands.

Two years of summer grazing trials with six systems, varying by first grazing date, were held. Residual effects were measured on three hay harvests in the third year. Alfalfa grazed at early bloom for a seven day period had similar weeds, regrowth, and stand density to non grazed alfalfa. Regrowth grazing at the early bloom stage caused increased frequency of weeds. The stand showed excellent growth in the third year, although the effects of grazing were still apparent. As the grazing period increased, weeds increased and yield decreased, although herbicides may have addressed both of these effects. Grazing at the early bloom stage did not harm the stand during the third year.

LAI remaining after summer grazing for two, four and six weeks was similar to that of the high stocking rate spring grazing system. This indicates good potential for a lighter stocking rate, which would leave more leaf area for photosynthesis. As grazing occurred later in the plant's life cycle, leaves were selectively grazed over stems and plant quality decreased. Increasing grazing period in a given area decreased the speed of regrowth. Regrowth was slower in the summer months.

It was concluded that long periods of spring grazing are not detrimental to either the stand or its future productivity. Summer grazing, although less flexible, provides good weed control.

Schmidt, et al. (1985) studied beef steer performance on alfalfa and *Sericea Lespedeza* pastures on Ora and Greenville soils in the upper coastal plain in northwestern Alabama. The study was performed in response to the need for definition of high quality pastures that can provide rapid gains into the summer months when cool season forages are not available. The study ran from 1982 to 1984. Angus x Hereford cross steers with a mean weight of 225 kg were assigned to one of four pasture treatments of 12, 1.2 ha paddocks. *Cimarron Alfalfa, Seral Sericea*, and an *Au Lotan* rotationally grazed pastures and an *Au Lotan* continuously grazed pasture made up the four treatments. The rotationally grazed pastures were further subdivided into three, 0.4 ha subpaddocks. Each received two weeks of grazing and one week of rest. Plant height was kept between ten to 20 centimeters. Steers were weighed every 28 days and were maintained on alfalfa or *Serala Sericea* pastures when not on test. Water, salt and shade were provided for all steers. Those steers on alfalfa also received poloxalene blocks.

Averaged over three years, mean grazing period was 163 days (March 30 through September 8) for alfalfa and 139 days (April 22 through September 8) for *Sericea* cultivars. Although carrying capacity didn't differ among treatments, alfalfa was the most severely effected by drought. Mean average daily gain was highest on alfalfa (0.98 Kg) followed by *Au Lotan* and *Serala Sericea*.

Continuous versus rotationally grazed *Au Lotan* provided similar gains, which were approximately half that showed by alfalfa. Gains per acre averaged over three years on the alfalfa, *Serala Sericea, Au Lotan Sericea* rotationally grazed and *Au Lotan Sericea* continuously grazed were 533, 278, 310 and 343 Kg per year, respectively. Weed pressure was not a problem with the exception of the alfalfa pasture in the late summer. Weeds were preferably selected over the high tannin Sericea. Alfalfa shoots decreased each year, probably due to inadequate root reserve replenishment. Persistence was moderate in the third year.

Russell (1990) evaluated grazing of corn crop residue in continuous versus strip grazing with a two week rotation system. Optimal stocking rate was found to be a function of body weights necessary for cow productivity maintenance, a function of a cows condition. In 1989, weight gains were 19.6 and 40.0 lbs per cow for the continuous and strip grazing systems, respectively over 56 days at a stocking rate of .5 acres per cow per month.

Total weight gains and increases in weight to height ratios of gestating cows strip grazing were twice that of those continuously grazing. As losses in plant matter did not differ, it was concluded that strip grazing resulted in a more efficient use of crop residues.

Weathering accounted for 45.1 to 64.1% of digestible dry matter loss from the residue. A downside of continuous grazing is that the most digestible portions of forage are grazed first leaving the least nutritious stover for when spring calving cows have a high nutritional need. Therefore, an energy supplement may be needed late in the season.

2.10.4 Grazing Systems for Dairy Cattle

Conrad and VanKeuren (1989) looked at top grazing of high protein forages as an option for medium and low input sustainable agriculture. Objectives of the study were to provide a continuous supply of immature, high-protein forage to lactating dairy cows from late spring to early autumn, to keep forages highly digestible by keeping them in a growing or vegetative state, to determine the effect of minimizing concentrate feeding on milk and milk protein production and to assess the relative amount of fossil fuel used in conventional dairy feeding systems versus those highly incorporating grazing.

Lactating cows were grazed on a legume or grass pasture system. The legume pasture consisted of alfalfa or a combination of alfalfa and Ladino clover. The grass pasture consisted of orchardgrass or perennial ryegrass. Perennial ryegrass was difficult to maintain throughout the summer.

Stocking rates of one to 2.6 cows per acre were used. Poloxalene was fed to cows as a bloat guard at 10-20 grams per day. In several seasons, heifers were used as follower animals to graze the excess forage, increasing labor use. The follower system was used in conjunction with a put and take system.

Plots ranging from 1.5 to six acres were divided using electric fencing. The legume pastures were divided into eight equal paddocks. A top-grazing procedure was used. Cows were placed in a paddock when the forage was 24 to 30 inches high and were removed when the forage was eight to ten inches high. A combination of rotation and strip grazing was used. The grazing period was two to four days, allowing approximately 21 days of regrowth. Excessive growth initiated harvesting and/or accelerated rotation. Orchardgrass pastures were more intensively grazed. A 12 day rest period resulted from grazing four plots for four days each. Regrowth was 16 to 18 inches and stubble was five to eight inches. Plant matter less than eight inches was less than 50% digestible.

Concentrates including corn, oats and minerals were feed to lactating dairy cows at zero, 11 and 21 lbs per day on alfalfa and at 28 lbs per day on orchardgrass depending on amount of forage consumed. A control ration consisting of 60% alfalfa silage and 40% concentrate was fed. The trials began between April 20 and May 8 and finished September 10. Heifers grazed in late October.

Grazing reduced fossil fuel use per unit of milk over the control group in the barn. Grazing systems used slightly less land than a concentrate system but resulted in 20% less milk per acre. Fencing costs were $200 per cow and were depreciated over six years. The maintenance of the fence proved to be a significant problem due to electrical difficulties. Fencing systems have since improved. The costs of the grazing system were inserted into the 1989 Ohio Dairy Enterprise Budgets for harvested forages and grazed forages for 6.5 months in a 13 month lactation period. Results indicated that summer feeding through grazing is economical.

The conclusion was that if harvest management and grazing were at an optimum given plant growth cycles throughout the season, digestible energy yield could increase four times and dry matter yields could increase two times with rotational over continuous grazing.

Johnson, et al. (1988) looked at polled Hereford milk production on cool and warm season forage systems under different levels of grazing management and with different forage types. Objectives of the study were to look at the effect of different input systems on milk production and to relate forage quality, availability and composition found to animal performance. Four input systems, low, medium, high and warm season were used. Stocking rates were 2.67, 2, 1.33, and 1.3 acres per cow/calve pair, respectively. There were 26 cows per replicate. Two replicates were milked two days per month and data on percent fat, percent protein and somatic cell count was collected. Species were as follows: low system; orchardgrass, medium system; orchardgrass, red clover and ladino seed, high input system; smooth bromegrass with alfalfa or birdsfoot trefoil, warm season input system; big bluestem.

The low input system consisted of 16 acres in three, 5.33 acre paddocks. Pairs spent two to three weeks in each paddock and one paddock was usually harvested as hay. The medium input system consisted of 16 acres in six, 2.67 acre paddocks. Pairs spent five to ten days in each paddock and two to three paddocks were harvested as hay as needed. The high input system consisted of 16 acres in 12, 1.33 acre paddocks. Pairs spent one to four days in each paddock and two to five paddocks were harvested as hay as needed. The warm season input consisted of six, 2.16 acre paddocks. Pairs spent five to seven days per paddock and no hay was harvested. Results are not yet available.

2.10.5 Forage and Grazing Demonstrations

Rayburn (1988) reported on the Northeast Farm Forage Demonstration Project in Maine, New Hampshire, New York and Vermont. Objectives of the study were to determine the quality of forage produced under intensive rotational grazing over a wide range of environment and management conditions, to develop a data base on pasture quality and factors which affect pasture forage quality and to obtain samples to develop a calibration for NIR analysis of fresh forage samples. Pastures over the entire study were approximately 70% mixed, mostly grass, 12% grass, 12% mixed, mostly legume, and 5% legume. Pastures by species were 9% alfalfa, 19% mixed grasses, 29% Orchardgrass, 10% tall fescue, and 13% white clover.

Sampling of pastures began July, 1988 and extended to October, 1988. One hundred eighty one complete pasture samples were taken on 17 farms in four states. Thirty to 50 random, but representative, samples of what cattle would eat were taken in each pasture prior to grazing. The three predominant species in each pasture were listed.

Results indicated a mean regrowth period of 34 days with a standard deviation of 13 days and a mean bulk height of 4.6 inches with a standard deviation of 2.2 inches, approximating 1980 pounds of dry matter per acre. The quality of intensive rotationally grazed pastures was measured. Fiber and energy was comparable to corn silage and was 40% higher than that usually found in hays and silages of similar forage types. Crude protein averaged 22% or twice that found in corn silage and mixed mostly grass hays, although pastures had a low protein solubility of 28%. Pastures were high in major minerals. Trace minerals were shown to be highly variable, indicating the need for a supplement.

Data collected in this first year of study indicated that quality of rotationally grazed pastures is a function of grazing management, soils, forage species, weather and fertilization practices. The average pasture yielded 23 pounds of dry matter per acre per day which would adequately support one 1000 pound animal. One conclusion of the demonstration is that pastures provide a high level of highly nutritious forage. Several improvements will be made for future demonstration. To see the effect of individual species on pasture quality and to increase practicality to field use, the major species will be defined more closely. How weather patterns and soil effect quality and pest infestations of pasture will be evaluated. On farm sampling will be used to look at forage availability and barn feeding.

Hearnshaw, et al. (1989) looked at genotype effects, the importance of genotype-environment (pasture quality) interaction and the implications for beef production under three extensive grazing conditions on post-weaning growth of Hereford and first-cross heifers in New South Wales, a subtropical climate. The study was run over a period of five years. Post-weaning growth, frame size and body condition of Hereford x Hereford and three different Hereford crosses, totaling 375 heifers, were evaluated. One group of heifers was raised from weaning (8 months) to 18 months on a high pasture system of Kikuyu, Paspalum, Rhodes grass and white clover, including supplementation of grains including corn and sorghum. Grains were supplemented at the rate of 1% of mean live weight per day from weaning to 16 months. Two other groups were raised to 30 months on low or medium quality pastures consisting of the same species in the high system plus carpet grass, and carpet grass, blady brass, blue couch and native grasses, respectively. Stocking rates for the high, medium and low pastures were 0.2 to 0.4 ha per heifer, 0.4 to 0.6 ha per heifer and one to two ha per heifer for the three systems.

Average daily gain between weaning and 18 months was 552, 272 and 97 grams per day on high, medium and low pastures. Genotype had a significant effect on gain and pasture x genotype interaction was significant in most cases. Crosses grew faster and were heavier than Hereford x Hereford animals on all pastures. Pasture accounted for the greatest amount of variation of any factors fitted and in only one case was there an overlap between pasture and mean live weight gain. Pasture systems affected crossbreeds differently. Advantage to crossbreeds for live weight at 18 months as a percent of Hereford value, ranges from eight to 12 on high, ten to 17 on medium and seven to 25 on low pastures. Adjusting for traits including frame and pelvic dimensions, condition scores and 30 month subcutaneous fat depth to a common live weight removed pasture effects. The pattern of genotype x pasture interaction observed was similar to that found by Parnell, Hearnshaw and Barlow in 1987.

After an initial loss for one month after weaning, live weight change was linear for the high system and seasonal, including a period of small or negative changes, for the medium and low systems. From weaning to 30 months, mean average daily gain of heifers on medium and low pastures was 283 and 146 grams per day, respectively. At mating, heifers on high pastures averaged 268 kg at 14 months and on medium and low pastures averaged 335 and 231 kg at 26 months, respectively.

2.11 Economics of Grazing

2.11.1 Revenues and Costs Associated With Intensive Grazing

In any business, profits are obtained by maintaining revenues from an activity above the costs associated with obtaining those revenues and an allocated fixed cost inherent in the business over the intermediate or long run. The costs of agricultural production have increased over recent years. These costs include capital costs of land investment, equipment and improvements (Malechek and Dwyer, 1983). In beef production, variable costs including purchasing, raising and marketing of stocker cattle, have also increased. Prices for fed beef have remained fairly static or decreased (Black, 1990). This static revenue, combined with increasing costs, has reduced the profit margin for beef producers.

It is therefore necessary to look for production alternatives to increase or steady the profit margin of beef production.

Interest in intensive grazing livestock as an alternative to feeding harvested feed in a feedlot situation has increased. Grazing systems offer potential to curb the rising costs of beef production. A profitable system of sustainable agriculture can be structured around grazing (Conrad and Van Keuren, 1989). Intensively grazed permanent pasture is typically one-fourth to one-half the cost of the cheapest harvested feeds, provides excellent quality and will rival the output from cropland and will be more profitable (Swayze, 1988).

Cattle are equipped to consume large amounts of roughages and can gain 1.25 to 2.00 pounds per day profitably using roughage as a prime feed source 4 to 5 months of the year (Gould, 1989).

The variability of land results in different optimal uses (Gould, 1989). Cash crops may not be the best use for a given unit of land. Grazing offers good potential for increased profit on under or unutilized land. If resources such as pasture, fence, facilities, water and capital are already available, grazing may offer good profit potential. Gould (1989) recommends a small first year investment and risk position, including starting with a few head and keeping close records of costs and returns.

Continuous grazing often results in increased costs associated with fence construction and watering facilities, in addition to a decreased carrying capacity of the land to allow adequate range recovery (Malechek and Dwyer, 1983).

Intensive rotational grazing has strong potential to improve the range naturally through secondary plant succession (Malechek and Dwyer, 1983). Use of intensive grazing can increase carrying capacity of the range almost immediately (Savory and Parsons (1980) in Walker, et al., 1989) through the substantial increase in quantity and quality of forage. The idea behind the intensive grazing method is that aggregated livestock will use a large proportion of plants, evenly distributed over the range. Plants are then allowed to rest for regrowth. Grazing improves the soils nutrient recycling and water infiltration (Malechek and Dwyer, 1983). This can improve long range production possibilities and thus, long term realized revenue from the land.

Feed is a major expense in animal or animal product production. For a beef cow/calf herd to be profitable, costs of production must be minimized, especially feed costs, to the optimal level. Strobehn (1989) in Russell, 1990, found that an average of 45.6% of all per cow costs are for feed and pastures. He found that the top one-third producers in terms of profitability fed 27.8% less stored feed per 100 pounds of beef that the lowest one-third. Strobehn inferred from this, that by decreasing stored feed usage, a producer can increase profits. Grazing can be used to reduce stored feed costs.

2.11.2 Case Studies in Economics of Grazing

Several examples are available to illustrate the economic impacts of pasturing livestock. The following cases are taken from research and popular literature. Through these, the use of economics as a tool to analyze grazing systems can be illustrated.

Consider the claim that the use of intensive grazing for dairy cattle can decrease feed costs. On one dairy farm, a producer divided a seven acre pasture into 17 paddocks. By allowing grazing on one paddock per day, he fed almost no forages and very little grain to his cows saving over $4000 in feed costs the first year (Jacobs, 1989).

A demonstration in Franklin county, Vermont was conducted in 1984 on several dairy herds. A $98 increase in net income per cow using controlled versus continuous grazing was shown. This demonstration was conducted with herds from 24 to 47 cows with a mean milk production of 18,000 lbs. Savings were equivalent to $.54 per cwt milk (Bartlett, 1991).

Controlled grazing offers the potential to increase carrying capacity per land unit. An increased carrying capacity can also reduce risk in nonfeed costs. Potential lost profit risk from transportation and marketing can be eliminated by additional on farm finishing made possible by additional carrying capacity (Nation, 1985).

The examples found in the literature and presented above claim that intensive grazing can increase profits through decreasing costs. Cost containment is the key. Beef production must be optimized, not maximized, for the given land resource base.

It is finding this optimal production level through the use of capital budgeting and break-even analysis that makes up the body of this thesis. A data set using the results of the Michigan State University stocker cattle grazing trial is used. Through the use of budgeting tools, an economic comparison between three defined grazing systems and harvesting corn will be made.

2.11.3 The Economic Model

The model to be used in comparing land use systems is similar to that used by Dowle and Doyle (1988). Only those costs which are not considered fixed over the 10 year time frame will be included.

The model as presented in Dowle and Doyle (1988) is as follows:

$$\text{Profit margin} = Z = V - C_n - C_f - C_h - C_a$$

Where
V = Overall value of meat and hay/silage produced
C_n = Total cost of nitrogen fertilizer
C_f = Total cost of supplemental feeds
C_h = Total cost of harvesting hay and silage
C_a = Other associated costs (e.g. veterinary costs, water costs...)

Profit is considered a function of the alfalfa yield and quality, management efficiency, initial animal weight and condition, environmental conditions, price margins, and input prices.

Good management is a key to making an intensive grazing program profitable. If the major enterprises on the farm are forage crops and ruminants, management needed is inversely proportional to other input use (Conrad and Van Keuren, 1989).

To compare grazing systems with cash crops, an estimate of performance per acre, as well as per animal must be obtained. A performance per animal estimate is necessary to guarantee that the minimal overhead costs of owning an animal are achieved. Performance results of land grazed with proper management must be available and carefully evaluated before comparison to that of other land uses.

In comparing grazed forage and hay production, the beef gain per acre in grazing alfalfa must offset the value of alfalfa for hay or the value of corn for grain for grazing to be a competitive alternative to cropping that same land. Value is also obtained from the flexibility offered to shift harvest dates through grazing as necessitated by dry weather or a need for high quality feed (Allen, 1985).

In economic terms, an intensive grazing system is distinguished from other land use alternatives by its unique capital requirements and the output obtained. Both grazing and row cropping systems require capital goods. These can include land, fencing, machinery, establishment and cattle costs. The purchase of these capital inputs is necessary to sustain production over time. The evaluation and the development of long range plans, such as those necessitated by deciding from among various land use options, can only be accomplished through the use of capital budgeting and financial analysis procedures. Capital budgeting is used to bring future cash flows from the enterprise to a common period in time. Financial analysis procedures such as partial budgeting and break-even analysis can then be used to assess the optimal strategy (Boehlje and Eidman, 1984).

Leung and Smith (1984) used capital and partial budgeting to analyze the profitability of the conversion from the use of conventional rotational grazing to an intensive grazing system. On 358 acres, the intensive grazing system produced an additional $26,000, or $72 per acre, return above allocated costs over the conventional system. Output gains from intensive grazing were higher than the additional input costs necessary to obtain these gains. Dowle and Doyle (1988) also used partial budgeting to compare land use systems. Smith, et al. (1986) describes the use of enterprise budgeting to compare an intensive grazing system with conventional rotational grazing. Pasture systems varied among the studies.

2.11.4 Explicit Costs of Beef Production

Forming a representative farm involves reviewing the literature and forming quantitative guidelines. Literature was reviewed on the costs of harvested forages and of pasture and confinement feeding systems. For a complete economic analysis, revenues and costs need to be made explicit, quantified and made time neutral. The revenue in this analysis will be income from beef and cash crop sales for the grazing and cash crop systems, respectively.

2.11.4.1 Harvested Forages

A large proportion of harvested forage is lost through harvesting and storage methods. It is not uncommon to lose 30% in outside storage of large bales (Watson, 1988). Losses can occur as protein and energy losses in standing forage not harvested at its peak nutritional value (40% and 20% respectively in 10 days), after mowing before baling (10-25%, mean TDN loss = 15%) and in storage (5-10% Dry Matter loss)

(Watson, 1988). Feed makes up a large proportion of the cost of producing beef. Thus, losses in these three areas can add greatly to the economic burden of the producer. Murphy (1989) states that feeding stored forages can cost two to six times more than pasturing.

2.11.4.2 The Cost of Pasturing

The cost of feeding cattle through pasturing is made up largely of cost of confining the animals and the cost of providing water. Cost of confining the cattle depends upon the existing fencing, the landscape and the control needed. The specific variables involved are covered in the fencing section, although cost of confinement is generally fairly predictable as a function of type of fence and materials used (Murphy, 1988).

Cost of watering can vary greatly between farms and is therefore very hard to generalize. The cost of providing water can range from nothing were there is a pond or stream present to low when a well or water line exists to potentially prohibitively high when a well must be dug, electricity must be available to pump water and pipe must be laid and maintained.

Confinement feeding has additional costs of additional borrowing additional, tilling land, planting, harvesting and storage of crops over a grazing system (Murphy, 1988).

Burkett (1989) states that costs including less wear on the equipment, less supplemental feed use, less manure handling, less land use per animal unit, higher quality feed, and a lower labor requirement can result from the use of intensive grazing (Burkett, 1989).

Intensive grazing, although requiring a relatively high management input, maintains profits while limiting capital expenses (Bartlett, 1991). Controlled grazing is a managerial technique that dairy farmers can use to decrease costs of mechanical harvesting while maintaining production per acre. Beef and sheep farmers can increase the length of the grazing season and therefore, increase beef output per acre and decrease wintering costs. The cost of intensive grazing is small in terms of money but large in terms of managerial expertise (Bartlett, 1991).

2.11.5 Risk

The incorporation of risk into the investment and resource use decision making process is addressed in the literature. Nicholson (1984) describes risk as the variability of the outcomes of some uncertain activity. Many factors in any decision contain uncertainty. In agriculture, uncertainty can be important for factors such as the useful life of capital equipment, weather and its affect on yield and death loss in cattle. It is the researcher's task to decide which variables are important enough (i.e. significant) to consider in decision making. Hertz (1964) describes risk as a product of the odds of various events occurring and the magnitude of the rewards or penalties involved when they occur.

Hertz (1964) criticizes the use of simple expected utility or 'best estimate analysis' for its lack of consideration of uncertainties inherent in the decision making process. Through the use of mathematics, the ability to solve problems with great precision has evolved, although there is a great deal of uncertainty surrounding the assumptions imputed into the model.

Various methods have been formed to improve the ability of models to explain empirical data. Attempts have been made to make more accurate forecasts, empirical adjustments to the model and revise cut-offs rates to stress risk (Hertz, 1964). Hertz (1964) describes a process by which a decision maker can explicitly incorporate risk associated with the values assigned to the various variables (i.e. assumptions). For each significant factor, a probability distribution function is created. From these, sets of factors are randomly selected. The rate of return is calculated for each combination of factors. From this set of calculations, probability distributions of the rate of return for a given action are formed. The use of this method helps the decision maker identify factors of uncertainty affecting the outcome of a particular action.

Calkins and DiPietre (1983) describe the use of decision trees to obtain certainty equivalents and stochastic dominance as methods by which to model uncertainty. They describe the method of stochastic dominance as a tool for determining the action which has the best probability distribution. In this method, outcomes are arranged in order of highest return (utility, profit) with the associated probability of that outcome. The probabilities are then added, forming a probability distribution. From here, the tradeoffs between risk and maximizing net return can be analyzed given the particular decision makers risk preference and risk bearing capacity.

Boehlje and Eidman (1984) define risk bearing capacity as the ability for the farm operation to withstand financial losses without being forced into liquidation or insolvency. For a mature farm, a debt to asset ratio of .3 is desirable. There are many areas of uncertainty in agricultural production. Boehlje and Eidman (1984) describe both financial and business risk. Financial risks are said to be those influenced by other business risks. They include physical production risk, price risk, health risk, risk of obsolescence, and risk involved in innovation, gross returns, net farm income and addition to retained earnings. Business risk is that which is inherent in the firm, independent of the method of financing. Examples of business risk include price and production, death loss and rate of gain in livestock uncertainty.

Boehlje and Eidman define risk preference by defining three categories in which a decision maker may fall for a given decision. These are risk averse, risk preferring and risk neutral. A risk averse decision maker is one who will pay to face a lower risk. An individual decision maker may not be in the same category for all decisions, but must consider the objectives and financial resources of the farm. In addition, risk attitudes change for a given person over time.

Understanding techniques that have been used for a similar evaluation help a decision maker adapt the tools of economics to a specific problem situation.

Boehlje and Eidman describe a methodology for dealing with risk in enterprise decisions. First, a decision maker needs to make sure the alternatives considered are relevant with the goals of the operation and feasible given the operator resources. All alternative actions should be specified and events (those happenings which the decision maker cannot control) identified. Subjective probabilities are then estimated. A cumulative distribution can be graphed. From here, several decision rules can be used. These include, but are not limited to, the maximization of expected utility, ranking of expected return, maximization of maximum gain, maximization of minimum gain, or maximization of gain subject to obtaining a certain level of income.

Chapter 3: Economic Model and Data Sources

3.1 Introduction

The net present value (NPV) approach is used to compare the economics of three rotational grazing systems of varying management intensity versus row cropping on soils in the Marlette-Capac-Owosso Association. The purpose of this chapter is to set forth and justify the tools and models used in Chapter Four to analyze the alternative land use options. The NPV approach is used to capture the implications of the uneven timing of cash flows across years. Break-even values using the AAR of alternative land use options as the opportunity cost will be calculated. Risk measures are incorporated to take into account variability of cattle gross margins and corn prices.

The soil described is a nearly level to rolling, naturally well drained to somewhat poorly drained loamy soil. Three soils present are Capac Loam (0 to 3% slope), Sisson fine sandy loam (2 to 6% slope), and Riddles-Hillsdale sandy loam (6 to 12% slope). This soil was chosen because it is common in central Michigan and is the soil on which the stocker cattle/alfalfa grazing experiment used as a data source was conducted.

The budgets are developed for 40 acres. This area is large enough to capture most of the economies of size present in both fencing and watering systems and the purchase of cattle.

3.2 Outline of Chapter

The economic models which will be used to compare the profitability and the risk adjusted profitability of the four land use systems will be described. The three rotational grazing systems are a four paddock system with two head per acre (4L) and two 13 paddock systems, one of two head per acre (13L) and one of four head per acre (13H). The fourth system is a continuous corn rotation which approximates the net return from row crop systems.

The specific systems are described in section 3.3. The economic models are described in section 3.4, including the net present value (NPV) procedure (section 3.4.1), capital expenditures for stocker systems (3.4.2), variable costs (3.4.3), prices and gross margins (3.4.4), partial budgeting (3.4.5), break-even analysis methodology (3.4.6) and risk considerations (3.4.7). The assumptions are described in section 3.5, including animal performance (3.5.1) and economic data (3.5.2).

3.3 System Definitions

Basic assumptions for the three grazing systems are similar. The gross margin of cattle depends upon purchase weight, sale weight and purchase and sale prices. The beef weight gain per acre depends upon the yield and quality trajectory of alfalfa pastures over time (years) within a grazing system and the grazing system.

The establishment of the alfalfa stand and fencing system constitute the main capital costs associated with the enterprise. The watering system can represent a third major capital cost, depending upon systems in place and natural sources. Variable costs include poloxalene[1] (with mineral supplement), labor and interest on variable expenditures.

Capital costs are those in which the input is purchased in one period, but yields services over several periods. All input expenditures are considered variable prior to a decision to implement a system; however, for purposes of this study, variable expenditures will be defined as those in which the input is used entirely within the period in which the expenditure occurs.

Holstein steers are purchased at an average weight of 500 pounds. The cattle are purchased in late April or early May and sold in early September. The grazing period begins on approximately May 6 and extends to September 1[2]. This period will vary in its beginning and ending dates, as well as its duration, depending upon pasture condition.

A grazing season of 117 days is assumed. A 117 day grazing period represents; (1) three, 39 day rotations within each 13 paddock

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[1] Poloxalene is used as a bloat preventative

[2] For purposes of this study, costs and weight gains associated with the period between purchase date and the beginning of grazing are ignored.

(pasture) system and (2) two full rotations, plus 21 days of a third rotation for the four paddock system. A final grazing or cutting of hay is often taken in October after the alfalfa root reserves are replenished adequately to maintain the next years stand. These alternatives are ignored in the study.

The 4 paddock grazing system (4L) is a pasture divided into four, 10 acre paddocks, representing a low intensity management system. The fencing, watering system, alfalfa establishment and variable expenditures associated with the system are described in Chapter 4. The layout is shown in Figure 3.1.

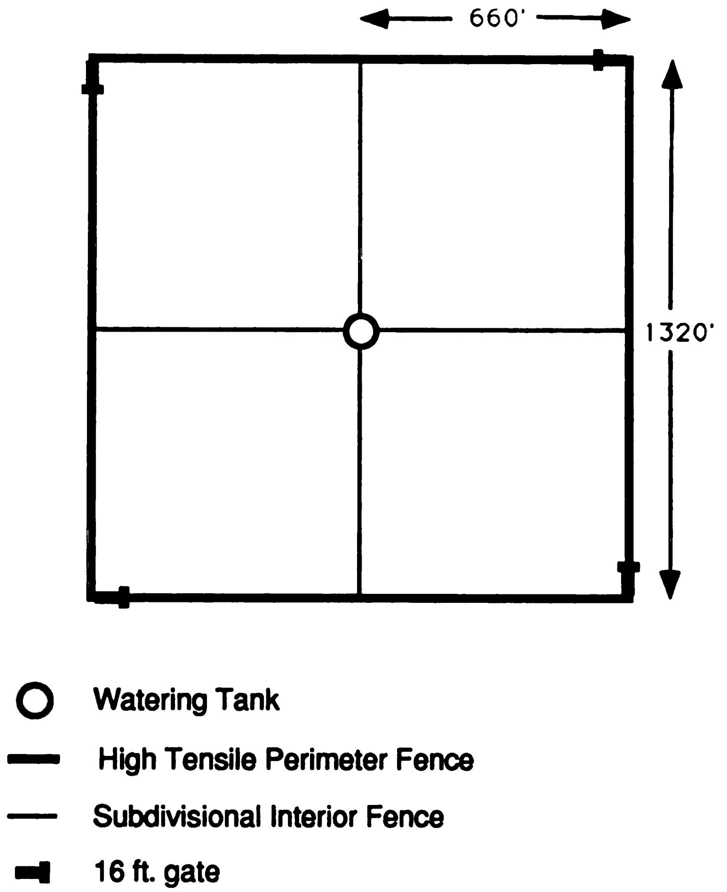

Figure 3.1 Layout of the Four Paddock System

The stocking rate is two head per acre. Cattle in this system occupy each paddock for approximately 12 days.

The thirteen paddock grazing systems (13L, 13H) are defined as intensive rotationally grazed alfalfa pastures consisting of 13, three acre paddocks. These systems represent high intensity systems. The layout of the pasture system is shown in Figure 3.2.

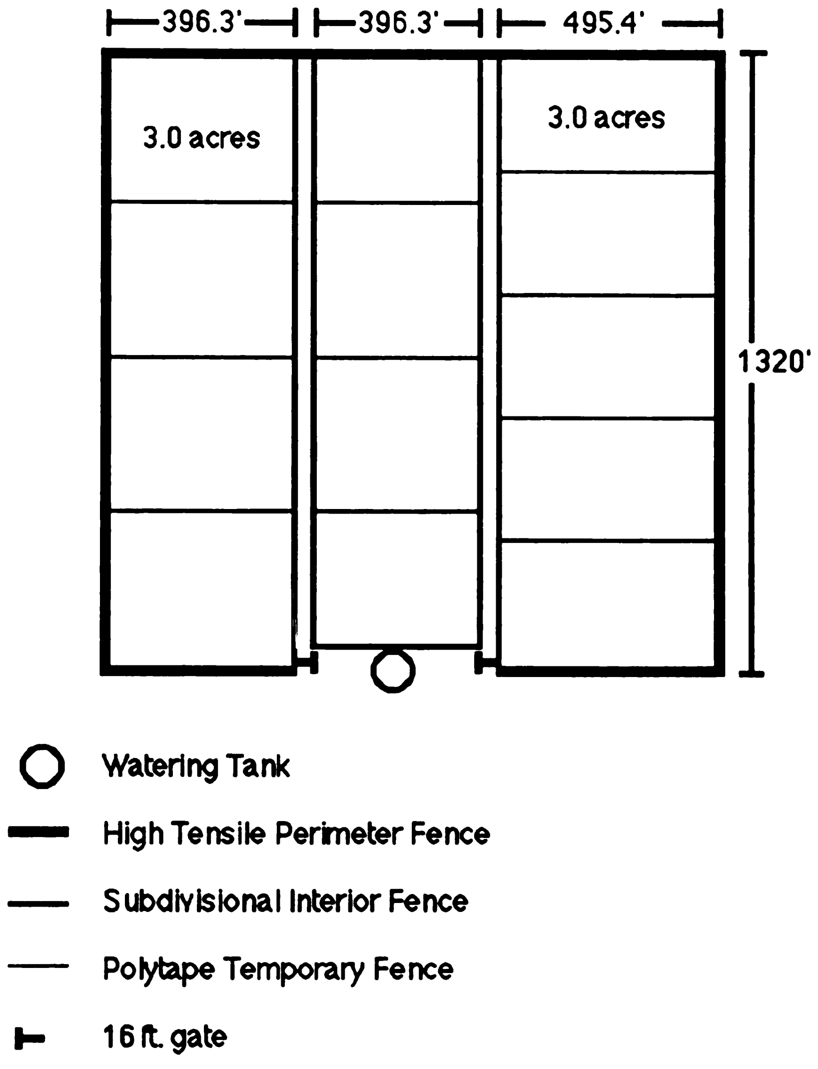

Figure 3.2 Layout of the 13 Paddock System

The 13L system's stocking rate is two head per acre. The 13H system supports four head per acre. Cattle in these systems occupy each paddock for approximately three days.

The fourth system is corn[3]. Although a crop rotation scheme would more accurately reflect Michigan cropping systems (e.g. corn-corn-soybeans)[4], for purposes of this analysis, corn after corn is chosen to represent row crop production[5]. Returns from the corn system are an adequate approximation of earnings from a rotation.

Estimated corn yields are based on historical yields for the field in which the MSU stocker cattle grazing trial was conducted and surrounding fields[6].

The costs associated with the growing of corn will be taken from the Michigan 1990 Estimates for Crop and Livestock Budgets (Nott, et al., 1990). Adjustments are made in the cost figures for corn production to reflect the strict corn after corn rotation. Costs

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[3] A similar analysis for the upper peninsula of Michigan could use hay or barley as the defender crop.

[4] Common rotations in the lower peninsula of Michigan may include corn, soybeans and wheat

[5] For simplicity, participation in USDA's ARP program (required to receive a deficiency payment on corn) is not included within this analysis.

[6] A yield of 120 bushels per acre was chosen to represent the average expected corn yield on the unit of land on which the MSU stocker grazing trial was held. This estimate was made to reflect historical yields on this and surrounding fields (Personal interview with Barry Darling, Michigan State University campus farm manager. January, 1991).

and revenues are found in chapter four.

3.4 Economic Model Details

Several economic models are used to analyze the four land use alternatives. Initially, a table will be developed showing the annual net cash flows for all systems[7]. The table depicts the pattern of cash inflows and outflows over the ten year planning horizon used in the analysis, allowing comparison to relevant capital constraints on farms. A common denominator (average annual return) describes these cash inflows and outflows in a common time period of one year[8].

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[7] A microcomputer spreadsheet, Quattro Pro, is used to perform relevant calculations.

[8] For comparing different systems, the average annual return per land unit is often used. Generally, when using economics to compare two systems, the procedure differs slightly depending upon whether or not a defender system is currently in place. The alternative system(s) being considered is (are) called the challenger system(s). The highest discounted average annual return over the life of the challenger(s) is (are) calculated and compared to the discounted next years return of the defender system. If the next years return from the defender system is higher than the discounted average annual return of the challenger, the defender system is kept in place. This simple economic comparison does not consider such intangibles as management preference and risk, which are considered in light of the economic comparison.

As imposed within this analysis, if no system is currently in place, the discounted average annual return of the alternative systems are compared. This comparison will simply indicate the land use option with the highest expected discounted average annual return above costs for the land unit. Then, additional factors, including variability, will be considered.

3.4.1 Net Present Value Procedures for the Comparison of Land Use Alternatives

NPV will be used in order to capture the effect of annual net cash flows of establishing and maintaining a grazing system over ten years. The NPV will be computed in 1989 dollars and is the sum (total) of the discounted cash flows in each year over the ten year planning period when present value is described by;

$$PV_{N=10}^{1989} = \sum_{t=1}^{N} \frac{CF_t^{1989}}{(1+r)^t}$$

Where:

$PV_{N=10}^{1989}$	=	Present value of system operated for N years in 1989 dollars
N	=	Number of years
t	=	Year in which cash flow occurs
CF_t^{1989}	=	Cash flow in period t in 1989 dollars
r	=	Real interest rate

Present values can represent costs, returns or net returns[9].

Present values of a system can also be described on an equal annual value basis. The equivalent average annual value (AAV) is found by multiplying the present value (PV) times an annuity factor (AF). It represents an equivalent equal annual cash flow (e.g. cost, return, net return) for a system over the N year planning horizon in constant, in this instance, 1989 dollars (Boehlje and Eidman, 1984). In equation form:

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[9] In this analysis, tax considerations are ignored.

$$AAV = PV * AF$$

Where:

AAV = Average annual value
PV = Present value
AF = Annuity factor

$$= \left(\frac{r}{\left(1 - \frac{1}{(1+r)^t}\right)} \right)$$

The annual cash flow for the grazing systems can be represented using the following Equation:

$$CF_t^{cattle} = (([P_S*W_S] - [P_P*W_P] - [r*D*P_P*W_P])_t - [VC_S*H] - V_S)$$

Where:

CF_t^{cattle} = Cash Flow ($/acre)
P_S = Sale Price ($/cwt)
W_S = Sale weight (cwt)
P_p = Purchase Price ($/cwt)
W_P = Purchase weight (cwt)
r = Interest (%/100)
D = Fraction of a year
VC_S = Variable cost/hd associated with the stocker operation (e.q. poloxalene)
H = Number of Head
V_S = Cash flow associated with the pasture (i.e. fencing, alfalfa establishment, labor...)

The component $([P_S*W_O]-[P_P*W_I]-[r*D*P_P*W_I])$ is frequently called gross margin. Sometimes interest on the feeder, $(R*D*P_P*W_I)$, is subtracted from the gross margin before developing comparisons.

The average annual net cash flows to land and other unallocated costs that are the same across systems for the corn system can be represented using the following formula:

$$CF^{corn} = [P_M * Y_A] - L_B - V_C - O_C$$

Where:

CF^{corn} = Cash flow in 1989 dollars($/acre)
P_{corn} = Market price ($/bu)
Y_{corn} = Yield (bu/acre)
L_B = Labor cost
V_C = Other variable costs (i.e seed, fertilizer)
O_C = Other ownership costs (i.e. building depreciation, maintenance and interest)
AAC_C = $L_B + V_C + O_C$

Within this analysis, the cash flow for the corn system is assumed to be identical in each year. Therefore, the cash flow for any given year represents the average annual return to the system in 1989 dollars or cash flows per period (cash inflow minus cash outflow). This average annual return also equals the net present value (over the ten year period) times the appropriate annuity factor or annual return (cash inflow) minus (NPV of cash outflow * Annuity factor) or average annual cost[10].

An Example

The following graphs will demonstrate the concept of converting uneven cash flows into a single measure of NPV or AAV for the four paddock stocker system.

Figure 3.3 shows the actual cash flows as they occur over the ten year period for the 13 L grazing system and Figure 3.4 shows the associated AAV summarizing these cash flows over the entire period.

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[10] The annuity approach used to calculate average annual costs on durable inputs (e.g. tractors, fence) is approximated in many analyses by depreciation and interest on average investment charge.

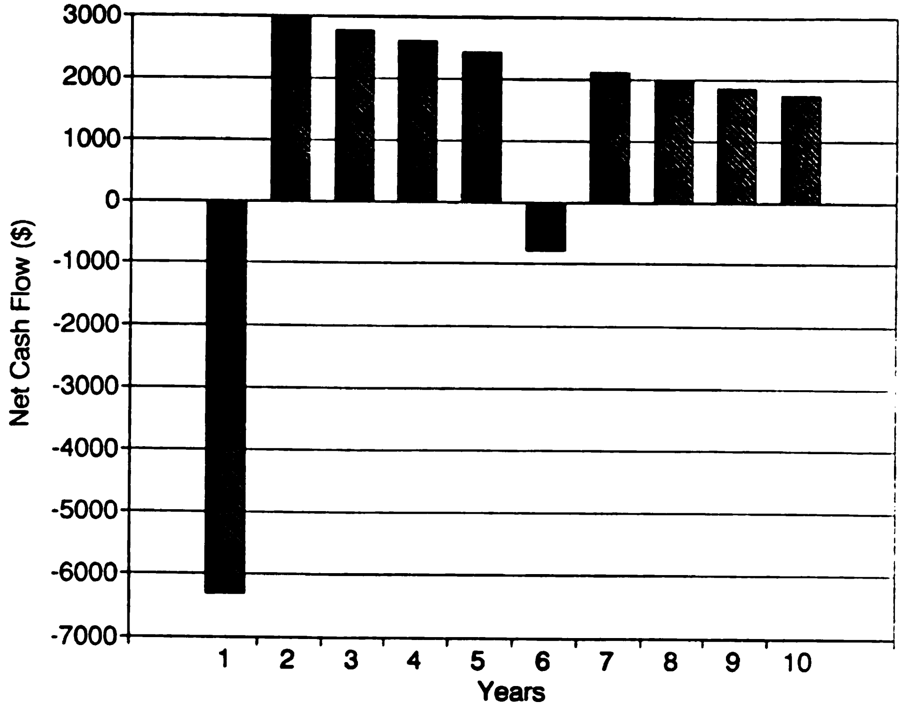

Figure 3.3 Actual Cash Flows Over a Ten Year Period (13L)

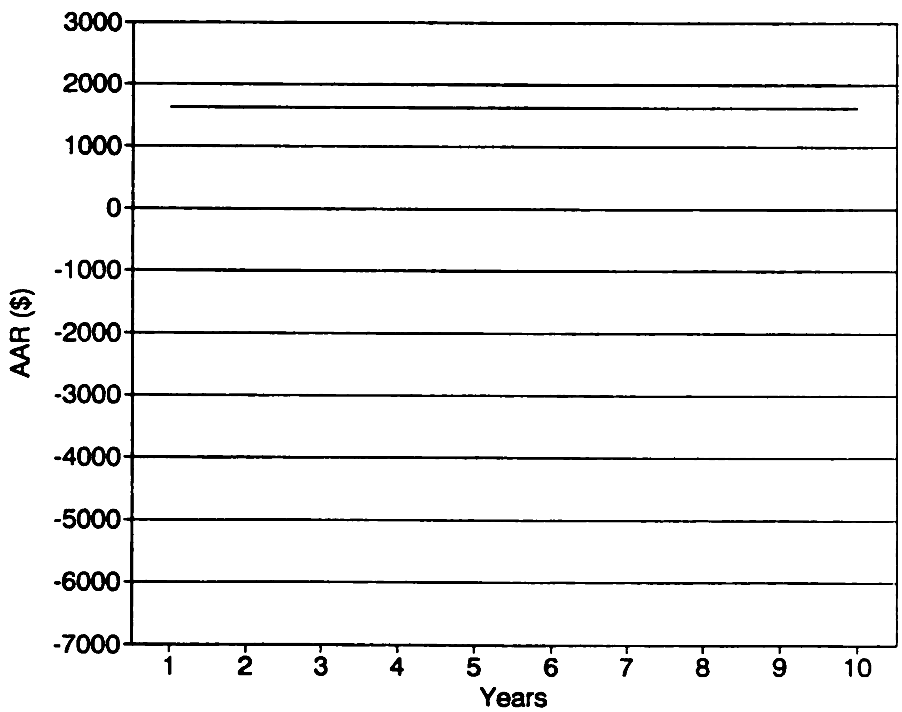

Figure 3.4 Average Annual Return for a Ten Year Period (13L)

3.4.2 Components of Capital Expenditures for Stocker Systems

Capital expenditures, those costs occurring in uneven increments but providing services over each year of the system, include establishment and maintenance of the alfalfa stand and the fencing system.

3.4.2.1 Alfalfa Stand

Due to its nutrient quality, the pasture crop representing the focus of this study is alfalfa. The forage stand costs are determined using RESEED (Hesterman, et al., 1989). The life of the stand is defined at five years. Seeding and fertilizer costs are calculated. The ten year planning cycle used as a common denominator throughout this analysis represents two alfalfa establishments and stand lives.

The costs involved in establishing and maintaining the stand include a complete seeding in years one and six and fertilization during the other years. Respective cash outlays by year for establishing and maintaining the stand are presented in Chapter Four.

3.4.2.2 Fencing System

Costs associated with the lifecycle of the fencing system include the high tensile perimeter fence, the interior subdivisional fence, polytape, an energizer and sixteen foot gates.

Fence maintenance costs vary greatly and tend to be relatively high in labor costs and low in material cost. Therefore, material costs for maintenance are not considered in the analysis. Maintenance labor costs are included in the general labor costs. If significantly large, material costs and/or additional labor costs of a particular farm operation can be included on the spreadsheet. Respective cash flows for the fence installation and maintenance are presented in Chapter Four. The high tensile perimeter fence, the energizer and the gates are purchased in the first year. An interior subdivisional fence is purchased in years one and six. Polytape is purchased every other year.

3.4.3 Variable Costs

As the length of the planning horizon increases, the number of costs which are considered variable, or those which should be carefully considered when making a long term production decision, increases. Within the ten year time frame of this analysis, all costs are variable[11]. For this study, the term variable costs will be used to represent those costs which are used up in the same period in which they are purchased. For the grazing systems, these costs include labor, mineral supplement, and cattle and interest on cattle costs. For the corn system, all costs are variable. Within this analysis, both capital and variable costs are deterministic.

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[11] The available management resource base may be considered fixed and a constraint is put on available land.

3.4.4 Prices Used in the Analysis

Two price series were used in the analysis; an average yearly corn price for Michigan and a gross margin on feeder calves using a Dodge City price series. The purchase price for calves was an average of 400 and 500 lb steer calves for April and May of each year.

The average gross margin of cattle is calculated by subtracting the total purchasing cost (average purchase weight times price of feeder calves times the number of cattle purchased) and the interest charge on cattle (total purchase cost times the nominal interest rate times (117/365) year) from the total sale price (average sale weight times price of feeder steers in September times number of cattle sold)[12]. For purposes of this thesis, gross margin will not include a charge for interest on cattle, but will simply represent the total sale price minus the total purchase price. Gross margin is included as a per animal cost throughout the analysis.

3.4.5 Partial Budgeting Procedures

Partial budgeting is appropriate to compare systems which have major inputs in common and differ in the use and amount of use in others. Each of the four systems in this study have an identical

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[12] Gross margin is then discounted to 1989 dollars by taking the gross margin for year t and dividing it by the CPI for that year using 1989 as a base (CPI89 = 1.00). This is also referred to as normalizing the data for the year 1989.

acreage of land as the major input and uses labor, management and planting machinery and other cropping inputs. Cash expenditures and inflows vary by system.

3.4.6 Break-even Analysis

Break-even analysis is used to calculate the minimum benefit required from an enterprise in order to justify proceeding with it over an alternative enterprise competing for the same fixed resources. It can be used for either short or long term decision making.

The average annual net return of the defender system to land and other unallocated costs that are the same for the defender and challenger is calculated and can be considered the opportunity cost of a challenging system. This opportunity cost is compared against a specific variable holding the value of all other variables fixed. For example, the value of beef gain per acre from grazing alfalfa, less associated costs, must offset the value of corn grown per acre, less associated costs, for grazing to be a competitive alternative with cropping that same land.

For the systems used in this analysis, the opportunity cost can take the form of many variables including corn or alfalfa yield, beef production, stocking rate or carrying capacity of a pasture, gross margin of beef, and price of corn. The break-even number indicates the threshold at which the systems competing for a given set of fixed resources become competitive.

The following break-even values are calculated:

(1) Break-even Price and Break-even Gross Margin
- (a) Break-even price of corn
- (b) Break-even gross margin of cattle

(2) Break-even yields
- (a) Break-even yield of corn
- (b) Break-even gain of beef
  - (i) Break-even total gain
  - (ii) Break-even average daily gain per animal
  - (iii) Break-even stocking rate

The break-even threshold of the defending system can be described by the following formula:

$$AAR-AAC-AOC = 0$$

Where:

AAR	=	Average annual return
AAC	=	Average annual variable costs
AOC	=	Opportunity cost (AAV of the next best alternative system)

When variables are present for which the costs or revenues depend upon input or production level, the equation can be written as follows:

$$AAR-(V_S+(VC_S*H)+AOC) = 0$$

Where:

$$AAC_S = V_S + (VC_S * H)$$

This formula can be manipulated to obtain the following break-even values:

(1) Break-even Price and Break-even Gross Margin

(a) Break-even price of corn

$$(Y_{CORN}*P_{CORN})-(AAC_C+AOC) = 0$$

Where:

AOC = Opportunity cost (AAR of next best alternative land use system)

$$Break\text{-}even\ price\ of\ corn = \left(\frac{AAC_c + AOC}{Y_{CORN}}\right)$$

(b) Break-even gross margin on cattle

$$Gross\ Margin_{BEEF} = (V_S + [VC_S * H] + I + AOC)$$

Where

AOC = Opportunity cost (AAR of the next best alternative land use system)

I = Interest on feeder cattle[13]

=

$$Interest\ on\ feeder\ cattle = (r * D * P_P * W_I * H)$$

(2) Break-even Yields

(a) Break-even yield of corn

$$Break\text{-}even\ yield\ of\ corn = \left(\frac{AAC_c + AOC}{P_{CORN}}\right)$$

(b) Break-even gain of beef

To reiterate, to calculate a break-even value, all variables within the analysis other than that which defines the break-even point,

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[13] Although interest charge is dependent upon purchase price, weight and number of head, these values are fixed in the analysis. Therefore, interest charge can be summarized using one number.

remain fixed. Therefore, the break-even sale weight will be found with purchase price and weight and sale price fixed[14]. Likewise, the break-even purchase price will be found with purchase weight and sale price and weight fixed.

The equation which defines the break-even point between a grazing system as the challenger and its defender is;

$$W_S*P_S-(((1+DL)*W_P*P_P)+((r*D)*W_P*P_P))*H-(AAC_S+AOC) = 0$$

Where:

DL = Death loss

(i) Break-even total gain

$$W_S = \left(\frac{(((1+DL)*W_P*P_P)+((r*D)*W_P*P_P))*H+(AAC_S+AOC)}{P_S*H}\right)$$

Once the break-even sale weight is calculated, break-even total gain can be calculated as follows;

$$(ii)\ \text{Break-even total gain} = (W_S-W_P)*H$$

From this equation, break-even gain per acre for system = Break-even gain per system/40 acres,

$$(iii)\ \text{Break-even ADG/hd} = \left(\frac{\text{break-even total gain}}{(H*DAYS)}\right)$$

Where:

DAYS = Number of days on pasture

---

14 Implicit within this technique is the assumption that the sale price is independent of the sale weight over the relevant range.

and

$$\text{Break-even stocking rate/acre} = \left(\frac{\text{break-even total gain}}{(\text{break-even } ADG*DAYS*ACRES)}\right)$$

(b) Break-even purchase price

$$\text{Break-even purchase price} = \left(\frac{W_S*P_S-(AAC_S+AOC)}{((1+DL)+(r*D))*W_P}\right)$$

3.4.7 Risk Considerations in Analysis Model Formulation

Each producer makes decisions based on expectations of the net return of the alternative enterprises, given available information; experience; enterprise preferences and risk preferences and risk bearing capacity. Producers never have complete information with regard to production, input performance, commodity prices and access to market, input prices and availability, borrowed capital price and availability, technology, labor, legal issues, institutional changes, and macro economic factors, such as interest rates. All of these factors create income and cost uncertainty for the producer.

There are methods available to minimize uncertainty, including obtaining more information to generate estimates of such variables as risks and returns associated with the forementioned factors, diversification of enterprises, crop insurance, forward contracting, and production practices such as irrigation and weed and pest control.

Although there are numerous sources of risk in stocker cattle operations and methods for their control, only specific sources of risk and methods for control will be considered in this thesis. Input prices and availability, commodity access to market, borrowed capital price and availability, technology, labor, legal issues and institutional changes will all be taken as deterministic. Production including yield per acre for corn and beef per acre for cattle will also be assumed deterministic. Uncertainties about commodity prices (purchase and sale price) and the implications of these uncertainties will be explored.

Economists have used several methods to incorporate risk into their analysis. For capital purchase decisions, such as in this analysis, expected benefit of various alternative decisions is often calculated.

The method is referred to as the expected benefit model (Freund, 1956 Robison and Barry, 1986). In this method, the expected benefit of each alternative land use option is calculated by the following formula:

$$E(B)=E(AAR)-1/2(CARA(VAR_{ARR}))$$

Where:

$E(B)$	=	Expected benefit
$E(AAR)$	=	Expected Annual average return
$CARA$	=	Coefficient of absolute risk aversion
VAR_{AAR}	=	Variance of average annual return

CARA takes on different values representing relative degrees of risk aversion with:

CARA = .00005 is slightly risk averse,
CARA = .00010 is fairly risk averse, and
CARA = .00015 is moderately risk averse.

The expected benefits of the alternative land use options are then ranked. The expected benefit model carries with it the strong assumption of the expected utility model that a given decision maker maintains an identical level of absolute risk aversion across all decisions.

A second method used to incorporate risk is through the analysis of cumulative probability distribution functions. In this model, the strong assumption of the expected benefits model is relaxed.

Cumulative probability distribution functions of average annual returns in 1989 dollars using gross margins over the period 1975 to 1989 are formed. The use of this method assumes independence between yearly net returns, but does not require them to be normally distributed.

Risk considerations are addressed as management options to decrease gross margin uncertainty for individuals with various risk preferences and risk bearing capacities. Risk bearing capacity can be defined in part by liquidity, capital constraints and non farm income. Likely outcomes over several systems are discussed.

3.5 Information/Assumptions

3.5.1 Animal Performance Data

Average daily gain data for the grazing systems will come directly from the Michigan State University stocker cattle grazing trial. The results of the trial cover two grazing seasons, 1989 and 1990 (Schlegel, 1991). Because only 2 years of data are currently available, an average daily gain, averaged for this period will be used to simulate a 10 year time period for each system. A ten year time frame was selected as the least common denominator for the useful life of purchased capital equipment.

The results of the MSU stocker cattle grazing trial and past literature could be integrated as data sources to form budgets representative of Michigan stocker cattle operations. This integration would add reliability to the use of two years of data to estimate a ten year time period. This will be addressed in future analyses.

3.5.2 Economic Data

Gross margins for steers are an inflation adjusted average for the period 1975 to 1990. The gross margin, defined for purposes of this study is a function of the interest rate and calf and yearling prices from Dodge City. The price margins are assumed the same for Dodge City and Michigan. Therefore, prices are not basis adjusted. Corn price is an inflation adjusted average for Michigan for the period 1975 to 1989 for the initial corn systems.

In addition, the same analysis was run using a break-even corn price defined as the economic threshold for participation in the ARP program (base acre considerations aside). This was done to more accurately reflect a forecast of the corn price over the next 10 years versus that provided by an inflation adjusted average for the past 15 years. The current estimated break-even price for participation in the government program for corn used is $2.55 (Hilker, 1991).

Cash outflows for the grazing systems (e.g. gates, fence) were obtained from several agricultural suppliers in Ingham County, Michigan. Costs associated with the establishment and maintenance of the alfalfa stand were calculated from RESEED (Durling, 1989).

A nominal interest rate of non-breeding livestock is used (Agricultural Finance Databook. Federal Reserve Board). The nominal interest rate is used as the effective interest rate for the purchase price of cattle. Individuals who are in a tight cash position will have a higher effective interest rate, while others in a very strong cash position may have a lower effective interest rate. The CPI index is be used to reflect inflation.

4 Economic Analysis

The economic analysis presented in this thesis is based on information from a stocker cattle experiment at Michigan State University[1].

4.1 Description of the Michigan State University Stocker Grazing Trial

In 1988, researchers at Michigan State University initiated a two year stocker grazing experiment (Schlegel, 1991) to determine; (1) the impact of stocking rate and intensity of rotational grazing on weight gain per acre and on persistency of alfalfa pastures; (2) the nutritive value of alfalfa throughout the grazing season under different grazing intensities; (3) the daily dry matter intake of animals grazing alfalfa and a nutrient value for alfalfa and (4) the expected and risk-adjusted average annual net return to land and other unallocated costs that are the same across systems. Researchers included animal scientists, crop and soil scientists and agricultural economists.

4.1.1 Experimental Methods (Animal and Plant Component)

In the fall of 1988, twenty-two acres on a Michigan State University farm with a loam, fine sandy loam and sandy loam

[1] See also Schlegel, M.L., 1991. Grazing Schemes for Direct Seeded Alfalfa Pastures, a companion thesis

soil types with a pH of 6.7 were direct seeded to alfalfa. The land was previously in wheat. The pasture was divided into ten, 1.88 acre plots (Figure 4.1). The experiment was a two by two factorial with two replications (Table 4.1).

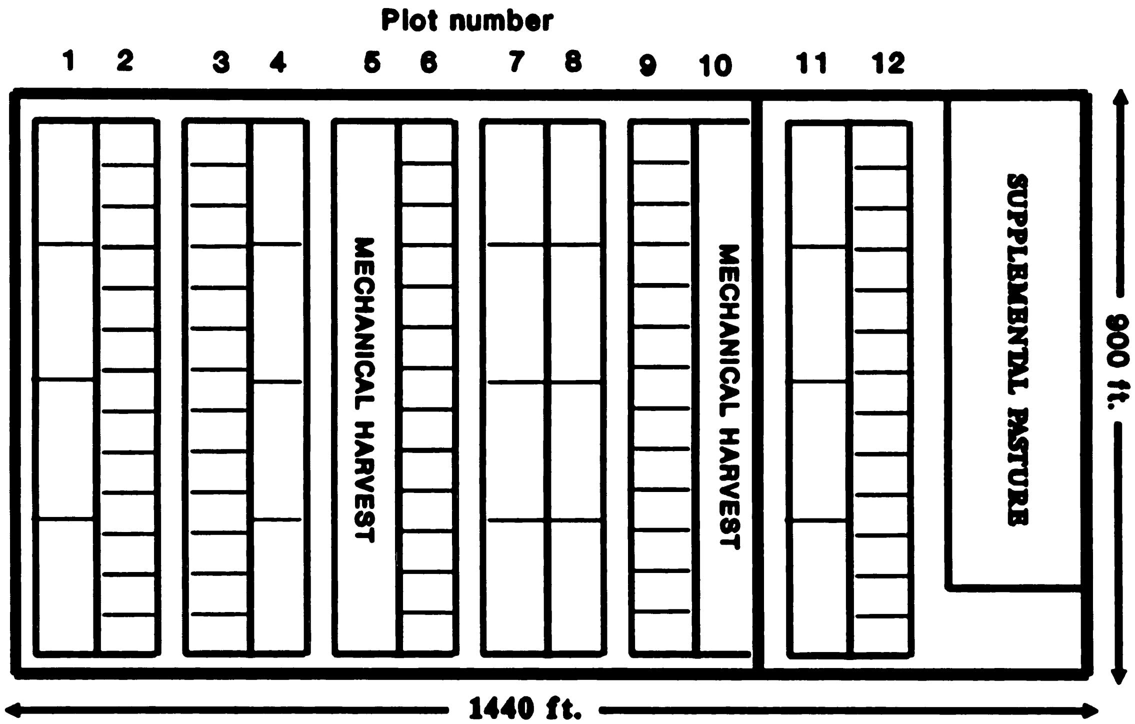

Figure 4.1 MSU Grazing Trial Pasture Layout

Table 4.1 Two by Two Factorial Arrangement of Experiment

Number of Paddocks	Stocking Rate	
	Low (2 hd/acre)	High (4 hd/acre)
4	4L	4H
13	13L	13H

Plots one through five served as the first replication and plots six through ten, the second. Plots five and ten were mechanically harvested twice each year as haylage to estimate forage production. The remaining plots were utilized to evaluate rotational grazing systems with two different grazing periods (4 versus 12 days) and two stocking rates (2 versus 4 head per acre). Each of the 4 treatments was randomly assigned within each replicate. The experiment is replicated over two years.

The four paddock system consisted of four plots, each grazed 12 days and allowed 36 days of regrowth. The thirteen paddock system consisted of 13 plots, each grazed three days and allowed 36 days of regrowth.

In the first year, seventy-two holstein steers were purchased in April of 1989 at approximately 400 lb. The steers were weighed, ear-tagged, dehorned, vaccinated and treated for parasites. Steers were placed on a diet of alfalfa haylage and mineral supplement one week prior to grazing to accustom cattle to a high forage diet. The mineral supplement contained dicalcium phosphate, magnesium oxide, trace minerals, selenium 200 and poloxalene, a bloat preventative.

Before grazing, steers were weighed on two consecutive days, implanted with estradiol[2] and divided into two weight groups. Each group of steers were divided randomly within the replications. Initially, the days grazed for the four and 13 paddock systems were two and eight days, respectively and the stocking rates were three and six head per acre. After 24 days, the grazing duration was increased to 12 and 3 days for the 4 and 13 paddock systems, respectively and the stocking rate was decreased to two and four head per acre. The change was made because it became clear that their was not adequate forage available to support the most intensive systems. The stocking rate and duration of grazing remained at this level for the remainder of 1989 and these revised stocking rates were used for the entire 1990 grazing season.

Cattle were weighed every 24 days. When all of the available forage within a paddock was consumed prior to the scheduled move to the next paddock, cattle were moved to supplemental pasture until the next move. Grazing was discontinued on approximately August 30 of both years.

Forage samples were collected by hand clipping three quadrants (2.69 ft^2) from each receiving plot every time cattle were rotated from one paddock to the next (either every three days or every 12 days) to give measures of quantity and quality of alfalfa available to the cattle. Canopy heights were

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[2] Compedose^R, A product of Elanco Animal Health. Indianapolis, IN.

recorded. Before cattle were released in a paddock, two steers fitted with esophageal canulas were allowed to graze to estimate composition of forage consumed. During the second half of the second year, dry matter weights of three quadrants of remaining forage after the cattle were removed were measured from each plot to obtain a more accurate indication of dry matter intake[3].

4.2 Results from the MSU Stocker Cattle Grazing Trial

Results from the MSU stocker trial are presented for 1989, 1990 and an average for both years. As indicated in the previous section, cattle were moved to supplemental pasture when the available forage in the paddock was exhausted. Cattle were moved to the next scheduled paddock at the appropriate time. Average daily gain calculation for each group of cattle reflects the total gain of the cattle,

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[3] A companion experiment was run on an adjacent alfalfa sward to provide data to develop an intake versus growth rate curve. The purpose of the development of this curve is to judge intake levels of the cattle participating in the first trial. Two rotational grazing plots with three and 12 day grazing durations and 36 rest days were established. The stocking rate was four head per acre resulting in 8 head for each of the 1.88 acre plots. Three groups of two animals in each plot were allowed to graze for six, ten and twenty-four hours to simulate three intake levels (70, 85 and 100 percent ad libitum). Cattle removed from the pasture were maintained in vegetation free holding pens until the next day. Fecal collection bags and harnesses were used during a portion of the first year to predict digestibility and forage intake. A regression on live weight gain per day will be conducted (Schlegel, 1991). The resulting equation will be used to estimate intake of steers in trial one from daily weight gain.

including the time spent on supplemental pastures[4]. Using this ADG, weight gain on supplemental pasture is subtracted from total gain to reflect system gain. The daily gains are biased upward because they include the expected higher gain while grazing ad libitum on supplemental pasture.

Tukey's test was used to test for interaction between paddock system and stocking rate. There was no significant interaction present between paddock system and stocking rate for animal performance (Schlegel, 1991). Animal performance could then be averaged across paddock system and across stocking rates. For purposes of the economic analysis of this preliminary data, means of the three relevant systems (4L, 13L and 13H) were used.

4.2.1 MSU Grazing Trial Results (1989)

Average daily gain and gain per acre for each system in 1989 are summarized in Table 4.2. The average daily gain and gain per acre with a low stocking rate was higher than with a high stocking rate in both systems.

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[4] ADG is calculated across both system and supplemental pastures. The strict 24 day weighing schedule does not allow for separating trial pasture and supplemental pasture gain. Any attempt to separate the gains results in additional assumptions such as effects of movement between plots on gut fill and changes in the diet (from a sparse diet one day to a plentiful diet the next) and in estimating gain while on supplemental pastures. Defining the movement of the cattle as endogenous results in more uncertain variables.

Table 4.2 MSU Grazing Trial Results (1989)

System	ADG (lbs/day)	Gain Per Acre (lbs)
4-L	1.30	300
4-H	.46	157
13-L	1.55	332
13-H	.34	140

During 1989, paddock system (four versus thirteen) was not significant for average daily gain or adjusted gain per acre[5]. Gain per acre was a function of stocking rate, average daily gain and days on pasture. Quality and quantity of forage available was similar for steers in both paddock systems during the first two pasture rotations. During the third rotation, steers in the 4 paddock system had a slight, but significantly greater forage availability than those in the 13 paddock system.

Due to higher average daily gains, steers in the low stocked pastures had greater final weights than those with a similar number of paddocks in the high stocked pastures due to less available forage per animal for animals in the high stocked pastures.

Total forage production per acre was similar for each of the four treatments and for the mechanically harvested plots

[5] Total gain attributed to each acre of the test plot was adjusted for days cattle spent on supplemental pastures.

(Schlegel, 1991). This implies that differences in gains between like stocking rates may be attributed to differences in paddock system design or implementation.

Death loss due to bloat was 7% (5 out of 72). This occurred in the fall after movement of cattle on supplemental forage (dry hay) overly lush, immature pasture. During this period, steers were consuming poloxalene at the rate of 257 grams/day (four times the recommended amount). This shows the important of taking multiple precautions to prevent bloat (see Chapter 2, section 2.5.4).

4.2.2 MSU Grazing Trial Results (1990)

Average daily gain and total gain per acre for each system in 1990 are summarized in Table 4.3.

Table 4.3 MSU Grazing Trial Results (1990)

System	ADG (lbs/day)	Gain Per Acre (lbs)
4-L	1.65	374
4-H	0.91	336
13-L	1.87	430
13-H	0.95	406

Steers in the 13 paddock system had a higher average daily gain than those in the four paddock system under the same stocking rate and demonstrated a higher gain per acre than those in the 4 paddock system under either stocking rate.

Death loss was 0% (0/48) during 1990. This can be attributed to more experienced management.

4.2.3 MSU Grazing Trial Results (Average of 1989 and 1990)

The average daily gain's and total gain per acre for each system combined over 1989 and 1990 are summarized in Table 4.4.

Table 4.4 MSU Grazing Trial Results (Average of 1989 & 1990)

System	ADG (lbs/day)	Gain Per Acre (lbs)
4-L	1.47	337
4-H	0.69	246
13-L	1.71	381
13-H	0.64	273
SEM	0.04	37.4

Stocking rate is significant for both ADG and gain/acre ($p<.01$). Given this limited data set, the evidence isn't strong enough to reject the null hypothesis that paddock systems are the same for ADG ($p=0.116$) and gain/acre ($p=0.073$). The level of significance is chosen conservatively because only two years of data are available.

Averaged over both years, the average daily gain is higher for the low stocking rate systems. Likewise, gain per acre is higher for the low stocking rate systems.

The averaged death loss over both years is 4.1%. The death loss of 7% (including cannulated steers) in 1989 can be largely attributed to mismanagement. Therefore, a much more conservative number of two percent death loss is assumed in the economic analysis (Rust, 1991).

4.3 Integration of Data Sources

Past studies indicate that gain per acre on pasture can reach 700 pounds per season depending upon management, breed of cattle, weather, and forage stand (Clark, 1990). In the 117 day grazing season assumed in this study, that translates into a gain of 3.0 lbs/day on forage with a two head/acre stocking rate and 1.5 lbs/day with a four head per acre stocking rate. For our purposes, break-even gain/acre calculations will be used to indicate the threshold at which a grazing system is equally profitable as a 120 bu/acre corn system, all else equal. A synthesis of data found in the literature and that found in the Michigan State University stocker cattle/ alfalfa grazing trial is left as future analysis (see Chapter 5).

4.4 Corn Systems

4.4.1 Specifics of the Corn Systems

Budgets were formulated for a continuous corn system. Previous corn crops on grazing experiment land have yielded 110 to 120 bushels/acre (Darling, 1991). Budgets were developed for three expected yield scenarios (80, 100 and 120 bu/acre). Michigan crop budgets (Nott , et al., 1990) and custom hire machinery rates (Schwab and Nogaard, 1988) were used.

Revenue was from the sale of no. 2 corn in Michigan. Annual costs include seeds, nitrogen, phosphorous, potash, limestone, insecticides, herbicides, building and equipment repairs, drying fuel, gasoline, fuel and oil, utilities, trucking and marketing. Custom rates are used to represent capital and labor costs. The specific assumptions associated with these costs are described in Appendix A.

All costs are in 1989 dollars. The price of corn used is a fourteen year average (1976-1989) in 1989 dollars. Table 4.5 shows the price of corn in nominal and 1989 dollars, in Michigan over the 1976 to 1989 period. Figure 4.2 shows the real price of corn in 1989 dollars.

Table 4.5 Real Corn Price: Michigan 1976-1989

Year	Michigan Corn Price	
	Nominal Price	Price in 1989 Dollars
1976	2.04	4.43
1977	1.92	3.92
1978	2.22	4.19
1979	2.48	4.20
1980	3.07	4.58
1981	2.35	3.22
1982	2.48	3.18
1983	3.20	4.00
1984	2.56	3.05
1985	2.14	2.46
1986	1.43	1.63
1987	1.97	2.14
1988	2.52	2.65
1989	2.34	2.34
Average	2.34	3.29
Std	0.44	0.88

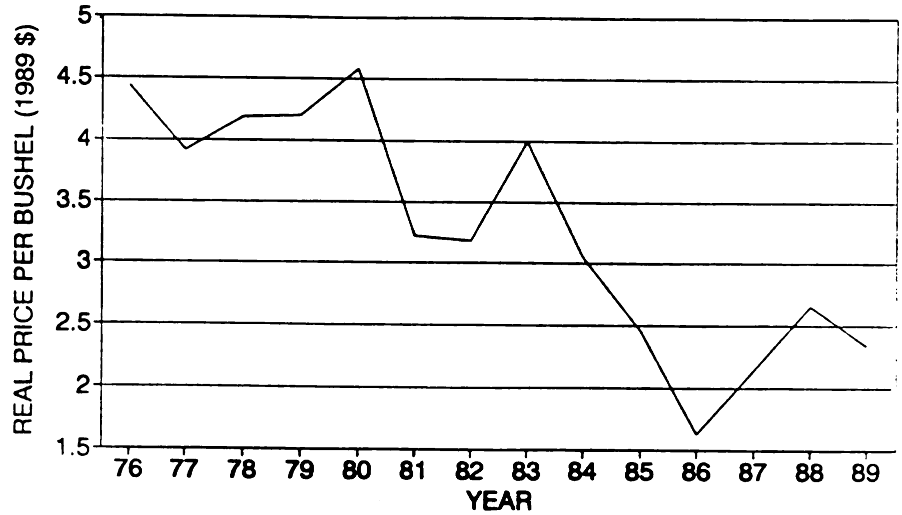

Figure 4.2 Real Corn Price Per Bushel (Michigan)

4.4.2 Corn System Analysis Results

Results of the corn system analysis are presented in Table 4.[6] The first set of corn budgets use a fourteen year average, inflation adjusted Michigan corn price of $3.29/bu. One management level yields 120 bu/acre. The following returns summarize its profitability[7]. The net present value (NPV) of this system (120 bu/acre) is $35,5581 or $890 per acre in 1989

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[6] Input prices and corn yields were treated as variables with fixed values.

[7] Profitability levels are returns to land and unallocated costs.

dollars. The average annual return (AAR) is $5,066 or $127

Table 4.6 AAR for Corn: Average and Standard Deviation ($)

	Expected Corn Yield/Acre[a]					
	80 bu		100 bu		120 bu	
Corn Price ($/bu)	AVG	STD	AVG	STD	AVG	STD
AVG (1976-1989)	35	71	86	84	127	106
Projected (1990)[b]	-24		12		38	

a Weighted average
b Based upon participation in the 1990 USDA Farm Program

per acre in 1989 dollars. The standard deviation (SD)[8] for the net return of the 40 acres over the ten year life of the system is $4,237 or $106 per acre.

Similar calculation were made for 80 bu/acre and 100 bu/acre management levels. The results have potential to be used for break-even and sensitivity analysis of corn yield in future analysis. For the 80 bu/acre yield, the NPV is $9,875 or $247 per acre in 1989 dollars. The AAR is $1,406 or $35 per acre in 1989 dollars. The SD for the 40 acres over the life of the system is $2,824 or $71/acre. For the 100 bu/acre system, the NPV is $24,034 or $601 per acre in 1989 dollars. The AAR is $3,422 or $ 86 per acre in 1989 dollars. The SD, due to price variation, for the 40 acres over the life of the system is $3,531 or $88/acre.

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[8] Since an average annual cost was used, standard deviation reflects only variability in price or gross margin.

The second set of corn budgets use a 1991 break-even corn price for participation in the government program of $2.55 (Hilker, 1991). The NPV for the 120 bu/acre management level is $10,633 or $266 per acre in 1989 dollars. The AAR is $1,514 or $38 per acre in 1989 dollars[9].

Similar calculation were made for 80 bu/acre and 100 bu/acre management levels. The results have potential to be used for break-even and sensitivity analysis of corn yield in future analysis. For the 80 bu/acre yield, the NPV is -$6,757 or -$169 per acre in 1989 dollars. The AAR is -$962 or -$24 per acre in 1989 dollars. For the 100 bu/acre system, the NPV is $3,244 or $81 per acre in 1989 dollars. The AAR is $462 or $12 per acre in 1989 dollars.

4.5 Grazing System Budgets

4.5.1 Specifics of the Grazing Systems

Budgets were developed for both a conventional rotational grazing system (4 paddock system) and an intensively grazed system (13 paddocks).

Budgets were developed for one four paddock system at two head

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[9] Standard deviation measures are not relevant here as no price variability measure was readily available.

per acre[10] and two thirteen paddock systems, one at each of two and four head per acre using an average of the 1989 and 1990 MSU stocker cattle rates of gain as performance measures.

In the budgets, the MSU 1989-90 stocker cattle grazing trials were scaled up to better approximate farm conditions; 40 acre plots were used as a frame of reference. All systems assumed a 117 day grazing period, from May until the last week in August. The August restriction was placed to allow adequate regrowth and replenishment of root reserves prior to the first killing frost. This 117 grazing day restriction is conservative, since it does not provide an allowance for fall grazing. The additional gain/acre realized by late fall grazing may increase beef sold and thus, average annual net returns. A producer may be limited from fall grazing due to inavailability or infeasibility of holding stocker cattle or profitably obtaining a second set of stockers.

Average daily gain is assumed deterministic. Purchase and sale prices of beef are taken as the inflation adjusted average of the Dodge City feeder cattle price series for 1975-1990.

The economic analysis details are presented in the appendices.

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[10] The four paddock system, with a stocking rate of four head per acre, was not included because number of days on pasture for this system was significantly different than days on pasture for the other three systems.

In Appendix A, the assumptions defining the source of costs and revenues for each stocker operation are presented. Revenue includes income from the sale of feeder cattle. Costs include fencing, watering system and associated costs, costs of establishment and maintenance the alfalfa stand, labor, mineral supplement (containing bloat preventative), transportation and interest charge on cattle[11]. The cost of the alfalfa stand establishment includes a machinery and a labor charge, seed, fertilizer and pest control. Stand maintenance includes a fertilizer charge. For simplicity, no charge is assessed for processing cattle, although this may bias the continuous corn versus grazing system analysis in favor of the grazing systems. Death loss is assumed to be two percent.

The analysis assumes 80 or 160 head of cattle for the 40 acre pasture (two or four head per acre) for the low and high systems, respectively.

A ten year planning cycle was used as a common denominator, reflecting the life of the fencing system. Appendix B depicts the cash flow of the three grazing systems using MSU stocker grazing trial gains. The values appearing in the table are

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[11] A land charge representing opportunity cost (often approximated using depreciation, taxes and interest under a wide range of assumptions) is not used, as it does not vary between systems. Therefore, net returns reported are considered a return to land and management.

the respective cash flows by year for each of the systems. They are depicted in the tables in 1989 dollars. A variable interest rate is used to coincide with the historical gross margins[12]. Individuals who are in a tight cash position will have a higher effective interest rate, while others in a very strong cash position may have a lower effective interest rate.

The USDA price series is used for the purchase (an average of April and May Dodge City calves at 400 to 600 lbs) and sale (August Dodge City feeder steers) price. Table 4.7 shows the gross margins for the three grazing systems considered.

Figure 4.3 depicts gross margins (1975 to 1990) for each of the grazing systems. Although attempts have been make to define a cattle cycle, it is difficult to pinpoint a series of years which lie on comparable points (e.g. peak to peak). For the purposes of this analysis, the price series from 1975 to 1990 is assumed to be representative of a cattle cycle.

In other words, it is assumed to accurately represent both the inflation adjusted average and standard deviation of feeder cattle prices, and not be overly influenced by a period of

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[12] Interest rates for the purchase of non breeding livestock were used throughout the analysis (with the exception of the calculation of average annual returns, where 7% was used) (Walraven and Rosine, 1991). The consumer price index was used to represent inflation.

Table 4.7 Gross Margins for Grazing Systems 1975-1990 ($/hd)

Year	Grazing System		
	4L	13L	13H
1975	195	237	111
1976	3	13	-73
1977	84	90	3
1978	198	204	79
1979	99	73	-43
1980	154	141	41
1981	69	88	-19
1982	91	105	8
1983	8	20	-62
1984	75	91	1
1985	32	29	-35
1986	118	123	46
1987	142	122	38
1988	58	56	-27
1989	104	102	18
1990	71	79	13
AVG	93	98	5
STD	55	59	48

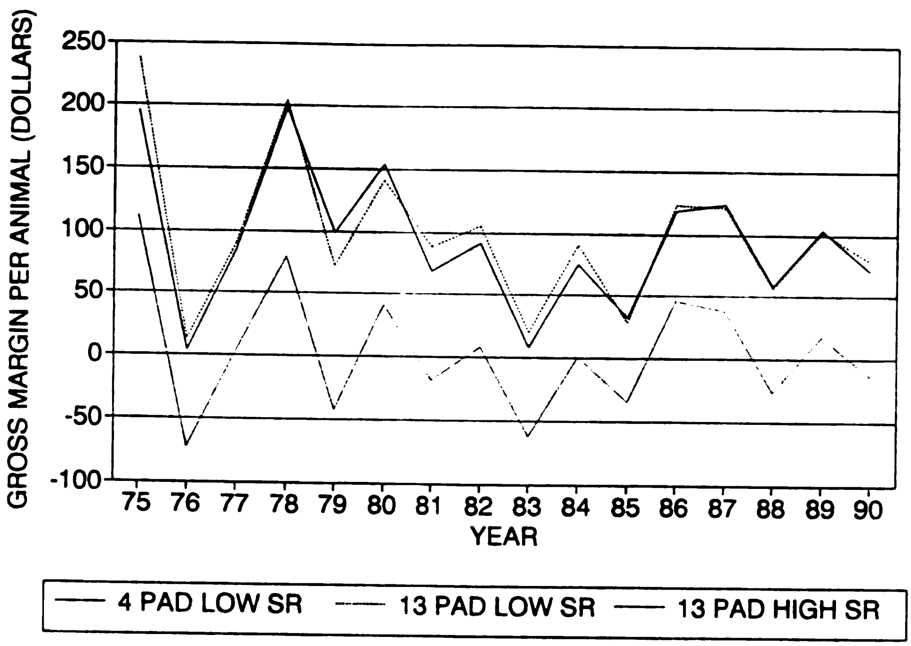

Figure 4.3 Gross Margins of Cattle

unusually low or high prices. The use of one cattle cycle will suffice for the purpose of this thesis, an initial look at the profitability of grazing systems. Relaxing the assumption of a 16 year price horizon and adopting a considerably longer period and performing a closer analysis to more precisely reflect the historic price series are directions for further research.

The alfalfa stand is maintained for five years; the sixth year reflects establishment costs for the second alfalfa stand in the ten year cycle following removal of the animals.

The net cash flows in Appendix B are comparable to net cash flow information you would use in developing a line of credit with a lender. The discounted net cash flows were converted to 1989 dollars using the same techniques lenders use to discount future returns back to the present. Net present value is the sum of the 1989 dollars discounted net cash flows in each year over the 10 year planning period. The net present values were converted into an equivalent average return/year because it is the measure that is most understandable by a wide audience.

4.5.2 Grazing System Analysis Results

Results of the grazing systems analysis is presented in Table 4.8.

Table 4.8 AAR for Grazing: Average and STD ($)

AAR ($/acre)	Grazing System Definitions		
	4L	13L	13H
Average	40	46	-178
Standard Deviation	110	117	194

For the four paddock system, the net present value is $11,332 or $283 per acre in 1989 dollars. The average annual return is $1,613 or $40 per acre in 1989 dollars. The standard deviation for the 40 acres over the life of the system is $4,411 or $110 per acre.

For the low stocking rate, 13 paddock system, the net present value is $12,946 or $324 per acre in 1989 dollars. The average annual return is $1,843 or $46 per acre in 1989 dollars. The standard deviation for the 40 acres over the life of the system is $ 4,684 or $117 per acre.

For the high stocking rate, 13 paddock system, the net present value is -$49,956 or -$1,249 per acre in 1989 dollars. The average annual return is -$7,113 or -$178 per acre in 1989 dollars. The standard deviation for the 40 acres over the life of the system is $7,753 or $194 per acre.

4.5.3 Grazing System Analysis Conclusions

The net returns to land and management were positive for both the four and 13 paddock, low stocking rate grazing systems. There is potential for these numbers to be higher, as average daily gains were lower than expected (and lower than those indicated by both the literature and state stocker cattle producers) given the forage quality and quantity available. The thirteen paddock low stocking rate system yielded a higher net present value ($12,946) than the four paddock, low stocking rate system ($11,332). The thirteen paddock system had both larger revenues, due to a higher average daily gain, and larger costs than the four paddock system. The net present value was negative for the 13 paddock, high stocking rate system, reflecting the low average daily gain.

4.6 Comparison of Land Use Alternatives

The average annual return, average annual return per acre, standard deviation and range lower and upper bounds of AAR are presented in Table 4.9.

Table 4.9 AVG AAR, STD and Range for Corn (historical price)

System Definition				
	Grazing	Corn (Historical Price)		
System	13-L	120 bu Yield	100 bu Yield	80 bu Yield
AAR	1,613	5,066	3,422	1,406
AAR/acre	40	127	86	35
STD	4,684	4,237	3,531	2,824
Range	17,383	14,194	11,828	9,463
Lower Bound	-4,429	-2,926	-3,238	-3,922
Upper Bound	12,954	11,268	8,590	5,541

In this section, the descriptive statistics of each of the three grazing systems and the corn system at each of three levels are used to compare land use alternatives.

Average annual return is over the 10 year time frame in 1989 dollars. The average annual return is highest for the 120 ($5,066) and 100 bu ($3,422) corn systems. The four ($1,843) and 13 paddock ($1,613) grazing systems showed lower, but still positive, average annual return per acre[13]. The corn system producing 80 bu/acre followed closely with an AAR of $1,406.

The 13 paddock, high stocking rate system, had a large and negative average annual return (-$7,113) due largely to poor animal performance in this system.

The net present value per acre allows easy comparison between land use options that may be of different size and reiterates the results represented by the average annual return.

The range of annual returns describes the variation in returns over the ten year time period. The lower bound figure represents the highest loss or lowest gain achieved from a system over a given period. A producer may compare this figure with the amount of loss the operation can expect to sustain in any one given year. Downside risk for the six systems lies between -$19,562 for the 13 paddock, high stocking rate system and -$2,926 for the 120 bu/acre corn system. The continuous corn systems show the smallest downside risk, indicating a strong potential for a risk averse individual to choose that system which offers a comparatively high AAR. The downside risk for each corn system (using MI

[13] The $46 and $40 per acre average annual return that the 13 and four paddock, low stocking rate systems, achieved, respectively, are lower than per acre rent payments on land with this productive capacity.

corn prices) is less than that of the grazing systems due to larger volatility of feeder cattle gross margins over corn price. The downside risk of corn decreases as yield increases[14].

The upper bound represents the highest gain or lowest loss achieved from a system in a given time frame. The upper bound of inflated net revenue ranges from $ 5,541 for the 80 bu/acre corn system to $ 11,268 for the 120 bu/acre corn system. Corn provides a high annual return upper bound over all three yields, although all three grazing systems provide a higher upper bound than either 80 or 100 bu/acre corn.

The standard deviation of the annual net returns to each system help a decision maker assess the risks. The standard deviation ranges from $ 2,824 in the 80 bu/acre corn system to $ 7,753 in the 13 paddock high stocking rate system. Standard deviation for the corn systems increases with the profitability of the system, as the effect of price volatility increases with yield, and is smaller over all yields of corn than for any grazing system. The standard deviation is similar for the 80 bu/acre corn system and the two low stocking rate grazing systems.

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[14] This is not surprising, as in the analysis, all costs other than those associated with revenue from corn or gross margin of cattle (i.e. price series for corn and cattle and interest rates) are common between like systems. For example, only the revenue from corn is variable for the corn systems, with price series variability being the same in all systems.

The use of a current estimated break-even price for corn for participation in the government program of $2.55 versus the 15 year Michigan average price of $3.29 changes the picture. Table 4.10 depicts the average AAR for a 40 acre corn system at break-even corn prices.

Table 4.10 AVG AAR for Corn (Break-even price)

System Definition			
	Corn (Break-even Price)		
System	120 bu Yield	100 bu Yield	80 bu Yield
AAR	1,514	462	-962
AAR/acre	38	12	-24

While a continuous corn system yielding 120 bu and 100 bu again provide positive AAR's, $1,514 and $462, respectively, both are less than those provided by the 13 and 4 paddock low stocking rate systems, $1,843 and $1,613, respectively. A continuous corn system yielding 80 bu/acre selling at $2.55/bu provides a negative AAR ($962). The use of a break-even price does not permit an analysis of price variance.

4.7 Calculation of Break-even Performance

Break-even were calculated to represent the minimum performance required from one enterprise for it to be at an equivalent economic threshold with an alternative enterprise.

The following break-even figures were calculated;

(1) Break-even Price and Break-even Gross Margin
    (a) Break-even price of corn
    (b) Break-even gross margin of cattle
(2) Break-even yields
    (a) Break-even yield of corn
    (b) Break-even gain of beef
        (i) Break-even total gain
        (ii) Break-even average daily gain per animal
        (iii) Break-even stocking rate

4.7.1 Break-even comparison of 13 paddock low stocking rate grazing system to continuous corn

(1) Break-even price/gross margin

(a) Break-even gross margin of beef/acre

Versus 120 bu/acre corn: $277

Versus 100 bu/acre corn: $236

Versus 80 bu/acre corn: $186

The break-even gross margin of cattle describes the gross margin per head at which the grazing system with the highest average annual return (13L) is equivalent to a corn system with fixed prices.

(b) Break-even price of corn

At 120 bu/acre: $2.62/bu

At 100 bu/acre: $2.90/bu

At 80 bu/acre: $3.43/bu

The break-even price of corn describes the price per bushel of corn at which a continuous corn system and the grazing system providing the highest average annual return given a fixed gross margin are equivalent.

(2) Break-even yields

(a) Break-even yield of corn: 95.5 bu/acre

The break-even yield of corn describes the yield per acre of corn at which a continuous corn system and the grazing system providing the highest average annual return given a fixed gross margin are equivalent.

(b) Break-even gain

(i) Break-even total gain:

2.53 cwt/hd or 5.06 cwt/acre[15]

The break-even total gain of cattle describes the total weight gain at which the 13L grazing system and the 120 bu/acre corn system are equivalent holding purchase and sale price and purchase weight fixed.

(ii) Break-even average daily gain: 2.16 lb/day

The break-even average daily gain describes the average daily gain at which the grazing system with the highest average annual return (13L) is equivalent to a corn system with fixed

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[15] When: P_S = 88.28/cwt, P_P = 100.7/cwt and W_P = 500 lb

prices and fixed gross margin.

(iii) Break-even stocking rate:

2.53 hd/acre (101 animals on 40 acres)

The break-even stocking rate describes the stocking rate at which the grazing system with the highest average annual return (13L) is equivalent to a corn system with fixed prices and fixed gross margin.

(c) Break-even purchase price: $93.15/cwt

4.8 Risk Assessment

4.8.1 Cumulative Distribution Analysis

Cumulative distributions were developed to compare the risk associated with each system.

Cattle prices are approximately normally distributed over the fifteen year time frame. Therefore, a sparse data set rule is used to plot cumulative distributions. The procedure is as follows: the yearly inflation adjusted net revenues are listed in ascending order by size. From this, the K_{th} observation is an estimate of the (n/(n+1)) fractile, where N is the number of observations in the set[16].

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[16] See Anderson, et al., 1977

Valuable information can be derived from a visual analysis of Figure 4.4 and Figure 4.5. Figure 4.4 shows the cumulative distribution of the stocker grazing systems. Implications can be drawn assuming the rate of gain approximates that found in the MSU stocker cattle/ alfalfa grazing trial. A Producer faces considerable downside risk in the 13 paddock, high stocking rate system, expecting negative returns (returns to land and other unallocated costs) in each year. Comparatively, the low stocking rate systems offer a higher upside potential, expected a loss in approximately one-third of the years.

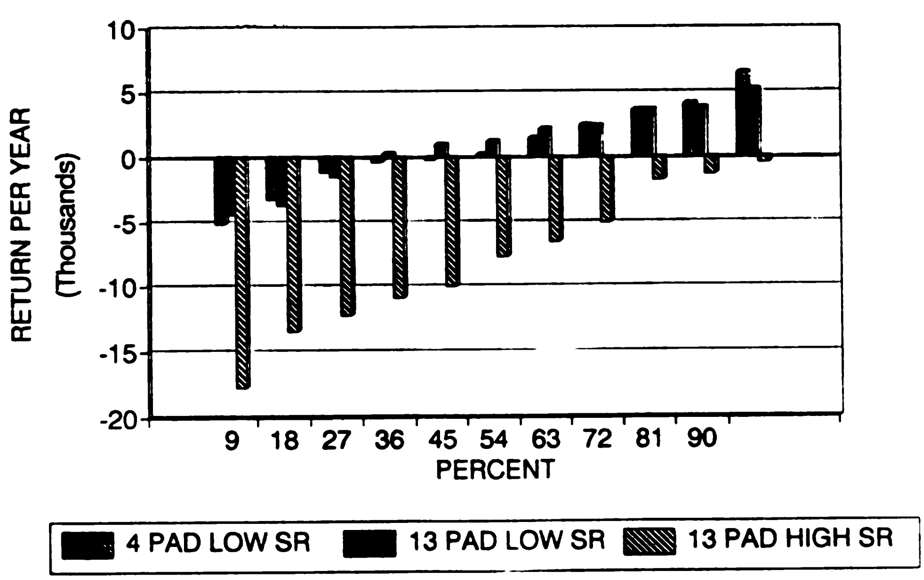

Figure 4.4 Cumulative Distribution of Stocker Cattle Systems

Figure 4.5 shows the cumulative distribution of the corn systems. There is minimal downside risk and large upside potentials for all corn systems[17]. High yield corn clearly offers both the largest expected returns and less downside risk than any of the grazing systems.

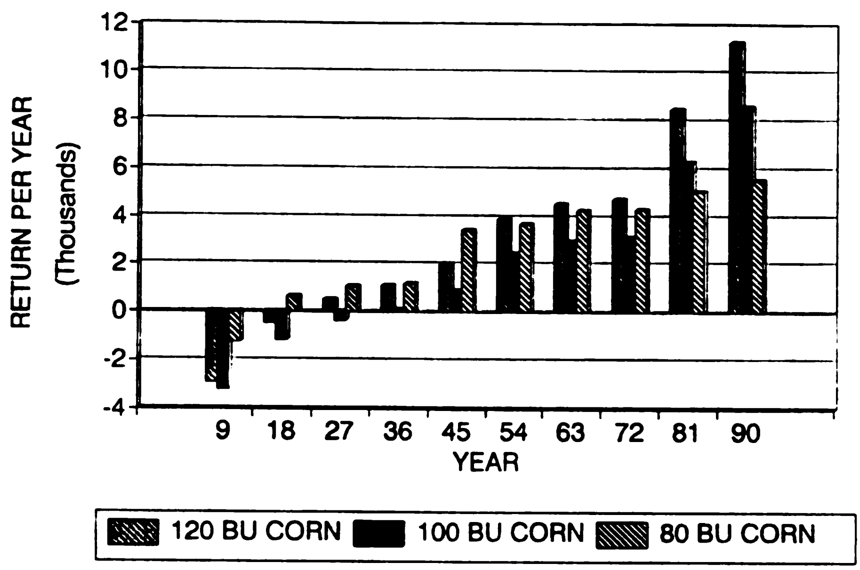

Figure 4.5 Cumulative Distribution of the Corn System

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17 The magnitude of both the up and downside risks for the corn systems are closely related to the yield per acre of the system. As discussed previously, this can be largely attributed to the notion that, in this analysis, yield is known with certainty and price variation is the same between systems.

4.8.2 The Expected Benefit Model

The expected benefit model was used to calculate the expected benefit of a system, incorporating risk preferences. The land use alternatives were then ranked according to expected benefit, where;

$$E(B) = E(ARR) - 1/2CARA(VAR_{ARR})$$

Where:

$E(B)$ = Expected Benefit
$E(ARR)$ = Expected Average Annual Return
$CARA$ = Coefficient of Absolute Risk Aversion
VAR_{ARR} = Variance of Net Revenue by Year

The incorporation of a coefficient of absolute risk aversion resulted in expected benefit reflecting the amount a decision maker would pay (or accept as lower revenue) for decreased risk. The ranking of systems in the expected benefit model for a fairly risk averse individual (CARA = .0001) except the 80 bu/acre corn system, which moves up above all grazing systems, are identical to the ranking of systems by comparing AAR's in Table 4.9. The low corn system was discounted less for risk relative to the grazing systems as price variability was less.

Table 4.11 Expected Benefit

	System					
	4L	13L	13H	120 bu	100 bu	80 bu
AAR	1,613	1,843	- 7,113	5,066	3,422	1,406
E(B)	640	746	-10,119	4,168	2,799	1,007
Rank	5	4	6	1	2	3

Chapter 5: Summary and Conclusions

5.1 Summary

Data from two years of a Michigan State University stocker cattle grazing experiment was used in an economic analysis to assess the economic viability of intensive grazing versus row crop systems on soils capable of averaging 110 to 120 bu corn per acre.

Annual net cash flows were developed and average annual return (ARR) to land and unallocated costs of a 40 acre enterprise were calculated from the annual net cash flows for (1) each of three grazing systems using alfalfa as the prominent pasture species and (2) a corn system at three yield levels using both a USDA Michigan price series and a break-even price for participation in a USDA ARP program.

The 100 and 120 bu/acre corn yields, using the 1976 to 1989 average real price, resulted in the highest net return. AAR for the 13 and four paddock, low stocking rate systems were 37 and 32 percent of the 120 bu/acre corn system, respectively. The AAR for the 80 bu\acre corn was slightly below that of the two low stocking rate grazing systems. Average annual return was positive for all of these systems. The average annual net return for the 13 paddock, high stocking rate system was negative and large.

Using a break-even price for participation in the ARP program ($2.55) as an estimate of current corn prices resulted in positive net return to land and unallocated costs for the 100 and 120 bu/acre yield systems less than that offered by the two low stocking rate grazing systems. The 80 bu/acre corn system had a negative AAR. The objective of using a break-even corn price was to more closely estimate what a producer might see in the 1990's. Therefore, this analysis indicates a growing comparative advantage of stocker systems over continuous corn production on similar land.

Including risk did not substantially change the results of the analysis. A review of cumulative distributions of net returns to land and unallocated costs helped to show the downside risk associated with grazing systems that yield low animal performance. The analysis did not discount the possibility of strong economic potential for grazing systems due to higher gains/acre than those resulting from the MSU trial as indicated in the literature review (e.g. Clark, et al., 1988) that yield greater animal performance to compete with moderate yield corn.

5.2 Implications of the Analysis

In order to operationalize this information, a producer must determine whether, given the resource base, the operation can sustain productivity similar to that found in the MSU stocker grazing trial.

This can be accomplished in two ways. The least risky method, if practical, is to look at the results of grazing systems of other producers in the same area or in an area with similar soils and weather patterns. These results will help indicate the practicality of grazing productive land, as well as provide an indication of the most efficacious grazing system. The second method by which a producer can judge whether grazing systems will be profitable is to implement a simple initial system. The results of the analysis do not exclude the possibility of large losses, resulting from low animal productivity and explicitly state the long run commitment to building a grazing system such as those seen in the 13H system. Therefore, a producer should start with a smaller enterprise.

It is not clear from this analysis that there is any significant advantage to intensive rotational grazing over rotational grazing. Although returns were slightly higher at the low stocking rate in the more intensive system, initial costs, and therefore commitment to the system, are also higher. Flexibility must be maintained; a more or less intensive system can evolve with the results of initial experience.

5.3 Computer Model

This study was done using numbers and variables unique to one or a finite number of situations. While considerations of three of the four grazing treatments have provided considerable insight into the costs and returns to a grazing system, latitude in defining implications to an individual producer could be expanded through the development of a computer model.

This is for two reasons. First, land use alternatives may not fit one of these systems due to resource, capital and management constraints and/or personal preference. For example, a producer may be fixed to a wagon wheel design due to the current fencing in place. Second, the costs and returns, while fixed in this analysis, will vary across time and among operators. Through the use of a computer model, a decision maker can change these assumptions to more closely reflect actual systems, costs and returns or run the model to test various combinations under consideration, using predicted costs and returns.

This economic analysis includes a large number of system specific assumptions in an effort to take an initial look at different management intensities for grazing systems and to compare grazing system returns to those of row crops. While the assumptions given for the analysis are realistic as a case beef operation, there are several decisions a manager must make throughout the planning and implementing phase of the operation that will depend on many unique variables (e.g. labor, management, climate,...). A computer model could assist a producer through explicitly considering specifics of a given operation across several areas;

(1) The relaxation or endogenization of the strict assumptions which consider variables in these areas exogenous. Sensitivity analysis could then be used to determine which of these decision factors is important to the profitability of the operation.

These factors may include decisions on marketing such as the use of price options, forward contracting and time of purchase and sale of cattle. Environmental conditions (i.e. rainfall), market conditions and the type of system implemented (e.g. put and take versus fixed stocking rate) influence the marketing behavior of producers. There are more options in a stocker operation to consider versus a feedlot operation in terms of flexibility of sale date. Date of sale of cattle may be a function of labor or management availability and the cash flow of the operation. Other decisions may include whether to supplement feed, when and if to take conservation cuttings and the application of fertilizers and pesticides.

(2) Development of a broader data base. In this analysis, grazing of an alfalfa pasture was compared to a corn system of three yields at two price levels. While the implications of the research and the analysis are useful across a wide range of situations, a broader data base including various plant species (both row crops and pasture species), crop rotations, management schemes, cattle species and climates would greatly improve the potential for forecasting the viability of a grazing system on any one farm operation. Both research and case studies would be considered for this data base.

(3) More precisely indicating Michigan specific conditions. To get an indication of how the improvement and increased use of grazing can impact Michigan agriculture, conditions throughout Michigan must be more closely studied. For example, the defender system in the upper peninsula will be different than that in the thumb area. In addition, the price series can be improved to better reflect cattle and crop markets in Michigan.

(4) Considering the expansion of this analysis on stocker operations to include the whole farm operation, including vertical integration of the cattle enterprises and/or use of cropping enterprises to supplement the pastures. This is important for producers who share resources across several enterprises.

The model could be as simple as a spreadsheet model or as complex as a full scale simulation model including sensitivity analysis parameters. Another option for the research community is to convert an existing research model to a user friendly model for use by Michigan cattle producers

5.4 Limitations of the Analysis

To gage to extent to which recommendations should be made given the research and analysis performed, it is necessary to consider several limitations: (1) The analysis is based on only two years of experimental data. Although the methods of economic analysis presented will hold for future experiments, several additional years of data are necessary on the biological changes within the pasture. The two years of data offer compelling evidence for performance of the low stocking rate (2 hd/acre) over the high stocking rate (4 hd/acre) in both net return and gain/hd. This two year period does not offer sufficient evidence of a difference between grazing systems (number of paddocks). While it is often adequate to look only at treatment differences when comparing grazing systems, level of profitability becomes the measure when comparing grazing systems with alternative land uses (e.g. continuous corn).

(2) This analysis is based solely on the MSU experimental data. A thorough review and integration of grazing studies performed to date must be considered to provide a synthesis of the available knowledge. This will allow applicability across a larger number of unique farm situations.

(3) Economic data and risk considerations are limited.

5.5 Future Research Objectives

There are several research objectives to overcome these limitations. Future research objectives are aimed toward pasture performance and economic and risk analysis.

5.5.1 Pasture Performance

(1) Continue the grazing trial over several years and include the results and implications of several long term studies to give a clearer picture of the ecological evolution of pastures overtime. It is clearly important in pasture studies to get a notion of the steady state pastures will reach under various conditions (e.g. grazing pressure, grazing system, climate...).

(2) Determine how one approximates a intensive grazing system from an experimental paddock system. Within this study, a 13 paddock system was used to approximate intensive grazing. A clearer picture will evolve on how these results

can apply to situations in which a stricter definition of time control is practiced.

(3) Including harvesting a portion or all of the first cutting as an alternative will add depth and applicability to the analysis.

5.5.2 Economics

(1) The gross margin estimates for cattle are a simple first cut. The use of a 16 year price series from a single source for a limited specification of cattle is not adequate to obtain strong precision on calf or short yearling prices for Michigan producers. The data base on gross margins must be expanded and include basis and transportation costs.

(2) Within this analysis, a single number was used to represent each of the cattle gross margin, corn price and costs over a ten year period. More data is needed to obtain a more precise picture of the cyclic behavior of and correlation between cattle gross margins, corn prices and other agricultural inputs and outputs.

5.5.3 Risk Analysis

(1) Corn was used as the defender crop throughout this analysis. Corn price was the only variable within the corn system for which variability (uncertainty) existed. Yield and government program variability/uncertainty must also be

included to more accurately reflect the uncertainty faced by producers.

(2) For this analysis, gross margin was the only source of variability within the grazing systems. In reality, plant yield, animal performance given plant yield, morbidity, mortality, processing and gross margin risk are present and thus, their inclusion within future analysis is warranted.

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APPENDICES

APPENDIX A

Assumptions of the Analysis

I. System definitions
- A) Grazing systems
  - 1. Days grazing
    - 4 Paddock system (two complete cycles + 21 days) 117 Days
    - 13 Paddock system (three complete cycles) 117 Days
  - 2. 40 Acre grazing system
  - 3. Head of cattle
    - Low stocking rate (two head/acre; 80 head)
    - High stocking rate (four head/acre; 160 head)
- B) Crop production
  - 40 Acres continuous corn

II External information
- A) USDA Dodge City feeder cattle prices (1975 to 1989)
  - 1. Purchased 500 lb steer calves in April
  - 2. Sold yearling feed steers (600 to 800 lb) in September
- B) USDA Michigan average corn price (1975 to 1989) and Break-even corn price for government program participation in 1991.
- C) Real interest rate
  - 1. Nonbreeding livestock interest rate (Agricultural Federal Reserve Bank)
  - 2. Adjusted average of historical data ($r = .07$)
- D) Inflation rate
  - 1. Consumer Price Index

Table A.1 System Investment: 4 Paddock Grazing System

Description	Expenditure	Lifespan (years)
Fencing Expenditures[1]		
Perimeter (5264 ft @ $0.85/ft)	$ 4,474.40	10 years
Interior Subdivision (2640 ft @ $0.15/ft)	$ 396.00	5 years
Polytape	$ 0.00	2 years
Energizer	$ 416.00	10 years
16 ft gate (1 @ $135/gate)	$ 135.00	10 years
Watering System Expenditures[2]		
150 gallon steel tank (1 @ $106.65/tank)	$ 106.50	10 years
Complete float set (1 @ $11/set)	$ 11.00	2 years
3/4" plastic hose (100 ft @ $0.30/ft)	$ 30.00	10 years
Hose installation (100 ft @ $5/ft)	$ 500.00	10 years
Electricity (117 days @ 1 hr/day @ $0.05/hr)	$ 5.85	1 year
Labor (30 minutes/day for 117 days + 15 minutes/day for 9 days @ $7.50/hr)	$ 455.63	1 year
Alfalfa Establishment		
Complete Establishment (40 acres @ $145/acre)	$ 5,800.00	5 years
Fertilizer (in nonestablishment years) (40 acres @ $46/acre)	$ 1,840.00	1 year
Bloat Guard ((80 hd - 1/2death loss[3]) @ (5/16)lb/day for 117 days @ $10.44/33lb	$ 916.11	1 year
Transportation Expenditure (80 hd * 5 cwt @ $2/cwt)	$ 800.00	1 year

[1] Fencing installation labor expenditure included.

[2] Maintenance and repair costs not included.

[3] The use of the term '1/2 death loss' represents the assumption that, on average, death loss occurs in midseason.

Table A.2 System Investment: 13 Paddock Grazing Systems

Description	Expenditure	Lifespan (years)
Fencing Expenditures		
Perimeter (5248 ft @ $0.85/ft)	$ 4,460.80	10 years
Interior Subdivision (5644 ft @ $0.15/ft)	$ 846.60	5 years
Polytape (2675 ft @ $0.03/ft)	$ 80.25	2 years
Energizer	$ 416.00	10 years
16 ft gate (2 @ $135/gate)	$ 270.00	10 years
Watering System Expenditures[4]		
150 gallon steel tank (1 @ $106.65/tank)	$ 106.50	10 years
Complete float set (1 @ $11/set)	$ 11.00	2 years
3/4" plastic hose (100 ft @ $0.30/ft)	$ 30.00	10 years
Hose installation (100 ft @ $5/ft)	$ 500.00	10 years
Electricity (117 days @ 1 hr/day @ $0.05/hr)	$ 5.85	1 year
Labor (30 minutes/day for 117 days + 15 minutes/day for 39 days @ $7.50/hr)	$ 511.88	1 year
Alfalfa Establishment		
Complete Establishment (40 acres @ $145/acre)	$ 5,800.00	5 years
Fertilizer (40 acres @ $46/acre)	$ 1,840.00	1 year
Bloat Guard[5] ((80 hd - 1/2death loss) @ (5/16) lb/day for 117 days @ $10.44/33lb	$ 916.11	1 year
Bloat Guard[6] ((160 hd-1/2death loss) @ (5/16) lb/day for 117 days @ $10.44/33lb	$ 1,832.22	1 year
Transportation Expenditure[7] (80 * 5 cwt @ $2/cwt)	$ 800.00	1 year
Transportation Expenditure[8] (80 * 5 cwt @ $2/cwt)	$ 1,600.00	1 year

[4] Maintenance and repair costs not included.

[5] Low stocking rate system

[6] High stocking rate system

[7] Low stocking rate system

[8] High stocking rate system

Table A.3 System Investment: 80 bu/acre Corn Yield

Cash Expenditures	Expenditures
Seeds and plants (22.0 K ker @ $0.90/lb)/acre	$ 792.00
Nitrogen Anhydrous (90.0 lb @ $0.12/lb)/acre	$ 432.00
Phosphate p205	$ 0.00
Potash k20 (70.0 lb/acre @ $0.11/lb)/acre	$ 308.00
Limestone[9] ($12.00/acre)	$ 480.00
Insecticides[10] ($15.00/acre)	$ 600.00
Weed sprays ($15.75/acre)	$ 630.00
Building repairs ($2.50/acre)	$ 100.00
Equipment ($18.00/acre)	$ 720.00
Irrigation labor and fuel	$ 0.00
Drying fuel ($24.00/acre or 960pt @ $0.0225/pt)	$ 960.00
Gas, fuel and oil ($9.80/acre)	$ 392.00
Utilities, phone ($2.00/acre)	$ 80.00
Trucking, freight ($16.00/acre)	$ 640.00
Marketing (0.80/acre)	$ 32.00
Capital costs (custom rates with labor)	
Spread potash (3.60/acre)	$ 156.96
Moldboard plow ($12.00/acre)	$ 523.20
Fitting with field cultivator ($6.20/acre)	$ 270.32
Planting with fertilizer attachment ($10.40/acre)	$ 453.44
Anhydrous ($6.40/acre)	$ 279.04
Spraying (3.90/acre)	$ 170.04
Cultivation ($4.60/acre)	$ 200.56
Harvest (20.70/acre)	$ 902.52

[9] Adjusted from $7.50/acre to reflect a continuous corn system

[10] Adjusted from $3.00/acre to reflect a continuous corn system

Table A.4 System Investment: 100 bu/acre Corn Yield

Cash Expenditures	Expenditure
Seeds and plants (22.0 K ker $0.90/lb)/acre	$ 792.00
Nitrogen Anhydrous (110.0 lb @ $0.12/lb)/acre	$ 528.00
Phosphate p205	$ 0.00
Potash k20 (90.0 lb @ $0.11/lb)/acre	$ 396.00
Limestone ($12.00/acre)	$ 480.00
Insecticides ($15.00/acre)	$ 600.00
Weed sprays ($15.75/acre)	$ 630.00
Building repairs ($2.50/acre)	$ 100.00
Equipment ($18.00/acre)	$ 720.00
Irrigation labor and fuel	$ 0.00
Drying fuel (1200 pt @ $0.025 or $30/acre)	$1,200.00
Gas, fuel and oil ($9.90/acre)	$ 396.00
Utilities, phone ($2.50/acre)	$ 100.00
Trucking, freight ($20.00/acre)	$ 800.00
Marketing ($1.00/acre)	$ 40.00
Capital costs[11] (custom rates with labor)	
Spread potash	$ 156.96
Moldboard plow	$ 523.20
Fitting with field cultivator	$ 270.32
Planting with fertilizer attachment	$ 453.44
Anhydrous	$ 279.04
Spraying	$ 170.04
Cultivation	$ 200.56
Harvest	$ 902.52

[11] Capital Costs are identical for all three corn systems

Table A.5 System Investment: 120 bu/acre Corn Yield

Cash Expenditures	Expenditures
Seeds and plants ((25.0 K ker @ $0.90/lb)/acre	$ 900.00
Nitrogen Anhydrous ((140.0 lb @ $0.12/lb)/acre	$ 672.00
Phosphate p205 (30 lb @ $0.18/lb)/acre	$ 216.00
Potash k20 (110.0 lb @ $0.11/lb)/acre	$ 484.00
Limestone ($12.00/acre)	$ 480.00
Insecticides ($15.00/acre)	$ 600.00
Weed sprays ($15.75/acre)	$ 630.00
Building repairs ($2.50/acre)	$ 100.00
Equipment ($18.00/acre)	$ 720.00
Irrigation labor and fuel	$ 0.00
Drying fuel (1440 pt @ 0.025/pt)/acre; $36/acre	$1,440.00
Gas, fuel and oil ($10.00/acre)	$ 400.00
Utilities, phone ($3.00/acre)	$ 120.00
Trucking, freight ($24.000/acre)	$ 960.00
Marketing ($1.20/acre)	$ 48.00
Capital costs (custom rates with labor)	
Spread potash	$ 156.96
Moldboard plow	$ 523.20
Fitting with field cultivator	$ 270.32
Planting with fertilizer attachment	$ 453.44
Anhydrous	$ 279.04
Spraying	$ 170.04
Cultivation	$ 200.56
Harvest	$ 902.52

APPENDIX B

Grazing System Net Cash Flows

Table B.1 System Net Cash Flows (4L)

	YEAR 1	YEAR2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
** Thirteen Paddock System **										
LOW STOCKING RATE (2 HD/ACRE)										
Fencing										
High Tensile Perimeter Fence	4460.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Subdivisional Fence	846.60	0.00	0.00	0.00	0.00	846.60	0.00	0.00	0.00	0.00
Polytape	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00
Energizer	416.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sixteen ft. Gates	270.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total fencing cost	6073.65	0.00	80.25	0.00	80.25	846.60	80.25	0.00	80.25	0.00
Alfalfa Stand										
Complete Seeding Cost	5800.00	0.00	0.00	0.00	0.00	5800.00	0.00	0.00	0.00	0.00
Top dress (maintenance) cost	0.00	1840.00	1840.00	1840.00	1840.00	0.00	1840.00	1840.00	1840.00	1840.00
Total alfalfa cost	5800.00	1840.00	1840.00	1840.00	1840.00	5800.00	1840.00	1840.00	1840.00	1840.00
Watering Equipment										
One 150-180 gallon steel tank	106.50	0.00	0.00	0.00	0.00	106.50	0.00	0.00	0.00	0.00
Complete Float Set	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00
Total watering costs	117.50	0.00	11.00	0.00	11.00	106.50	11.00	0.00	11.00	0.00
Electricity to pump	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85
Cost of hose	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost of hose installation	500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost of Watering System	770.85	5.85	27.85	5.85	27.85	218.85	27.85	5.85	27.85	5.85
Labor Cost	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88
Bloat Guard Block 2 hd acre	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11
Transportation Expenditure	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
AVERAGE GROSS MARGIN OF CA	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38
Net Cash flow for year										
Net Revenue by Year	-7003.11	3795.55	3693.30	3795.55	3693.30	-1224.06	3693.30	3795.55	3693.30	3795.55
Net Revenue by Year (discounted)	-6544.96	3315.18	3014.83	2895.60	2633.27	-815.64	2300.00	2209.04	2008.91	1929.46
Non-cattle Cost Flow	14672.49	4073.84	4176.09	4073.84	4176.09	9093.44	4176.09	4073.84	4176.09	4073.84
Non Cash Flow (discounted)	13899.52	3558.25	3408.93	3107.91	2977.49	6059.34	2600.66	2371.01	2271.51	2070.93
Net Present Cost	42325.54									
Average Annual Cost	6026.21									
Net Present Value	Forty acres	Per acre								
Eighty Head	12915.69	323.64								
Average Annual Return	Forty acres	per acre								
Eighty Head	1843.17	46.08								

Table B.2 System Net Cash Flows (13L)

	YEAR 1	YEAR2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
** Thirteen Paddock System **										
LOW STOCKING RATE (2 HD/ACRE)										
Fencing										
High Tensile Perimeter Fence	4460.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Subdivisional Fence	846.60	0.00	0.00	0.00	0.00	846.60	0.00	0.00	0.00	0.00
Polytape	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00
Energizer	416.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sixteen ft. Gates	270.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total fencing cost	6073.65	0.00	80.25	0.00	80.25	846.60	80.25	0.00	80.25	0.00
Alfalfa Stand										
Complete Seeding Cost	5800.00	0.00	0.00	0.00	0.00	5800.00	0.00	0.00	0.00	0.00
Top dress (maintenance) cost	0.00	1840.00	1840.00	1840.00	1840.00	0.00	1840.00	1840.00	1840.00	1840.00
Total alfalfa cost	5800.00	1840.00	1840.00	1840.00	1840.00	5800.00	1840.00	1840.00	1840.00	1840.00
Watering Equipment										
One 150-180 gallon steel tank	106.50	0.00	0.00	0.00	0.00	106.50	0.00	0.00	0.00	0.00
Complete Float Set	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00
Total watering costs	117.50	0.00	11.00	0.00	11.00	106.50	11.00	0.00	11.00	0.00
Electricity to pump	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85
Cost of hose	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost of hose installation	500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost of Watering System	770.85	5.85	27.85	5.85	27.85	218.85	27.85	5.85	27.85	5.85
Labor Cost	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88	511.88
Bloat Guard Block 2 hd acre	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11	916.11
Transportation Expenditure	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
AVERAGE GROSS MARGIN OF CA	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38	7869.38
Net Cash flow for year										
Net Revenue by Year	-7003.11	3795.55	3693.30	3795.55	3693.30	-1224.06	3693.30	3795.55	3693.30	3795.55
Net Revenue by Year (discounted)	-6544.96	3315.18	3014.83	2895.60	2633.27	-815.64	2300.00	2209.04	2008.91	1929.46
Non-cattle Cost Flow	14872.49	4073.84	4176.09	4073.84	4176.09	9093.44	4176.09	4073.84	4176.09	4073.84
Non Cash Flow (discounted)	13899.52	3558.25	3408.93	3107.91	2977.49	6059.34	2600.66	2371.01	2271.51	2070.93
Net Present Cost	42325.54									
Average Annual Cost	6026.21									
Net Present Value	Forty acres	Per acre								
Eighty Head	12945.69	323.64								
Average Annual Return	Forty acres	per acre								
Eighty Head	1843.17	46.08								

Table B.3 System Net Cash Flows (13H)

	YEAR 1	YEAR2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
** Thirteen Paddock System **										
HIGH STOCKING RATE (4 HD/ACRE)										
Fencing										
High Tensile Perimeter Fence	4460.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Subdivisional Fence	846.60	0.00	0.00	0.00	0.00	846.60	0.00	0.00	0.00	0.00
Polytape	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00	80.25	0.00
Energizer	85.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sixteen ft. Gates	270.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total fencing cost	5742.65	0.00	80.25	0.00	80.25	846.60	80.25	0.00	80.25	0.00
Alfalfa Stand										
Complete Seeding Cost	5800.00	0.00	0.00	0.00	0.00	5800.00	0.00	0.00	0.00	0.00
Top dress (maintenance) cost	0.00	1840.00	1840.00	1840.00	1840.00	0.00	1840.00	1840.00	1840.00	1840.00
Total alfalfa cost	5800.00	1840.00	1840.00	1840.00	1840.00	5800.00	1840.00	1840.00	1840.00	1840.00
Watering Equipment										
One 150-180 gallon steel tank	106.50	0.00	0.00	0.00	0.00	106.50	0.00	0.00	0.00	0.00
Complete Float Set	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00	11.00	0.00
Total watering costs	117.50	0.00	11.00	0.00	11.00	106.50	11.00	0.00	11.00	0.00
Electricity to pump	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.85
Cost of hose	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost of hose installation	500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost of Watering System	770.85	5.85	27.85	5.85	27.85	218.85	27.85	5.85	27.85	5.85
Labor Cost	511.88	682.50	682.50	682.50	682.50	682.50	682.50	682.50	682.50	682.50
Bloat Guard Block 2 hd acre	1832.22	1832.22	1832.22	1832.22	1832.22	1832.22	1832.22	1832.22	1832.22	1832.22
Transportation Expenditure	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00	1600.00
AVERAGE GROSS MARGIN OF CA	733.56	733.56	733.56	733.56	733.56	733.56	733.56	733.56	733.56	733.56
Net Cash flow for year										
Net Revenue by Year	-15524.01	-5227.01	-5329.26	-5227.01	-5329.26	-10246.61	-5329.26	-5227.01	-5329.26	-5227.01
Net Revenue by Year (discounted)	-14508.44	-4565.47	-4350.26	-3957.66	-3799.69	-6827.75	-3318.80	-3042.17	-2595.76	-2657.15
Non-cattle Cost Flow	16257.60	5960.57	6062.82	5960.57	6062.82	10980.17	6062.82	5960.57	6062.82	5960.57
Non Cash Flow (discounted)	15194.01	5206.19	4949.07	4547.29	4322.71	7316.55	3775.62	3469.11	3297.77	3030.07
Net Present Cost	55108.37									
Average Annual Cost	7846.19									

Net Present Value	Forty acres	Per Acre
One Hundred Sixty Head	-49956.15	-1248.90

Average Annual Return	Forty acres	per acre
One Hundred Sixty Head	-7112.63	-177.82