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Properly functioning riparian systems are vital to the health of watersheds and provide an important forage and habitat resource for livestock and wildlife. Riparian grazing management strategies that are economically feasible and achieve environmental goals are needed by resource managers and livestock producers. The objective of this thesis was to examine the economic impacts of providing off-stream water and salt in pastures to influence cattle distribution between riparian and upland areas. A field test of the project was conducted at Oregon State University's Hall Ranch in Union, Oregon during mid July through August of 1996 and 1997. A bioeconomic nonlinear programming model using collected data was constructed to test the economic feasibility of the project for a 300 cow-calf operation in northeastern Oregon over sixty years. Nine states of nature were created from historical data to account for the uncertainty of precipitation and cattle market prices. When an environmental management objective of restricting riparian vegetation utilization to thirty-five percent was strictly enforced, permitted animal unit months from summer pastures on public lands were reduced from traditional levels. This reduction resulted in a long run equilibrium herd size that was ten percent lower than current levels. However, when the dispersion project was employed,

cattle were distributed more evenly across pastures and consumed more upland forage before desired riparian levels were reached. Consumption of more upland forage allowed the long run equilibrium herd size to remain at traditional numbers. This result combined with improved animal performance yielded positive net returns for the project. The off-stream water and salt dispersion project has an annual expected net return of \$4,517, \$7,358 and \$11,054 at low, median and high cattle prices, respectively, for a 300 cow operation in northeast Oregon.

The Economic Feasibility of Off-Stream Water and Salt to Reduce Grazing Pressure in Riparian Areas

by

Amy M. Stillings

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Major Professor, representing Agricultural and Resource Economics

Redacted for Privacy

Chair of Department of Agricultural and Resource Economics

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Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Amy M. Stillings, Author

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A.M.S.

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Chapter 1: Introduction

Problem Statement

Oregon and Idaho contain approximately 44 million acres of rangeland with riparian areas comprising only one to three percent of the total area (Chaney et al., 1990). These green ribbons of land bordering streams and lakes are unique ecosystems, able to support a highly diverse species composition of both plants and animals. Streamside vegetation stabilizes the streambanks, slows spring run-off, filters sediments and provides shading that decreases temperature fluctuations in the stream. In a study conducted in the Blue Mountains of eastern Oregon, eighty percent of wildlife species were dependent upon these areas (Padgett, 1982).

Riparian areas are also an important source of forage for livestock production. In the Pacific Northwest, riparian meadows cover about one to two percent of the summer livestock range but can potentially provide up to twenty percent of the summer range forage (Kauffman, 1982). In one study located in the Blue Mountains of eastern Oregon, Roath and Krueger (1982) found that eighty percent of total forage consumed by cattle came from riparian areas in mountainous terrain.

Although riparian vegetation is a valuable resource in livestock grazing, traditional ranch management, until recently, generally has not taken into account the special needs of riparian zones (Platts, 1984). Sixty percent of public and private rangelands were found to be in fair and poor ecological condition, with riparian areas comprising the majority of the damaged areas (GAO, 1988; Flather and Hoeksta, 1989). Alternative grazing strategies that are economically feasible and achieve environmental goals are needed by resource managers and livestock producers. Information in this area is limited, usually focusing on ecology but neglecting the economic impacts.

The Hall Ranch Study

An interdisciplinary study was conducted at the Eastern Oregon Agricultural Research Center in Union, Oregon at the Hall Ranch location during the summers of 1996 and 1997. The objective of the study was to determine the environmental and economic impacts of providing trace mineralized salt and an alternative water source upslope for grazing cow-calf pairs during a forty-two day summer grazing period in pastures with anadromous fish rearing habitat. The four focus areas of this study were: (1) animal behavior and performance, (2) riparian area assessment, (3) biodiversity estimated by insect community and (4) economic feasibility. This thesis represents the economic feasibility analysis.

Thesis Objectives

This combination of economic analysis with ecological and animal production studies will provide information to livestock producers and land managers on the feasibility of using upslope water and salt as a cattle dispersion method. In addition to the economic assessment, this thesis also examines related issues such as riparian utilization standards. There are three specific objectives of this thesis:

(1) To determine the economic impact of providing off-stream water and salt on a 300 cow-calf operation,

(2) To test the sensitivity of model results to the discount rate and planning horizon length and

(3) To determine the economic impact of differing riparian regulation scenarios on a 300 cow-calf operation.

Procedure

A bioeconomic, multiperiod, nonlinear programming model was designed to simulate a typical 300 cow-calf ranch in northeastern Oregon. The decisions determined within the model are the type of forage fed to the cattle and the culling rates of the animal classes that determine the herd size. Chapter 5 of this thesis details the outline of the program model and the assumptions made in its creation. The specific objectives are achieved through changing parameters within the model and interpreting the results within the context of the assumptions.

Overview of Thesis Chapters

This thesis consists of seven chapters. The second chapter is the conceptual framework for the thesis. It outlines the ecological and economic theory that act as the foundation for this research. The next chapter contains the literature review of similar studies in preparation for this research. The fourth chapter is an outline of the procedures followed in the Hall Ranch cattle dispersion study. The next chapter is a detailed description of how the bioeconomic model was designed. The author's goal for this chapter is to eliminate the "black box" syndrome that is often associated with complex computer models. The chapter following the model description contains the results and discussion of scenarios run on the bioeconomic model. The last chapter reviews the conclusions of the thesis and what impact this project could have on range management policy.

Chapter 2: Conceptual Framework

Ecological Principles

Humans are part of the ecosystem and often depend upon livestock grazing to function as "energy brokers." Cattle and other ruminants have a digestive system that allows for the conversion of cellulose, or the fiber in plants, into a form that humans can digest. The fundamental ecological dilemma in grazing management is how to both optimize the capture and conversion of solar energy by plants and the efficient harvest of these plants by herbivores (Briske and Heitschmidt, 1991). Grazing animals remove a portion of the plant's leaves, reducing the amount of solar radiation that can be captured and influencing the rate of senescence (Johnson and Parsons, 1985). Thus, overgrazing causes loss in the capability of primary production (photosynthesis). On the other hand, undergrazing prevents reaching the full potential of livestock production that could have been realized with a sustainable harvest. By leaving excess plant biomass in the field, the energy that could have been converted into meat production is left to dissipate through decomposition. Bryant (1985) also found that future production of grasses and forbs decreased when left ungrazed in riparian pastures.

In economic terminology, range forage has both flow and stock natural resource properties (Stevens and Godfrey, 1972). The renewable, or flow portion, is the annual forage production, which if harvested at a sustainable level does not diminish future production. However, if the forage is being consumed faster than it can regenerate, the stock is reduced. Thus, the resource stock can be "mined" like an exhaustible resource

(Pearce and Turner, 1991). Evidence of mining, or overgrazing, of rangelands is apparent from historical documentation where pastures of high quality forage have been transformed into less desirable species composition (Fleischner, 1994).

How do land managers avoid exhausting their forage resources? Being knowledgeable about the growth curve of the renewable resource is an important step. Forage has a yearly growth curve illustrated in Figure 2.1. The horizontal axis shows forage biomass stock and the vertical axis is the rate of growth of the stock. X^{min} represents the threshold level of stock that is necessary to support a viable population. At low levels of stock, the forage rapidly grows until the plants begin competing for sunlight, water and other necessities. When competition begins, the rate of growth decreases until it reaches the carrying capacity of the system at X^{max}. Maximum sustainable yield (MSY) occurs at the point where the rate of forage growth reaches

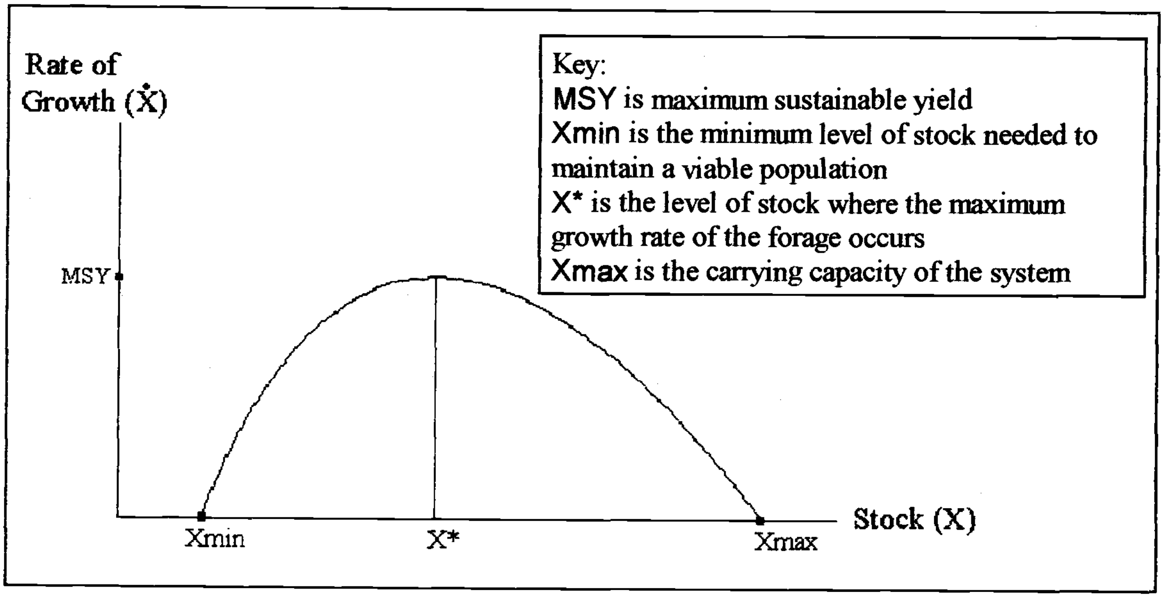

Figure 2.1. Rate of vegetation growth at different stock levels (Abedin, 1995; Pearce and Turner, 1991).

its maximum rate, X*. When MSY is harvested every year, the stock can regenerate itself in the next year to the same levels, if growth conditions remain constant. If forage harvests are larger than MSY, then the stock is reduced in the long run. Harvests that cause the threshold level, X^{min}, to be surpassed, will cause changes in the plant community. This change will be in the form of a lower ecological state, such as poor quality forage or bare ground (Westoby et al., 1989). Removal of livestock after this transition occurs has little effect on improving range condition. A transition back to a higher state may require a large energy input such as the reseeding of pastures, increased management intensity or other range investments (Laycock, 1991).

Economic Theory

The biological optimum harvesting rate, MSY, may not be the economic optimal harvesting rate (Wilson and Macleod, 1991; Pearce and Turner, 1991). It is not until monetary values are placed on the inputs and outputs of the physical model that economically optimal harvesting levels can be derived.

This thesis assumes that the ranch manager's objective is to maximize the present value of total gross margins. Gross margin is defined as revenue minus variable costs[1]. Profit can be calculated from gross margin by subtracting fixed costs. Gross margin is chosen since fixed costs (with the exception of the investment in providing off-stream water and salt to cattle which is called the dispersion project) remain constant. Other

[1] For the purposes of the bioeconomic model described later, gross margin will be used to represent revenue minus variable cost minus the fixed costs of the off-stream water project. All other fixed costs are ignored.

possible ranch objectives include minimizing environmental impacts, increasing herd size, minimizing fluctuations in income or maintaining a way of life. Another assumption of the model is that the ranch is operating in a perfectly competitive market. The conditions for perfect competition are: (1) firms produce a homogenous product, (2) both firms and consumers are numerous and do not affect sale prices (firms are price takers for inputs and outputs), (3) in the long run, entry and exit into the market is free and (4) there is perfect information for both firms and buyers (Henderson and Quandt, 1980). The fourth condition of perfect information means there is complete knowledge of future prices. This assumption is often not true in economic systems.

Rangeland productivity is dependent upon a number of controllable and uncontrollable factors (Pickford and Reid, 1948). A number of studies have indicated the most critical factor in determining annual production in rangeland ecosystems is precipitation (Sneva and Hyder, 1962a; Hanson et al., 1983). Precipitation is highly variable, both within and between years. Highly variable range forage production, unstable market prices, national and international trade and monetary policies and other factors result in risk for the ranching operation (Rodriguez and Taylor, 1988; Standiford and Howitt, 1992).

The firm's production decisions are based upon its production function. Equation 2.1 describes the production function of a range enterprise (Trapp and Walker, 1986).

$$Y = f(x_1 \ldots x_k, x_{k+1} \ldots x_n, z_1 \ldots z_n) \tag{2.1}$$

where: Y represents output

$x_1 \ldots x_k$ represent controllable (decision) variables

$x_{k+1} \ldots x_n$ represent predetermined variables for the planning period

$z_1 \ldots z_n$ represents uncontrollable variables

The production function illustrates the relationship between all the possible combinations of inputs and the resulting output.

In the short run, production occurs if gross margin is positive. However, in the long run, ranch managers must maintain positive net return (profit) to insure the survival of the ranch operation. Ranch profits (equation 2.2) can be expressed by total revenue minus total costs[2].

$$\Pi = \sum_{j=1}^{n} p_j y_j - \sum_{i=1}^{n} c_i x_i \qquad y_j, x_i > 0 \tag{2.2}$$

subject to: $g(x_i) = b_i$

where: Π represents profit

p_j represents a matrix of price coefficients of the outputs, $y_j \ \forall\, j$

y_j represents a matrix of output quantities $\forall\, j$

c_i represents a matrix of cost coefficients of inputs, $x_i \ \forall\, i$

x_i represents the quantities of inputs $\forall\, i$

b_i represents the resource constraint matrix for $x_i \ \forall\, I$

One solution method for constrained optimization problems is the Lagrangian multiplier method (Chiang, 1984). Equation 2.3 is the constrained profit equation transformed into the Lagrangian function.

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[2] This thesis used an objective function which maximized total gross margin since changes in gross margin or profit were equivalent when fixed costs were held constant.

$$\mathcal{L} = \sum_{j=1}^{n} p_j y_j - \sum_{i=1}^{n} c_i x_i + \lambda\, g(\, b_i - x_i\,) \qquad y_j, x_i > 0 \tag{2.3}$$

where : $\mathcal{L}$ represents constrained Π

λ represents the Lagrangian multiplier

The first order conditions necessary for a maximum are found by taking the partial derivatives of equation 2.3 with respect to y_j, x_i and λ $\forall$ i, j and setting them equal to zero. At the solved points, the slope of the function is equal to zero and represents where marginal cost is equal to marginal revenue. A second derivative of these partials will confirm if the calculated input and output ratios produce a maximum or a minimum point. If the second order conditions hold, this point designates the profit maximizing solution set. The Lagrangian multiplier, λ, represents the unit change in the objective function if the constraint value is changed by one unit. In a ranching example, the λ assigned to the initial herd size would be equal to the value in terms of increased profit, of adding an additional cow to the herd in the first year.

<u>Mathematical Programming</u>

The classical optimization technique utilizing calculus, as demonstrated above, cannot handle constraints that are inequalities. Mathematical programming was developed in the 1940's to find optimal solutions for these types of constrained problems. The necessary and sufficient first order conditions for an optimum point are called the Kuhn-Tucker conditions (Henderson and Quandt, 1980). The Lagrangian multipliers for the inequalities have the same interpretation as they do for equality constraints.

The most restrictive form of mathematical programming is linear programming. These types of problems contain a linear objective function, linear constraints and decision variables that are continuous and static. Nonlinear programming allows for a model where the objective function and/or constraints are nonlinear.

Bioeconomics

One method for combining economic theory and ecology is through the development of bioeconomic models. These mathematical representations describe ecological functions and estimate the effects of managerial decisions on those processes. The common characteristics of bioeconomic models include the dynamic relationship between exogenous environmental conditions and management inputs, limitations caused by resource constraints and a calculation of the economic costs and benefits (King et al., 1993).

One of the challenges in bioeconomic model development is simplifying a complex ecosystem into a mathematical representation. Due to the nature of ecological processes, bioeconomic equations need to be modeled over a time period long enough to account for biological time lags and allow for uncertainty. A method for accomplishing this task would be through the use of multiperiod nonlinear programming. This type of programming can be viewed as a multi-stage decision making process. It finds the optimal decision pathway from initial resources to a terminal state, given constraints on resources. In the thesis ranch example, the model solves for three market decisions. The number of cows, yearling heifers and heifer calves to retain. Each of these decisions has two consequences. The first effect is on the returns for the decision year. The number of animals sold has a direct correlation to the amount of revenue received. The other outcome will be the effect on the resource base of the ranch. For example, the size of the herd left to be wintered will determine the number of calves born in the next decision year. This type of transformation is captured in the equations of motion. These equations are the mathematical representations of the biological time lags. In addition to equations of motion, there are four other elements to a multiperiod model: (1) the initial conditions, (2) the terminal value, (3) the planning horizon and (4) the discount rate (Hazell and Norton, 1986; Chiang, 1992).

Initial Conditions, Planning Horizon and Terminal Value

To define the resources in year one, it is necessary to specify the initial state from which the decision making process starts. The model begins in disequilibrium but will eventually reach a long run equilibrium where the same decisions are made yearly if the planning horizon is sufficiently long to allow for any lagged effects (Kennedy, 1986). The time period of this model is sixty years. Although the ranch may be in operation beyond sixty years, present value calculations of gross margin beyond sixty years essentially become zero due to discounting. This point will be illustrated when discussing the discount rates used in the present value calculations.

Including a terminal value in the objective function acts as a linkage between planning periods. In other words, the model is designed so that it does not liquidate the herd before reaching the 60th year. The terminal state can either be fixed or free

(Chiang, 1992). In this thesis, the problem is set up with a fixed time horizon, allowing for a flexible terminal state at the end of the planning horizon. This means that there are no constraints on ending resources that need to be met such as a minimum herd size.

Discount Rate

A dollar in the future is not equal to a dollar today because of opportunity cost (potential investment and earned interest), risk (unforeseen circumstances could prevent receiving payment) and inflation (a time preference to have payment now for consumption) (Kay and Edwards, 1994; Workman, 1986). To compensate for the time value of money, future benefits and costs are discounted to represent the value of receiving the funds today. The net present value of an investment decision can help determine the worth of a project when returns are received in the future. The net present value equation is given in equation 2.4.

$$\text{Net Present Value} = \sum_{t=1}^{T} \frac{Benefit_t - Cost_t}{(1+r)^t} \tag{2.4}$$

where: T represents the time horizon

t represents individual years

r represents the discount rate

Table 2.1 is an illustration of how the value of a dollar today is worth less as time and the discount rate increase. The "correct" value for the discount rate is subject to debate. The higher the discount rate, the smaller the present value of future benefits or costs. As the present value of future benefits decreases, current consumption will be chosen over

Table 2.1. Present value of a dollar received at the end of different years in the future.

Year	Discount Rate 3%	7%	10%
1	$0.97	$0.93	$0.91
5	$0.86	$0.71	$0.62
10	$0.74	$0.51	$0.39
25	$0.48	$0.18	$0.09
60	$0.17	$0.02	$0.00

future consumption. This tradeoff between present and future consumption raises questions about intergenerational equity involved in choosing a discount rate.

There are several theories used in determining the appropriate discount rate. One approach is to combine the real interest rate (the cost of borrowing money) with the expected inflation rate and a risk premium (Kay and Edwards, 1994). This method is considered the private discount rate. The federal government often uses a social discount rate that is lower than the private discount rate to reflect intergenerational equity. For example, the Forest Service uses a four percent discount rate for cost-benefit analysis (Workman, 1986). The discount rates for this thesis are set at three percent, seven percent and ten percent to examine the sensitivity of the model results to discount rate changes.

Many authors suggest that other safeguards such as safe minimum standards and sustainability requirements are more effective for ensuring intergenerational equity (Pearce and Turner, 1991; Norgaard and Howart, 1991; Daly and Cobb, 1994). Both safe minimum standard and sustainable yield requirements are based on scientific research. A safe minimum standard is when harvesting levels are set so that the resource is not harvested beyond a level where irreversible damage to the ecosystem is done unless the costs to society of doing so are high (Bishop, 1978). The concept of sustainable yields was discussed earlier in the chapter.

Chapter 3: Literature Review

Riparian Ecosystems

Properly functioning riparian ecosystems are an important element in the management of watersheds (USDI, 1995). Vegetation growing along streams stabilizes the banks, slows spring run-off, filters sediment and provides shading that may decrease diurnal water temperature fluctuations. In a study conducted in the Blue Mountains of eastern Oregon, 80 percent of wildlife species relied upon these areas as a source of water, shelter and forage (Padgett, 1982). In the Great Basin of the southeastern Oregon, 299 of 363 identified land vertebrates were directly or heavily dependent on riparian habitats (Thomas et al., 1979).

Aquatic ecosystems are sensitive to changes in riparian health. Removal of riparian vegetation decreases shade and may increase fluctuations in water temperature (Kauffman and Krueger, 1984). Higher water temperatures induce stress, promote disease and reduce reproductive success among cold water fish species (Armour et al., 1991). Sedimentation also diminishes reproductive success by blocking dissolved oxygen flows to the developing embryos (Armour et al., 1991). McIntosh et al. (1994) found that all of the anadromous fish runs in eastern Oregon are at risk of becoming extinct. The authors attributed the major causes of this decline to mortality during the passage through dams on the Columbia River, degradation of riparian lands and over exploitation of fisheries.

One contributor to riparian habitat decline is improper livestock management. Cattle show a strong preference for riparian areas due to (1) microclimatic conditions such as shading, (2) the availability of water, (3) the quality and quantity of forage and (4) the decreased slope of the land (Skovlin, 1984). Cattle grazing affects the riparian ecosystem through two avenues. The first is through the consumption of forage. The removal of vegetation decreases ground cover, impacting run-off flows, erosion, infiltration and stream shading. The degree of consumption will also have long term effects on productivity and species composition (Kauffman and Krueger, 1984). Depending upon the timing and duration of grazing and the plant species involved, grazing can stimulate plant growth and vigor or it can negatively impact the plant (Wagner, 1983). The second avenue is through mechanical impacts such as trampling of streambanks that compact soils and alter channel morphology resulting in wider and shallower streambeds. The combination of the two impacts may allow stream temperatures to increase and may lead to increased sedimentation and erosion.

Riparian Grazing Management

Riparian lands were often seen as "sacrifice" areas in traditional range management (GAO, 1988). Although recognized for its forage value by livestock producers, riparian areas were not managed any differently than uplands. Cattle preference for riparian areas cause those areas to receive twenty to thirty percent more use than surrounding uplands (Bauer and Burton, 1993). Concerns raised recently over water quality and wildlife and fisheries habitat and their linkage to livestock grazing practices have focused the need for riparian grazing management that accounts for the multiple uses of the area. Degradation of riparian areas, particularly on public lands, has become unacceptable to society (Holechek et al., 1989).

Godfrey and Pope (1990) outline in a perspective paper the five major arguments used for the removal of livestock from public lands. One reason is the negative externalities associated with livestock grazing such as the impact on riparian areas and the competition with wildlife for forage. This leads to the second argument that there are alternative uses such as recreation for land currently grazed that are "worth" more to society.

The fee for grazing permits is another source of contention in the public lands debate. Torell et al. (1994) stated, "The federal government is not collecting the full market value for grazing public lands, but ranchers are paying full value through the current fee, non-fee grazing costs and investments in grazing permits" (p. iii). The fourth argument outlined by Godfrey and Pope (1990) is that federally subsidized grazing on public lands is unfair competition to other operators. The fifth argument employed is that the amount of forage provided by public lands could be available from other sources. It is estimated that less than four percent of the feed for beef and sheep production comes from federal lands (Godfrey and Pope, 1990). But as Elmore and Beschta (1987) argued, the real issue is improving management in regard to riparian areas, not the conflict over the correct pricing of an AUM[3].

[3] Federal grazing permits are sold in term of AUMs. An AUM is the amount of forage needed to feed an animal unit for one month.

Today's management of riparian lands should strive to incorporate the multiple uses of these specialized ecosystems for recreation, fisheries, wildlife, timber and livestock. The Federal Land Policy and Management Act (PL-94-579), authorized by Congress in 1976, stated that public lands are to be managed for multiple uses and sustainable yields. This includes providing food and habitat for fish, wildlife and domestic animals (Obermiller, 1994). Within a multiple use framework, livestock grazing can be compatible with other uses (Kauffman and Krueger, 1984; Armour et al., 1991; Heady and Child, 1994).

The management of riparian livestock grazing has four principle areas that should be considered. The first is the age and type of livestock. Grazing of sheep is less damaging to riparian areas than cattle because sheep are more easily herded and trained to remain in the uplands (Heady and Child, 1994). Herding cattle out of riparian areas is a labor intensive task (Winward, 1994). Yearlings are more likely to spread out naturally into the uplands as compared to cow-calf pairs that tend to cluster and graze along streamsides (Kinch, 1989; Bryant, 1982).

The season of utilization is another factor of influence. Siekert et al. (1985) found that spring grazing had no effect on channel morphology while Marlow and Pogacnik (1985) found that spring grazing had the greatest effect. The Siekert et al. study on an ephemeral stream in Wyoming found cattle grazed upslope during the spring months, resulting in less time in riparian areas. During a drier year, cattle concentrated in the riparian zone, which resulted in heavier bank damage. In contrast, Marlow and Pogacnik (1985) found that the quantity of use by cattle was an insignificant influence on streambank stability but timing of use was the most important factor. They found the susceptibility of trampling was positively correlated with soil moisture.

Specialized grazing systems may potentially provide the best method for meeting land management objectives, but are often difficult to manage (Winward, 1994). The greatest amount of stress on the plant community is during the summer, when the period of regrowth and replenishing carbohydrate reserves is shorter (Kinch, 1989). Bohn and Buckhouse (1985) found that rest rotation systems speed the recovery of riparian areas. This type of system calls for rest periods for individual pastures during the growing season on a rotating basis. Good distribution of cattle between uplands and riparian areas is often seen in early season grazing (Heady and Child, 1994). Late season grazing also provides possible riparian improvements because it allows protective mats to be maintained on streambanks during critical run-off periods (Platts, 1989). Holechek et al. (1982) found no disadvantage or advantage from a cattle performance standpoint for delayed use of riparian meadows in the Blue Mountains of Oregon. The primary drawback from specialized systems is the increased costs of management and fencing (Platts, 1989; Holechek et al., 1982).

Another technique for influencing riparian forage use is through upslope placement in pastures of water, salt and supplemental feed sources. Water and salt placement are considered the two primary factors in distribution (Roath, 1979). Forage utilization is directly correlated with distance from water (Skovlin, 1984). Bryant (1982) found alternative water and salt sources upslope were ineffective for distributing cattle when they had access to riparian areas during summer long grazing. Miner et al. (1992)

found that an alternative watering source in the winter months eliminated ninety percent of the cattle's use of a stream.

The fourth principle of riparian management is the degree of forage utilization. Utilization is defined as "the proportion of the current year's biomass production which is removed or damaged by grazing animals" (SRM, 1989). Hall and Bryant (1995) proposed that a three inch stubble height of the most palatable species be an indicator for proper forage utilization. After the three inch height is reached, forage quality has declined due to dryness and cattle change their grazing preferences. They begin to graze woody vegetation and continued to graze forage species below three inches. This is often the point where damage occurs in riparian areas.

Monitoring riparian vegetation utilization is a management tool used by public land management agencies. The Forest Service outlines in its Land and Resource Management Plan for each national forest the utilization standards for grazing allotments. These standards are based on consultations with the National Marine Fisheries Service in areas with anadromous fish and compliance with the Endangered Species Act and the Clean Water Act. For example, the Wallowa-Whitman National Forest in Oregon allows up to 40 percent utilization of riparian vegetation (USDA, 1990), while Challis National Forest in Idaho maintains a thirty percent utilization standard[4]. Variations in standards are due to the current condition of the grazing allotment, the vegetation found in the pasture, the requirements of wildlife and fish habitat and management objectives (USDA, 1990; Lindenmuth, 1997).

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[4] Johnson, C. Gregory. 1996. Forest Service communication to grazing permittee.

The scientific community however, questions the use of utilization standards as the primary monitoring tool (Sanders, 1997). Livestock graze in a manner in which certain "ice cream" species will be heavily grazed and others are left untouched. If sampling is done on a total production basis, then it does not determine which species are being grazed. Also the degree of defoliation is not directly linked with the regrowth or reproduction of the plant. Utilization must be combined with other factors such as timing, duration and period of rest to determine the grazing impact on plants (Burkhardt, 1997). Forage utilization by itself cannot function as a long term indicator of rangeland trends (Lindenmuth, 1997).

Total exclusion of livestock and other grazing animals from riparian areas through fencing provides the quickest rate of riparian recovery (Skovlin, 1984). Improvements in fish habitat are estimated to occur in 3 to 5 years and vegetation communities respond in 5 to 7 years (Skovlin, 1984). Although exclusion of livestock will lead to an improvement in riparian conditions, there is a great amount of scientific uncertainty as to whether this is a necessary condition (OSU, 1996). Changes in timing and intensity of utilization may result in the same results but without the expenses of fencing and non-use (Armour et al., 1991; Elmore and Beschta, 1987).

Fencing the stream corridor may meet riparian recovery objectives, but at the high cost of fence construction and maintenance and the loss of forage available for grazing. The costs of fencing both sides of a stream are $8,000 - $12,000 per mile and a yearly maintenance cost of $100 - $200 per mile of stream (OSU, 1996). Alternative forage, if available, costs approximately $10 per animal unit month (OSU, 1996). Fencing generally is not an economically viable alternative for riparian management if all costs are absorbed by the rancher (Wightman and Eisgruber, 1994; Roath, 1979; Hancock, 1989). Fencing the stream also blocks access for wildlife and recreationists (Kinch, 1989).

Specialized riparian management techniques will continue to evolve as scientific knowledge increases. However, these methods will not be implemented unless they are "sold" to the rancher (Hancock, 1989). Multiple use management that improves wildlife and fisheries habitat may be at the loss of prime livestock forage. Although social benefits are increased, ranching returns may be decreased and questions of efficiency, equity and sustainability need to be addressed (Obermiller, 1994). The 1988 General Accounting Office report concerning the degradation and restoration of riparian areas failed to discuss the economic feasibility of these improvements (Gardner, 1991). The lack of economic knowledge in this area is commonly cited throughout studies (Obermiller, 1994; Skovlin, 1984; Armour et al., 1991).

Range Economics

One way to "sell" riparian management is to demonstrate the benefits of a healthy riparian ecosystem. Evidence in eastern Oregon showed that as riparian ecosystems recover, they provide more forage (Elmore and Beschta, 1987). There are also examples of how grazing pressure, the relationship between animal numbers and amount of forage, influences economic returns through average daily gains and forage production.

Grazing pressure can be set at light, moderate or heavy levels. Heavy pressure is 60-80 percent utilization of the herbage and usually exceeds the carrying capacity of the range (Skovlin, 1984). At moderate levels, 40-59 percent utilization, the current range condition may be maintained. Only the choice plants and areas are used at light grazing levels, 20-39 percent forage utilization, and sufficient biomass is left to develop increased herbage productivity (Kipple and Bement, 1961).

Van Poollen and Lacey (1979) reviewed literature on grazing intensities and grazing systems and found they influenced herbage production. When forage utilization was reduced from heavy to moderate, future forage production increased by 21 to 49 percent. Changes from moderate to light levels increased forage production by 15 to 41 percent in later years. The large variation of results emphasized how the environmental factors of the study location affect grazing intensity on the land.

Hart et al. (1988a), in a study examining different grazing systems, found that 66 percent of the variation in a yearling's average daily gain could be attributed to grazing pressure. As grazing pressure increased, the steers exhibited a decline in average daily weight gain. As forage becomes less available, livestock must spend more energy grazing, often consume less forage and have less nutritional choices for grazing (Holechek et al., 1989).

Short Term versus Long Term Planning

Pope and McBryde (1984) demonstrated the sensitivity of planning horizons and discount rates on the rancher's willingness to undertake range improvements. They defined the carrying capacity of the study sites as the number of AUMs that could be sustained indefinitely. Net annual returns were a function of the carrying capacity and stocking rate. A dynamic decision model was constructed with the functional relationships of net returns, range improvement usage and costs. With a one year planning horizon, the optimal herd size resulted in the overstocking of the range. This short term planning had a long term effect of reducing the carrying capacity by 25 percent in the tenth year. This result also produced a loss of 27 percent of net returns over the ten years. With an infinite planning horizon, stocking rates were maintained at a level that sustained the current carrying capacity, unless the discount rate was increased to a level above 6.4 percent. This discounting of future returns induced higher stocking rates, resulting in a deteriorated range condition for future years. When range treatments such as reseeding were introduced, the rancher could periodically overstock and apply range improvements for higher returns.

Torell et al. (1991) also tested the hypothesis of whether economically optimal stocking rates were different for a single year planning period as opposed to a dynamic or multi-year situation. Analyzing data from a long term yearling grazing study in Colorado, the authors found several rangeland trends. In both types of models, grazing pressure impacted current period beef production. As grazing pressure increased, rangeland productivity was negatively impacted, as were average daily gains. In both models, stocking rates varied from year to year following price trends. In the dynamic model, stocking rates were lower, but not significantly. The driving force in animal performance was the current year's grazing pressure, not the impact on future year's forage production. This contrasted with results given in Pope and McBryde (1984). The authors noted that the variation in rangeland productivity and type of livestock may cause either result to be appropriate.

Uncertainty

Current range condition is a product of annual stocking rates, range improvement projects, precipitation and previous year's conditions. Without precise ecological knowledge of how these factors interrelate, decision making contains uncertainty. Karp and Pope (1984) modeled decisions to implement low and high cost range treatments as a stochastic control model. Their model indicated the deterministic model may underestimate the economic value of the rangeland. The more risk adverse the rancher, the lower the stocking rate and the less likely range improvements would be applied.

Considering the principle sources of risk in cattle operations as market prices and forage production's dependency on precipitation, Rodriguez and Taylor (1988) tested the certainty equivalence of decision making in a yearling operation. The certainty equivalence property holds when the same decisions are applied to the deterministic model (where all information is known) and the stochastic model (where an element of randomness with known probabilities is included). The certainty equivalence held at low stocking levels but was rejected at high levels. With a risk neutral rancher, the largest expected net present values were associated with higher stocking rates combined with flexible marketing strategies.

Standiford and Howitt (1992) used a bioeconomic model to analyze the ranch enterprises of firewood, cattle and hunting on California's rangelands. Through the use of chance constraints, the uncertainty of precipitation and price expectations were introduced into the model. A chance constraint sets up the probability for the element of risk meeting a minimum or maximum requirement. The whole ranch view allows the manager to view the trade-offs between the various enterprises. The conclusion of the model was that the cattle operation was a risky venture and the optimal results bent toward the relatively financially stable enterprises of wood production and hunting.

Dynamic Model Examples

Chavas et al. (1985) developed a dynamic agricultural response model for swine production. They found that knowledge of biological growth is an important factor in determining the economic efficiency of dynamic production processes. A dynamic model was more realistic and allowed for a more flexible decision modeling approach. The authors also concluded that this type of model points to the lack of economic data in dynamic settings.

Utilizing stochastic dynamic optimization, Lambert and Harris (1990) examined optimal rangeland investment in spring forage production and herd sizes. They generated nine states of nature (three possible beef cattle price data sets and three precipitation sets) and employed a safety-first financial constraint to examine the investment under uncertainty in the long term. They found that investment depended upon initial resources and stocking level of the ranch. They also addressed the difficulty in finding data sources for range models of this type.

Chapter 4: The Hall Ranch - Milk Creek Cattle Dispersion Study

Concerns about wildlife and fisheries habitat and water quality have raised questions regarding the impact of livestock grazing in riparian areas. There is a critical need at this time for grazing management that achieves environmental goals and is economically feasible for the rancher. One such strategy may be the placement of off-stream water and trace mineralized salt in the uplands of pastures to draw cattle out of riparian areas. This improvement is termed the dispersion project within this thesis.

To test this hypothesis, an interdisciplinary multi-state project group was formed. The overall objective of the project was to determine the impacts of the cattle dispersion method and to provide a demonstration site for community education. There were four focus areas in the research project: (1) animal behavior and performance, (2) riparian area assessment, (3) biodiversity and (4) economic feasibility.

The research was conducted at Eastern Oregon Agricultural Research Center's Hall Ranch on the Milk Creek pastures. The study site is located in the foothills of the Wallowa Mountains, in the northeastern corner of Oregon. Milk Creek is a tributary to Catherine Creek and is classified by Oregon's Department of Fish and Wildlife as a salmon rearing stream.

Methods

Utilizing Geographical Information System (GIS), the study site was mapped for slope, canopy cover, type of soil and vegetation communities. A complete randomized block design was used with the study area being broken into three blocks. Each block was further divided into three treatment pastures of approximately 30 acres. The project layout is shown in Figure 4.1. The three treatments included a control pasture where no livestock grazing was allowed, a pasture with the off-stream water and salt treatment (dispersion) and a pasture containing no alternative water or salt (non-dispersion). The creek flowed through all pastures and cattle had open access to it throughout the study period. Elk and deer are known to use the entire study area.

For pastures with upslope water, a hydraulic ram pump was installed next to the creek for transportation of water uphill (150 ft. gain in elevation and 1,500 - 1,700 linear ft. distance) to two tank locations. A water permit is not required by the State of Oregon if (1) the delivery system is enclosed, (2) the upslope tanks have automatic shutoff values or a means for returning the water to the stream and (3) it is on land that the livestock would already have access to the stream[5]. A stockwater pond that fills with spring runoff was used in the third pasture. The salt containers were approximately 15 feet from the upslope water sources.

Sixty cow-calf pairs were divided into six age groups. One pair in each group was randomly assigned to a pasture so that all pastures had an even mix of age classes. About one third of the cows were first calf heifers in the first study year. In the second year, only first calf heifers were used in the study. The stocking rate was 2.9 acres per pair. The groups were turned out in mid July and remained in the pastures for 42 days in both years. The grazing objective was to achieve a fifty percent forage utilization rate

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[5] Engel, Cory C. 1997. Oregon Water Resources Department. Personal communication with author.

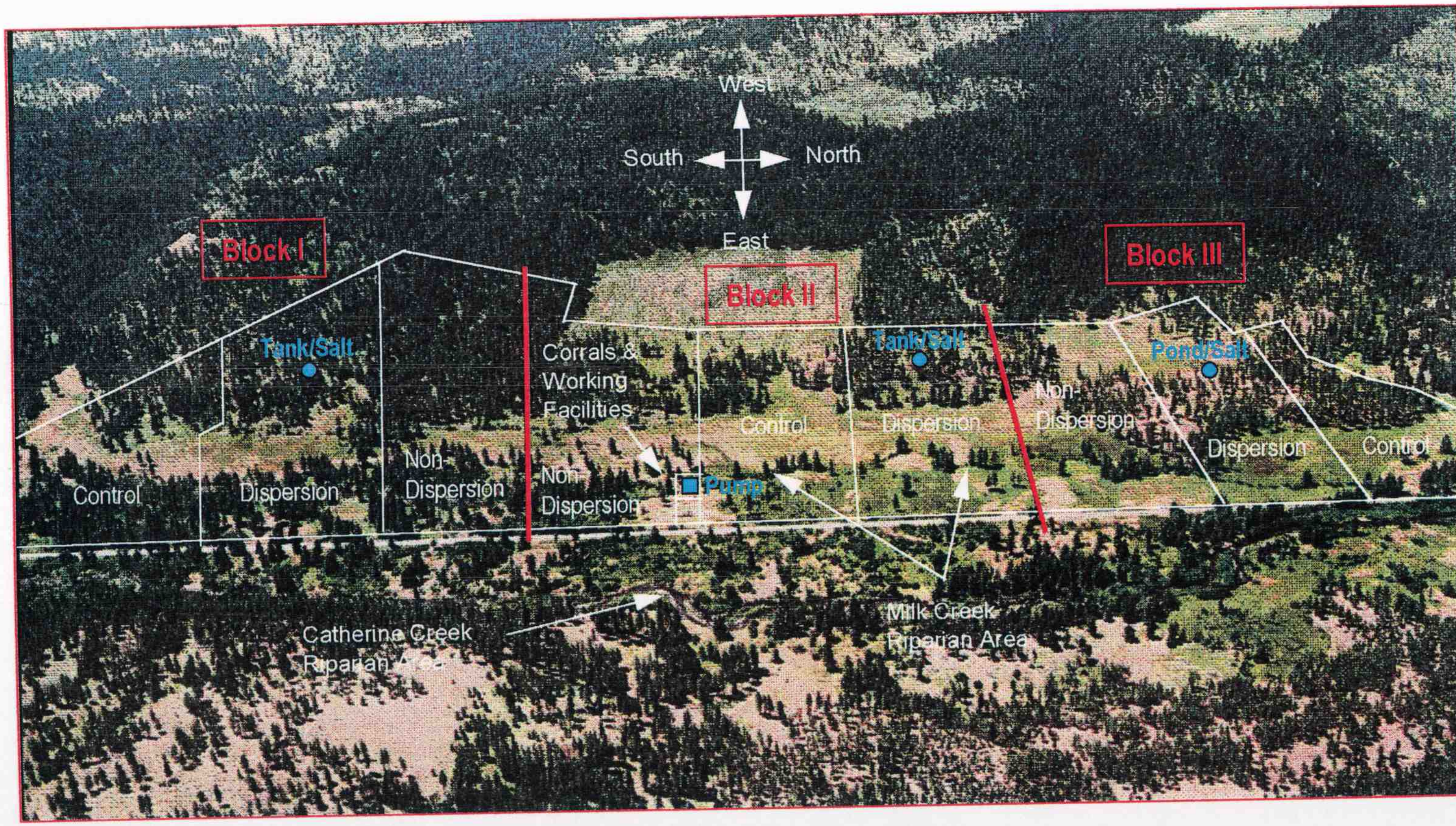

Figure 4.1. Hall Ranch -- Milk Creek dispersion study pasture layout, 1996 and 1997.

over the entire pasture. Cow and calf body weights and body condition scores were determined prior to turnout and at the end of the study period. The cattle were observed five times a day for six days during the second and sixth weeks of the grazing season to determine distribution. The cows' locations and activities were recorded on aerial photographs. Four cows from each pasture were also randomly selected to be equipped with vibracorders (records grazing patterns) and pedometers (records distance traveled) to monitor behavior during these observation periods.

Forage utilization in the riparian and uplands was also used to estimate cattle distribution. Transects of approximately 100 feet were set up north to south in the study pastures. A random number of paces was walked from the fenceline and a 0.25 m^2 plot placed. The site was classified in one of seven categories based on the dominant vegetation of the plot. These categories were termed riparian grass, riparian sedge-rush, riparian gravel bar, upland with cover, upland open, upland elk sedge and upland rush communities. At the beginning of July, the peak forage production point of the year (Sneva and Hyder, 1962a), vegetation at each site was identified and clipped to one inch stubble height. The herbage was dried, weighed and analyzed for nutritional content. Vegetation sampling was repeated post-grazing. Utilization was calculated using a control and post-season clip and plot method. In the second year, an ocular method to determine utilization (USDI, 1996) was also employed.

Photo points were established in the riparian area to monitor changes throughout the season. A greenline classification of the riparian area (Bauer and Burton, 1993) was conducted at the conclusion of the grazing season. This analysis looked for interruptions in the greenline vegetation and assigned a cattle versus other/unknown cause.

Streambank stability and cover were also measured following the Environmental Protection Agency protocol (Bauer and Burton, 1993).

Water quality samples and fecal pat counts along the streambanks were also analyzed from each pasture to determine management impacts. Entomologists monitored terrestrial macroinvertebrates, focusing on lepidoptera (moth) as an indicator of biodiversity. In the second year the monitoring was expanded to included aquatic macroinvertebrates.

The procedure for economic analysis of the project was to construct a bioeconomic model for a hypothetical 300 cow herd in the region of the study area. Details on the creation of the model are given in the next chapter. Data collection consisted of meetings with County Extension agents and ranchers to produce an enterprise budget to determine the average expenses and revenues for ranchers of the region. Other expenses involved in the implementation of the dispersion project were collected. Annual operating costs of providing off-stream water and salt were estimated from discussion with project workers.

Data Results

For the bioeconomic model, animal performance and forage utilization data were incorporated into the model. Data collected in addition to these measurements has significance when discussing the social benefits and costs derived from the changes in riparian condition and biodiversity. At the time of this writing, analysis of data collected in other aspects of the study is in the beginning stages.

Cows used in the study were assessed for initial and ending weight and body condition scores. Initial and final body condition scores (1 - 9, 1 = extremely emaciated; Wagner et al., 1988) were assigned by two trained technicians and scores were averaged. In the first year of the study, cows arrived at the project with an average weight of 917.7 lb and an average condition score of 4.7. Average calf weight was 268 lb. During the second year of the study, cows had an initial average weight of 918.3 lb and an average condition score of 4.5. The calves in the second year arrived with more weight than the previous year with an average weight of 312.4 lb due primarily to an earlier calving date.

An analysis by treatment (dispersion versus non-dispersion pastures) of the two years of data in cattle weight gains and change in cow body condition scores were conducted using the general linear models procedure (SAS, 1990). No yearly effect was found for weight gains. Table 4.1 outlines the results of this analysis. Cattle provided off-stream water and salt did show improved weight gains ($p<0.01$). Cows in dispersion pastures gained on average an additional 0.6 lb/day than cows without off-stream water and salt. There was no significant change in body condition scores for cows between

Table 4.1. Comparison by treatment of average daily gain (lb/day) for cattle and change in body condition scores for cows, 1996 and 1997.

Treatment	Cow average daily gain	Calf average daily gain	Change in cow body condition score
Dispersion pasture	1.53 ± 0.04^a	2.22 ± 0.01^a	0.18 ± 0.10^a
Non-dispersion pasture	0.93 ± 0.04^b	1.91 ± 0.01^b	0.09 ± 0.09^a

^{a,b} Means ($\pm$ standard errors) in the same column followed by different superscript differ ($p < 0.01$).

treatments (p<0.56). Calves with off-stream water and salt gained on average 0.3 lb/day more than calves in non-dispersion pastures (p<0.01).

A study conducted in the West (Sneva and Hyder, 1962a) found that 75 to 90 percent of forage yield fluctuations could be attributed to variations in the amount of precipitation received during September through June. Sneva and Hyder (1962a and 1962b) developed a forecasting model for range herbage production in eastern Oregon. They found that the response of forage yields to changes in precipitation are consistent on a percentage basis even though productivity among study sites varied. Their model was validated with sites at high elevation in southwestern Idaho (Hanson et al., 1983). The following example used forage production values collected in the 1996 sampling period to determine the median forage production for the pastures on Milk Creek.

Forecasting Range Herbage Production Adapted from Sneva and Hyder (1962a)

Step 1: Determine the median crop year (September through June) precipitation. Figure 4.2 illustrates Union, Oregon crop year precipitation data from 1962 through 1990. Precipitation that falls between September and June is used because summer rain for regrowth is rare and should not be depended on for forage yield calculations (Pickford and Reid, 1948). The median precipitation is 12.59 inches for Union, Oregon (Taylor et al., 1993). The median value is used as opposed to the average value to lessen the weight of outlier years of extreme drought or rain. No autocorrelation was found in the crop year precipitation data utilizing a Durbin-Watson statistical test.

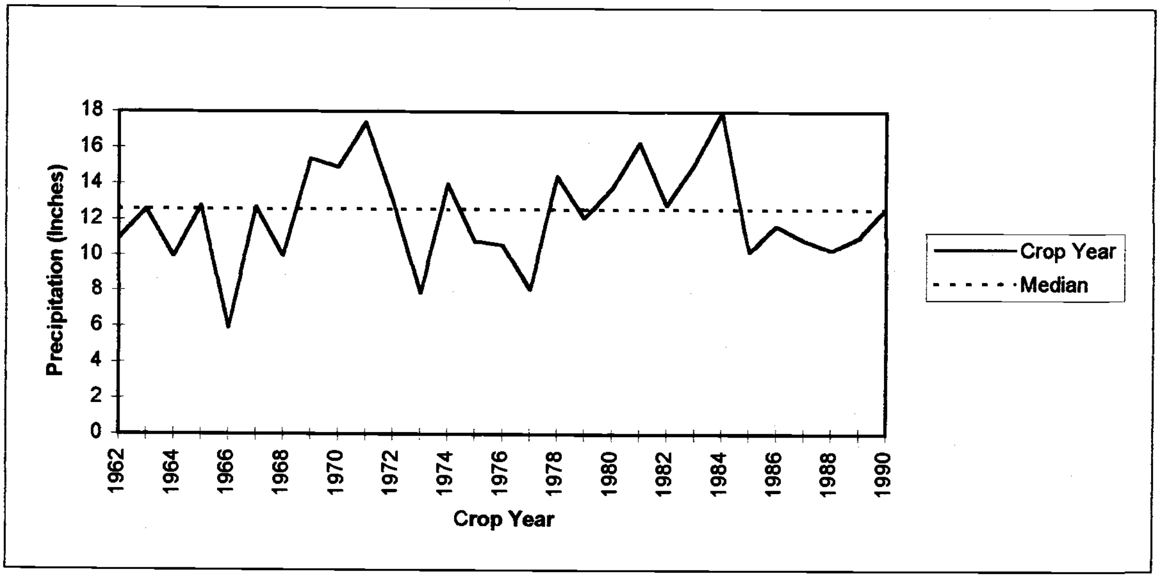

Figure 4.2. Union, Oregon crop year precipitation,1962 - 1990 (Taylor et al., 1993).

Step 2: Sum current crop-year precipitation for the year. The precipitation between September and June 1996 was 16.26 inches[6].

Step 3: Compute the precipitation index. The precipitation index is found by dividing crop-year precipitation (16.26 inches) by the median amount (12.59 inches) and multiplying by 100 percent.

Precipitation index = (16.26/12.59) * 100% = 129%

Step 4: Calculate the forage yield index. Utilizing data from studies in three states, Sneva and Hyder (1962a), found the regression:

Yield Index = 1.11 * Precipitation Index - 10.6

Yield Index = 133%

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[6] Slater, R. 1997. Eastern Oregon Agricultural Research Center. Personal communication with author.

Step 5: Forecast current range production by multiplying the normal range herbage production by the current season's forage yield index. Normal range herbage production is found by sampling the pasture to estimate herbage production at its peak and then dividing it by the yield index for that year (Step 4).

From the July vegetation sampling, 1996 production of dried vegetation was calculated for the riparian lands as 1,541.25 lb/acre and 960.87 lb/acre for the uplands. By having a wet crop year, total vegetative production was estimated to be about 33 percent higher for 1996 than in a normal rain year. Setting the yield index to 100 percent, normal production is estimated at 1,158.8 dry lb/acre for riparian land and 722.5 dry lb/acre of upland.

The Sneva and Hyder (1962) forage forecasting model underestimated forage production for the second year of the study. Crop year precipitation for the area was 15.28 inches[7] which produced a yield index of 24 percent over median vegetation levels. Sampling of pasture vegetation at peak in 1997, showed production at 63 percent over median levels. A reason for the difference between actual and predicted levels may be that Sneva and Hyder's sampling sites were located in the semi-arid region of eastern Oregon. The authors suggested that while their regression may be applicable to Union, Oregon, it was not be validated. Another cause for the difference may be due to the large variation in production samples within community types between the two years. This could indicate that growth conditions do not affect plant species of the Blue Mountains on the same percentage basis as suggested by Sneva and Hyder (1962a). Also statistical

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[7] Slater, R. Eastern Oregon Agricultural Research Center. Personal communication with author.

analysis on the vegetation clipping samples were not done and the wide fluctuations may be a product of an insufficient sampling size.

The distribution of cattle was determined by comparing the utilization ratio between riparian vegetation and upland vegetation. Vegetation samples taken post-grazing at the Hall Ranch study site were analyzed for utilization. The Bureau of Land Management's utilization formula, shown as equation 4.1 was used (USDI, 1996).

$$\text{(control plot - treatment plot) / control plot} = \text{\% utilization} \quad (4.1)$$

Averaging the two years of data, cattle in pastures without off-stream water and trace mineralized salt utilized 55 percent of the riparian vegetation and 39 percent of the available upslope forage. In contrast, the water project distributed the cattle away from the creek, with 18 percent of the riparian vegetation utilized and 35 percent of the upslope vegetation[8].

The observational points of the cows' locations were input into a database analyzed using a Geographical Information System (GIS). An average distance from the stream was calculated for cattle in both types of pastures. Statistical analysis of the first year's data revealed a significant difference in the treatment (dispersion pasture and non-

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[8] Utilization can be difficult to estimate (Burkhardt, 1997). The method used here was on a total vegetation production basis. Thus, species such as rushes, which are not a favored forage species of cattle and were left untouched in riparian sampling areas, may cause misleading utilization results. Pastures within blocks were assumed to have similar vegetation compositions, however further vegetation mapping is necessary to confirm this assumption. A more rigorous utilization analysis is being undertaken by Marni Dickard (1997. University of Idaho. Personal communication) to account for vegetative differences in pastures. The sampling size of clipped plots was not statistically validated. The utilization values listed here may not be "exact" but should be considered an indication of the riparian and upland utilization ratio that is achieved when the dispersion project is used.

dispersion pasture) versus season interaction (first observation period and last observation period)[9]. During the first observation week, cows with off-stream water and salt had a mean distance further from the stream than cows without the dispersion project. In contrast, during the second observation at the end of the grazing period, the opposite was true. This would verify the utilization pattern that cows with upslope water and salt were better distributed throughout the grazing period, whereas, the non-dispersion treatment cows consumed riparian forage first and then had to travel further upslope for forage later in the season.

[9] Dickard, Marni L. 1997. University of Idaho. Personal communication.

Chapter 5: Model Construction

This chapter outlines the bioeconomic model constructed for the economic analysis of the Hall Ranch - Milk Creek dispersion project when implemented on a representative 300 cow-calf ranch in northeastern Oregon. Typical costs and returns for producing calves in this mountainous region are based upon a draft OSU enterprise budget (Turner et al., 1996). All the variables used in the program are listed in Table 5.1. The term exogenous means the parameter value was predetermined, or given, in the model. Variables labeled endogenous are decision variables that the model solves to achieve an optimal solution set.

A multiperiod program can be summarized in five parts (Conrad and Clark, 1987). They are: (1) objective function, (2) state variables, (3) control variables, (4) constraints and (5) equations of motion. The objective function specified in this thesis is to maximize the present value of total gross margin (revenue minus variable costs) and terminal value (an infinite set of net returns from herd) less dispersion project costs over a sixty year planning horizon. Gross margin can be converted to terms of profit by subtracting the fixed costs of the enterprise.

In optimization models, the endogenous (solved within the model) variables are a function of time (t). They can be divided into the two categories of state variables and control variables. State variables describe the system in time (t). Control variables are those variables that function as decision variables. These variables then influence the state variables in the next time period through equations of motion. An equation of motion is the mathematical representation of how one state (year) transforms into the

Table 5.1. Variable listing from GAMS program.

Subscripts	
G	Forage location: G1 riparian vegetation, G2 upland vegetation
L	Forage supply: L1 private land, L2 public lease 35%, L3 private lease, L4 hay, L5 over utilization on public. L2 & L5 are also referred to as summer allotments.
P	Summer pastures: P1 non-project, P2 water project pasture
t	Time (years)
Parameters - Exogenous Variables	
$ACRE_{G,P}$	Number of acres in summer allotments
C_L	Cost of forage supply per AUD
CALFFWT	Selling weight of heifer calf (cwt)
CALFMWT	Selling weight of steer calf (cwt)
CLF	Calving % (includes conception rate, birth rate and death loss)
COWCST	Variable cost of a cow per month. (Does not include forage cost)
COWWT	Selling weight of a cow (cwt)
CP	Control period (cattle equation of motion not valid the first year)
CULL	Cull cow rate
DEATH	Cow death ate
DF_t	Discount factor
LEASELMT	Limit to amount of AUDs that can be purchased from private lease
OWNLMT	Limit to amount of AUDs off own rangeland
PRECP	Median precipitation of crop year (inches)
r	Discount rate
$UTIL_{G,P}$	Standard utilization levels
YEARWT	Selling weight of yearling heifer (cwt)
$YIELD_G$	The normal yield of forage in terms of dry lb per acre
Exogenous Parameter - May change due to State of Nature	
MKTCALF	Market price for beef calves per cwt
MKTCOW	Market price for beef cows per cwt
RAIN	Crop year rain in inches
Endogenous Variables	
$AVAILFOR_{G,P,t}$	Available forage calculated from Sneva & Hyder (1962a), crop year rain and penalty loss
COW_t	Mature cows
$FIRST_t$	First calf heifers
$HERD_t$	Herd size
$INCOME_t$	Income for the year
$OVER_{G,P2,t}$	Utilization percentage beyond standard
$OVERFOR_{G,P2,t}$	Forage consumed from L5
$REPL_t$	Number of heifer calves held as possible herd replacements
$SELLCALFF_t$	Number of heifer calves sold
$SELLCALFM_t$	Number of steer calves sold
$SELLCOW_t$	Number of cows sold
$SELLYEAR_t$	Number of yearling heifers sold
TERM	Terminal value
$VARCST_t$	Variable costs
$X_{L,t}$	Amount of forage from each supply
Z	Present value of gross margin less dispersion project costs

next year. For example, the number of cows that are culled and the number of yearling heifers retained will determine the number of calves born in the next year. Many of the resources of the ranch are limited so the objective function is maximized subject to resource constraints.

The core of the economic analysis is to compare the net returns in equilibrium of a ranch operating with and without off-stream water and salt under varying crop year precipitation levels and market price conditions (states of nature). To accomplish this task, several parameter values are changed depending upon whether the project is in use and the current state of nature.

Cattle Equations of Motion

Figure 5.1 is a flowchart of cow/calf production and illustrates the equations of motion. There are four age classes on the ranch: calf, yearling replacement heifer, first calf heifer and cow. Calves are born in April and weaned in October. The initial herd size, represented by equations 5.1, 5.2 and 5.3, is 255 cows (COW_1), 45 first calf heifers ($FIRST_1$) and 60 replacement heifers ($REPL_1$). All replacement heifers are raised within the operation.

$$COW_1 = 255 \tag{5.1}$$

$$FIRST_1 = 45 \tag{5.2}$$

$$REPL_1 = 60 \tag{5.3}$$

Equation 5.4 is the heifer calf production function and equation 5.5 is the steer calf production function.

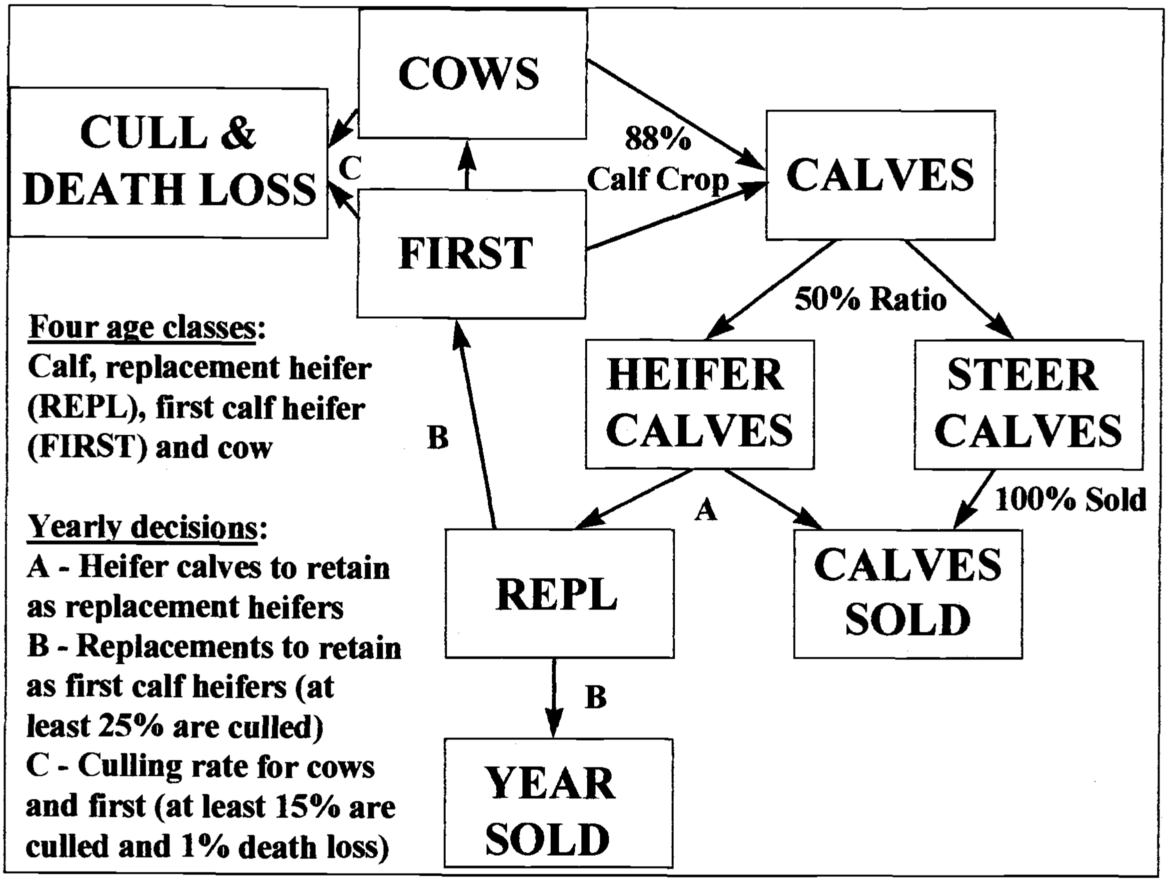

Figure 5.1. Cattle equations of motion flowchart (Turner et al., 1996).

$$SELLCALFF_t = (COW_t + FIRST_t) * CLF * 0.5 - REPL_{t+1} \tag{5.4}$$

$$SELLCALFM_t = (COW_t + FIRST_t) * CLF * 0.5 \tag{5.5}$$

The calf weaning success rate (CLF) is 88 percent. This is based on a 95 percent conception rate for cows (all replacement heifers were pregnancy tested in the fall), a two percent death loss during calving and a five percent calf loss after birth (Turner et al., 1996). In November, heifers calves can be sold ($SELLCALFF_t$) or kept as heifer replacements for the next year ($REPL_{t+1}$). All steer calves are sold ($SELLCALFM_t$). Net cost of maintaining bulls is included as a variable cost of the cows. All variable costs are described later.

For the year after their birth, retained heifer calves ($REPL_t$) are considered part of the herd as yearlings. After being pregnancy tested in the fall, these possible replacements are either sold as yearling heifers ($SELLYEAR_t$) or kept as part of the herd for the next year ($FIRST_{t+1}$) as shown in equation 5.6.

$$REPL_t = FIRST_{t+1} + SELLYEAR_t \tag{5.6}$$

Due to low conception rates and the desire to keep only the best replacements, it is assumed that at least twenty five percent of the possible heifer replacements are culled in November (equation 5.7).

$$SELLYEAR_t \geq 0.25 * REPL_t \tag{5.7}$$

The size of the herd (equation 5.8) is a function of the previous year's cow herd, number of replacements kept as first calf heifers from the last two years and the number of cows lost due to mortality or culling.

$$HERD_t = COW_t + FIRST_t + REPL_t \tag{5.8}$$

Equation 5.9 represents the equation of motion for cows.

$$COW_{t+1} = (COW_t + FIRST_t)*(1\text{-}DEATH) - SELLCOW_t \tag{5.9}$$

The death loss rate (DEATH) is assumed to be one percent. Equation 5.10 sets the culling rate of mature cows to be at least 15 percent.

$$SELLCOW_t \geq COW_t * 0.15 \tag{5.10}$$

Calf survival rates are a function of the mother cow's age. The lowest survival rates correspond to the youngest mothers (Stringham, 1983). To maintain the calf crop success rate of 88 percent, the herd is restricted by equation 5.11 to limit first calf heifers to less than one third of the number of cows.

$$FIRST_t \leq (COW_t + FIRST_t) * 0.33 \qquad (5.11)$$

Other resource constraints, represented by equation (5.12), such as corral capacity and equipment, limit the herd (cows, first calf heifers and yearling heifers) to a total of 500 animals.

$$HERD_t \leq 500 \qquad (5.12)$$

Forage Equations of Motion

The typical rancher of the northeast Oregon mountain region supplies feed in the form of native and feeder quality alfalfa hay, public range and pastures (Turner et al., 1996). In the model, a 345 animal unit[10] herd (300 cows at one animal unit (AU) and 60 yearlings at 0.75 AU) are fed hay for five months in the winter, graze privately owned spring range and stringer meadows for three months and graze Forest Service lands for four months. The model also includes the option of leasing 345 AUMs of private pasture. The type of feed is represented as the variable X_L in the model. Table 5.2 is an outline of the yearly forage supply and the amount of forage available. Since the focus of the economic analysis is on summer grazing when the herd is on Forest Service pastures, the number of AUMs available from privately owned pastures and privately leased

[10] An animal unit is defined as a 1,000 lb cow and her calf. An AUM is the amount of forage necessary to feed an animal unit for one month. An AUD is the forage to feed an AU for a day.

Table 5.2. Yearly forage supply for a typical 300 cow-calf operation.

	Spring	Summer	Fall	Winter	Flexible
Source	Own	Public Lease	Own	Hay	Private Lease
AUMs	690	1,380	345	1,725	345
Guaranteed	Yes	No[a]	Yes	Unlimited[b]	Yes[c]

[a] depends upon rain conditions and utilization of riparian forage
[b] must provide at least 5 months of feed
[c] private lease is an option for spring through fall months

pastures are fixed regardless of precipitation conditions as shown with equations 5.13 and 5.14.

$$X_{L1,t} \leq 1{,}035 \text{ (AUM) or } 31{,}567 \text{ (AUD)} \tag{5.13}$$

$$X_{L3,t} \leq 345 \text{ (AUM) or } 10{,}523 \text{ (AUD)} \tag{5.14}$$

For a minimum duration of 5 months (winter, 152 days), represented in equation 5.15, the herd is fed a mixture of native and alfalfa hay as the only available form of feed. Heifer calves and yearlings are not supplemented with grain. Hay may be fed longer than 5 months if summer forage production is low.

$$X_{L4,t} \geq (COW_{t+1} + FIRST_{t+1} + 0.75 * REPL_t)*152 \tag{5.15}$$

Data collected from the Hall Ranch study was for the period of mid July through August which was only a month and a half of grazing out of the usual four months of public land grazing. For analysis of the dispersion project, the public lease pastures are divided into one pasture where the dispersion project can be implemented for one and a half months (subscript p2) and two non-dispersion pastures (subscript p1).

The Forest Service regulates the maximum utilization level ($UTIL_{g,p}$) of vegetation from their allotments. This model assumes that the utilization standards are

35 percent of riparian vegetation (subscript g1) and 50 percent of upland forage (subscript g2). Grazing permits purchased by the ranch allow for 1,380 AUMs to be consumed. This amount of forage provides feed for 345 animal units for four months at regulated utilization conditions when crop year precipitation is at normal levels. Changes in precipitation will cause the quantity of forage produced from the Forest Service lands to vary. In years of low precipitation, the ranch manager must decide to either decrease herd size, remove cattle early, exceed the utilization standard or any combination of the three.

There are consequences for exceeding the 35 percent utilization standard in the riparian zone. While penalties vary among administrative units, this model assumes the agency will revoke twice the percentage exceeded ($OVER_{g,p,t}$) from the total permitted amount from the next year's permit. For example, if the monitored riparian pasture is grazed at a 45 percent utilization level, 10 percent more than the agency's desired level, then the agency will lower the total permitted number of AUMs by 20 percent for the next year. Again, the ranch manager would face a decision to reduce herd size, remove cattle early or exceed the utilization percentage[11]. The nonproject pastures are restricted to the regulated levels, so the monitored site for riparian utilization is the mid July to the end of August grazed pasture, where off-stream water and salt can be provided.

Forage supplied from public lands is divided into two categories. X_{L2} is vegetation consumed at or below the regulated utilization levels while X_{L5} represents

[11] The model design does not account for a penalty that is cumulative. It is unlikely that the agency would permit the rancher to continue to exceed the standard without enacting harsher penalties.

consumption above the limits. The quantity of X_{L2} is given in equation 5.16. Utilizing Sneva and Hyder's (1962a) forage production forecasting model described in the last chapter, equation 5.17 predicts the amount of forage available for consumption.

$$X_{L2,t} \le \sum_{g=1}^{2} \sum_{p=1}^{2} AVAILFOR_{g,p,t} \tag{5.16}$$

$$AVAILFOR_{g,p,t} = ((RAIN_t / 12.59) * 111 - 10.6) / 100 * YIELD_g / 25 * ACRE_{g,p} * (UTIL_{g,p} - 2*OVER_{g1,p2,t-1}) \tag{5.17}$$

$AVAILFOR_{g,p,t}$ is the amount of forage available from the summer public permit pastures. $ACRE_{g,p}$ is the exogenous number of acres of riparian and upland area in the pastures. $(RAIN_t / 12.59) * 111 - 10.6) / 100$ is Sneva and Hyder's regression equation for the forage yield index. $RAIN_t$ is an exogenous parameter that can be set at a low, median or high value, depending upon the crop year precipitation condition desired. $YIELD_g$ is the calculated amount of forage produced during a median year of crop year precipitation. (This figure was calculated from vegetation sampling as described in the last chapter). It is divided by 25 lb/AUD to convert the equation into terms of animal unit days.

Nonproject pasture utilization ($UTIL_{g,p1}$) is set at the agency's desired utilization level of 35 percent riparian usage and 50 percent utilization for the uplands. Utilization on the second public lease pasture ($UTIL_{g,p2}$) depends upon whether off-stream water and salt is provided. Data collected at the Hall Ranch suggests the ratio between riparian and upland utilization is influenced by off-stream water and salt. When off-stream water and salt is provided, a larger percentage of upland vegetation is grazed compared to riparian vegetation. This is not true when off-stream water and salt were not provided. If cattle have to be removed when utilization reaches the 35 percent in the riparian area, more upland forage can be consumed before reaching this restriction if cattle are distributed out of the riparian area. The study shows only 25 percent of the upland forage will have been grazed when the 35 percent utilization level is reached in the riparian area. Table 5.3 lists the allowable utilization levels.

Table 5.3. Riparian utilization standard and resulting upland utilization for public lands.

	Nonproject Pastures (p1)	Project Pasture (p2) without Off-Stream Water	Project Pasture (p2) with Off-Stream Water
Riparian Vegetation	0.35	0.35	0.35
Upland Vegetation	0.5	0.25	0.5

The model is provided with the option of continuing to graze beyond the desired utilization levels. $OVER_{g1,p2,t-1}$ is the percent of the riparian vegetation that is consumed beyond 35 percent the previous year in the treatment period pasture, P2. It also acts as the agency's penalty and is calculated in equation 5.18. This equation allows for grazing above the restricted levels and represents the forage available for consumption as X_{L5} (equation 5.19).

$$OVERFOR_{g,p2,t} = ((RAIN_t / 12.59) * 111 - 10.6) / 100 * YIELD_g / 25 * ACRE_{g,p} * OVER_{g1,p2,t} \tag{5.18}$$

$$X_{L5,t} \leq \sum_{g=1}^{2} \sum_{p=1}^{2} OVERFOR_{g,p,t} \tag{5.19}$$

The physical limit to vegetative utilization is set at 75 percent (equation 5.20).

$$UTIL_{g,p} + OVER_{g,p,t} \leq 0.75 \tag{5.20}$$

Results from the two years of the dispersion study showed pastures without upslope water and salt utilized 55 percent of the riparian vegetation and 39 percent of the upslope forage. In contrast, the water project distributed the cattle throughout the pasture, with 18 percent of the riparian area forage utilized and 35 percent of the upslope vegetation. Equations 5.21 and 5.21a are the ratios of utilization based upon the data collected at Hall Ranch.

$$OVER_{g1,t} \geq 1.4 * OVER_{g2,t} \tag{5.21}$$

$$OVER_{g1,t} \geq 0.7 * OVER_{g2,t} \tag{5.21a}$$

The assumption has been made that the cattle are grazing in the same distribution ratio between the riparian and upland throughout the grazing season. Based upon the GIS analysis from the first year, this appeared to be true for cattle in pastures with off-stream water and salt. In contrast, the non-dispersion project pastures showed cattle concentrated in the riparian early in the grazing period and in the uplands more heavily in the latter parts of the grazing period.

Equation 5.22 represents forage demand for the entire year. Cow/calf pairs are calculated as one animal unit and yearlings are 0.75 of an animal unit. Calves, bulls and horses are assumed not to consume from the forage available.

$$\sum_{L=1}^{5} X_{L,t} \geq (COW_t + FIRST_t + 0.75 * REPL_t)*365 \tag{5.22}$$

Objective Function

The objective function (equation 5.23) is set to maximize the present value of total gross margin (revenue minus variable costs) and terminal value (an infinite set of net returns from herd) less dispersion project costs over a sixty year planning horizon. Sixty years were chosen to represent the lifetime of the operation. As noted earlier, the ranch may still be in operation beyond the sixty years, but discounting will cause the present value of costs and benefits beyond this time frame to be very small and is accounted for in the terminal value.

$$\text{Max } Z = \sum_{t=1}^{60} DF_t * (INCOME_t - VARCST_t) + TERM \qquad (5.23)$$

Gross margin (Z) is defined as revenue ($INCOME_t$) minus variable costs, ($VARCST_t$) minus the annual share of the water project investment. Present value is calculated by multiplying the annual gross margin by the discount factor (DF_t) shown in equation 5.24. The present value of the stream of gross margin values is then found by summing those discounted values. TERM represents the terminal value that is discussed later.

$$DF_t = (1 + r)^{-t} \qquad (5.24)$$

The discount rate, r, is used for converting future values to present values. As discussed in the theory chapter, three, seven and ten percent discount rates have been chosen to represent a social, moderate and private discount rate, respectively.

Equation 5.25 represents the revenue of the operation.

$$INCOME_t = (SELLCOW_t * COWWT + SELLYEAR_t * YEARWT)$$

$$* MKTCOW_t + (SELLCALFF_t * CALFFWT + SELLCALFM_t$$

$$* \text{CALFMWT}) * \text{MKTCALF}_t \qquad (5.25)$$

$SELLCOW_t$, $SELLYEAR_t$, $SELLCALFF_t$ and $SELLCALFM_t$ are all endogenous variables. Calves in pastures with off-stream water and salt were found to have gained 0.3 lb/day more than calves raised in pastures without the dispersion project ($p<0.01$). Typical selling weights for calves are 5.25 cwt for heifer calves and 5.75 cwt for steer calves (Turner et al., 1996). Calf weights (CALFFWT and CALFMWT) are increased to 5.38 cwt and 5.88 cwt, for heifer and steer calves respectively, that are grazed in pastures containing the dispersion project. Weight is set at the typical selling weight of the region for calves not grazing dispersion project pastures. Yearling heifers were not studied at the Hall Ranch, so the selling weight for yearlings is set at 8.0 cwt for all models.

A significant difference was found between treatments for the average daily gain by cows and first calf heifers ($p<0.01$). Those cows grazing within the pastures with upslope water and salt gained 0.6 lb/day more than cows in the nontreatment pastures. This translates into an extra 27 pounds of weight gain over the 1.5 months of grazing with upslope water. COWWT is set at 11 cwt for cows in the basic model and at 11.27 cwt in the water project version.

The selling price ($MKTCOW_t$ and $MKTCALF_t$,) that ranchers receive for their product is a source of risk. Plotting the real prices for beef cattle in Oregon against time illustrates a price cycle as shown in Figure 5.2. Stringham (1983) hypothesized two reasons for this cyclical nature. Producers, motivated by profit, base decisions on expected prices. The other reason is the biological characteristics of bovine reproduction and growth that requires a lag of 3 to 5 years before shifts in cattle numbers are realized. The model design accounts for the biological time lags through its equations of motion

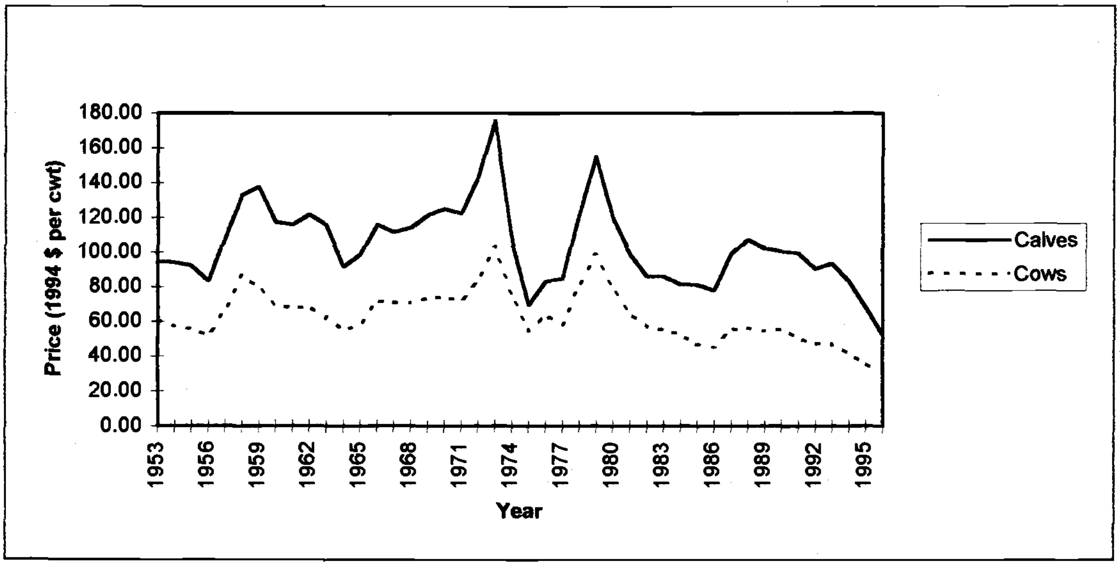

Figure 5.2. Oregon beef cattle price cycle, November 1953-1996 (USDA, 1997).

for cattle. The model assumes future prices are known with certainty. Three values representing low, median and high market prices for cows and calves are used in the model for sensitivity analysis.

Firms have two types of costs, fixed and variable. Fixed costs are those expenses that do not change with the level of production and exist even if production ceases. They are an important factor in the decision of whether or not to produce, but not in the level of production (Workman, 1986). Thus, fixed costs have not been calculated in this model, with the exception of the investment in the dispersion project equipment.

The initial investment of the dispersion project is estimated to be $2,400 which includes the hydraulic ram pump, associated plumbing, water transport system, salt feeders and labor. The useful life of the project is 10 years. If the installation cost is spread out over its useful life, the pump costs $240 per year to employ. Labor costs for employing the system are $42 for the 1.5 months of use based on annual startup time and

15 minutes every other day at a wage rate of $7.00 per hour. Maintenance costs are $36.40 for the water system and $120 for a 1.5 month supply of trace mineralized salt for 300 cows. The total annual cost of the dispersion project is $438.40 per year and is added to the cost equation when running the project version of the model. There is no salvage value associated with the dispersion project beyond its useful lifetime.

Variable costs (equation 5.26) are tied to the level of production.

$$VARCST_t = 12 * (COW_t + FIRST_t) * COWCST + \sum_{L=1}^{5} X_{L,t} * C_L \qquad (5.26)$$

Table 5.4 outlines variable and forage costs of a typical cow/calf ranch in northeastern Oregon. $X_{L,t}$ represents the quantity of forage supplied by hay, private and public pastures and is solved within the model. C_L is the cost of each type of forage and is also listed in Table 5.4.

Equation 5.27 denotes the terminal value. Since investment in the ranch will last beyond the planning horizon, the terminal value incorporates these revenues into the decision in the last year, T. It is calculated as the present value of an infinite series of net revenue multiplied by the number of animals in the herd in the last year. NETREV is calculated by placing low, median and high market prices in the Turner et al.(1996) enterprise budget for 300 cow-calf operation to yield typical returns for that price state.

$$TERM_{60} = ((HERD_t - SELLCOW_t - SELLYEAR_t)*NETREV)$$

$$/ r * (1-1/(1 + r)^T) \qquad (5.27)$$

Table 5.4. Variable costs for a cow-calf operation.

Variable Costs (COWCST)	*per cow - month*
Bull Service	0.93
Horse Service	0.17
Salt & Minerals	0.47
Fuel & Lube	0.79
Interest on Capital	0.62
Labor (hired & family)	6.20
Repairs to Equipment	0.96
Supplies	0.28
Utilities	0.67
Vet & Med	1.18
Brand Inspection	0.14
Marketing Fees	0.97
Accounting	0.33
Legal and Related Expenses	0.28
Miscellaneous	0.42
Total :	$14.41

Cost of Forage Supply per AUM (C_L)	*Own*	*Public Lease*	*Private Lease*
Maintenance	2.50	1.97	0.69
Lease	0	1.80	7.77
Miscellaneous	0	1.48	0.05
Total :	$2.50	$5.25	$8.51

Hay Supply per AUM (market price)	
Native Hay Production	24.00
Alfalfa Hay Production	30.00
4:1 native to alfalfa	$25.20

Source: Turner et al., 1996; Obermiller, 1992.

Solution Method

The program code is written to be solved by the General Algebraic Modeling System (GAMS) developed by Brooke et al. (1992). GAMS was created to provide a system structure and programming language that would ease the construction of large and complex mathematical programming models. The specific GAMS solver used is GAMS/MINOS (Modular In-core Nonlinear Optimization System) developed by Murtagh and Saunders (Gill et al., 1992). Models with nonlinear constraints using the MINOS solver are optimized through a projected Lagrangian algorithm. The complete GAMS code for the model is found in Appendix A.

Chapter 6: Results

In this section, the interpretation of the model solutions is given along with a reminder of the assumptions made. Discussion follows on how the model parameters are transformed to answer thesis objectives. These objectives include determining the economic impact of providing off-stream water and salt in pasture uplands (dispersion project), testing the sensitivity of the model results to discount rate and planning horizon and estimating the impact of public land riparian utilization standards on ranches. The economic impact of the dispersion project is determined under two scenarios. The first scenario is the one described in the previous chapter where the penalty for exceeding the riparian utilization standard is a decrease in the amount of forage permitted for the next year. The other scenario examines the economic impact of the dispersion project if grazing is allowed at a fifty percent utilization of total pasture vegetation. The model is also modified to examine how changes in the discount rate, planning horizon and riparian utilization standards change ranch decisions under the first scenario.

Interpretation of Model Solution

A common simplification in mathematical programming is the relaxation of constraining variables as integers. According to Kennedy (1986), it is only important to constrain activity levels to integers when values of decision variable are low. Although a cow could be split into units smaller than one by selling it before the end of the decision year, several variables reported in this thesis are rounded to the nearest whole number, since parameter values are based on sales occurring once a year. The variables that are rounded to the nearest whole number are cows, first calf heifers, yearling replacement heifers and calves.

The model is run using a 60 year time horizon to capture the economic value of the variables over the lifetime of the ranch. This produces 60 activity levels (one for each year) for each decision variable. As a set, these values will maximize the objective function subject to resource constraints. Decision variables include such items as the number of cows to cull and the amount of hay to feed. Refer back to Table 5.1 for a complete listing of the variables. An example of the complete solution set for the model run with the dispersion project and median levels of crop year precipitation and market prices is included in Appendix B. Components of this solution set are described in the next paragraph.

Throsby (1967) describes the three decision variable sets within the solution. The first series is a period of adjustment in which initial resource numbers are moving toward equilibrium levels. In the solution example, year one includes the initial resources. Years two through eight reflect adjustments in herd size. In this case, more heifer calves are being retained in the present so that the number of mother cows in the future can increase to the long run equilibrium level. Throsby's second set is the steady state or long run equilibrium in which the decision variables repeat the same activity levels each year. Notice in Appendix B that for years 9 through 54 in the example solution set, the activity levels for the number of mature cows remain at 283, 54 for first calf heifers, 72 for replacement heifers and so on for all the decision variables. The last series of values are the adjustment from the equilibrium state to levels that help maximize the objective function through the terminal value equation. In this case, the model maximizes the number of animals in the herd for years 57 to 59 so that a large amount of revenue can be obtained for the last years. The planning horizon of the model is sufficient to solve for a long run equilibrium state that is not influenced by the terminal value. The values reported in this analysis are the long run equilibrium activity levels (years 9 through 54 in the example). Thesis objectives are achieved by comparing ranch operations in long run equilibrium. The last adjustment period and terminal value do not have relevance to this thesis.

The solution also contains information on the Lagrangian multipliers, λ, or shadow prices for constrained resources. A shadow price is the amount the objective function changes when a unit of a constrained resource is added to the resource mix. For example, the ranch starts with an initial herd size of 255 mature cows in the model. In years of high forage production, the herd size in long run equilibrium is larger than this initial endowment. The ranch loses potential revenue because of time lags while adjusting its herd size. The shadow price assigned to the initial cow constraint generates the additional gross margin if there were 256 cows in year one. If the shadow price is zero, this indicates that the resource constraint is not binding. An example is given in the discussion of objective one.

Information pertaining to decision variables not in solution is also available. Variables not in solution are those variables that have activity levels of zero or are not used in long run equilibrium. The reduced cost is the amount the objective function is reduced when an activity not in solution is forced into use. For example, with low cattle prices, privately leased AUMs are not a cost effective forage source. The reduced cost associated with this supply would establish the necessary price decrease in private lease rates before it would enter as a forage supply. An example is given later for reduced cost pricing in the discussion of objective one.

Reminder of Major Assumptions

It is important to reiterate the assumptions made in the construction of this model. The ranch is acting under the conditions of perfect competition that include the knowledge of future prices and crop year precipitation. Precipitation conditions only influence forage production on public lease pastures. The ranch is based upon an Oregon State University enterprise budget for a 300 cow-calf operation in the northeastern mountain region of Oregon (Turner et al., 1996). There is one major modifications from the budget's outline. Three hundred forty five AUMs of private lease pasture are added as a forage supply option. In this region, a high percentage of pasturelands are public lands making private leasing not a readily available option. However, it was felt that this would be a potentially viable alternative. This private lease option could inflate the model's herd size by approximately 29 animal units over the typical 300 cow ranch.

Objective One: Economic Impact of Providing Off-Stream Water and Salt

The economic impact is the change in the ranch's annual gross margin, less annual dispersion project costs, when off-stream water and salt are provided to cow-calf pairs during one and half months of summer grazing. The economic feasibility analysis does not include any multiplier effects to other parts of the economy nor does it calculate the total economic benefit/loss that a properly/improperly functioning riparian system would provide.

The dispersion project has three significant impacts on annual gross margin. The first is the direct cost of the dispersion project. The fixed costs are spread over the lifetime of the equipment and termed the annual dispersion project cost. Increases in variable costs such as labor are also included as an additional annual dispersion project cost. The second impact is the benefit of better cattle distribution. This allows more forage to be consumed in the uplands of pastures with off-stream water and salt, before the riparian utilization limit is reached. This translates into more animal units allowed to graze or fewer AUMs purchased from other sources such as leased pastures and hay. The third impact is the increase in weight gain for cows and calves grazing in pastures with the dispersion project.

For simplification in the interpretation of the model results, the economic analysis of the dispersion impacts is run at the seven percent discount rate to reflect a moderate discount rate. Objective two in this section will explore how the activity levels change as the discount rate is altered. The nine states of nature representing combinations of precipitation and market price conditions have been assigned numbers to simplify interpretation of the model. The model number refers to the levels of crop year precipitation and cattle prices with 1 = low, 2 = median and 3 = high. When a p is present, off-stream water and salt are provided in the uplands of the summer pasture.

Scenario A. Riparian Utilization Penalty

Scenario A assumes that there is a 35 percent utilization limit on public land riparian areas. If utilization above this level occurs, a reduction in the ranch's permit is invoked for the next year. This penalty is set so that at a seven percent discount rate, ranches do not find it profitable to exceed the limit. The list of the steady state market activity levels, phase two of the solution variable set, are displayed in Table 6.1 for the nine states of nature (three crop year precipitation levels and three cattle price levels) which the model is run under. The culling rates, subject to minimum constraint levels, are 15 percent for cows and 25 percent for yearlings. In all states of nature, 48 percent of heifer calves are retained as possible replacements. These rates are consistent with those included in the OSU enterprise budget.

Table 6.2 is a more detailed presentation of the number of cows stocked under each state of nature. Herd size fluctuates based on precipitation, price level and employment of the dispersion project. Forage consumption also fluctuates with precipitation, price and implementation of the dispersion project as shown in Table 6.3. Private lease as a forage supply option is undertaken only when prices are in the median and high categories. This means that herd size is reduced by approximately 42 cows during low cattle prices. Under the condition of limiting riparian utilization to 35 percent on public lands and low cattle prices, this also means that a 300 cow ranch cannot support the herd if off-stream water and salt are not provided during median precipitation years. In all model versions, the maximum allowable level of forage is consumed from privately owned range, which is restricted regardless of precipitation conditions to one

Table 6.1. Long run equilibrium decision levels for production under scenario A (penalty for exceeding 35 percent utilization of riparian vegetation on public lands) at seven percent discount rate.

	Cattle Numbers				
Model	Mother Cows	Repl. Calves	Culled Cows	Culled Yearlings	Culled Calves
11*	239	51	36	13	160
11p	264	56	40	14	176
21	266	57	40	14	177
21p	295	63	44	16	197
31	294	63	44	16	196
31p	331	71	50	18	220
12	281	60	42	15	188
12p	307	65	46	16	205
22	307	66	46	16	205
22p	337	72	51	18	225
32	336	72	50	18	224
32p	373	79	56	20	248
13	281	60	42	15	188
13p	306	65	46	16	204
23	307	66	46	16	205
23p	337	72	51	18	225
33	336	72	51	18	224
33p	373	80	56	20	248

* Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

month of feed for 345 animal units[12]. Under all price conditions, hay is fed only during the required five months of winter. The highest allowable level of forage use, under desired riparian utilization levels, is consumed from public lease. Notice in Table 6.3,

[12] If all pastures had been allowed to fluctuate under the various crop year precipitation levels, herd size would have more dramatic decreases in dry years, remain constant in median years and higher increases in wet years.

Table 6.2. Long run equilibrium number of cows for ranches operating with and without the dispersion project under scenario A (penalty for exceeding 35 percent utilization of riparian vegetation on public lands) at seven percent discount rate.

	Precipitation					
	Dry		Median		Wet	
Price	Non-project	Project	Non-project	Project	Non-project	Project
Low	239	264	266	295	294	331
Median	281	307	307	337	336	373
High	281	306	307	337	336	373

Table 6.3. Long run equilibrium decision levels for forage usage (in AUD) under scenario A (penalty for exceeding 35 percent utilization of riparian vegetation on public lands) at seven percent discount rate.

	Feed Source			
Model	Own forage	Public lease	Private lease	Hay
11*	31,740	27,446	0	42,236
11p	31,740	33,465	0	46,532
21	31,740	33,871	0	46,821
21p	31,740	41,299	0	52,122
31	31,740	40,979	0	51,894
31p	31,740	49,967	0	58,307
12	31,740	27,446	10,350	49,622
12p	31,740	33,465	10,350	53,918
22	31,740	33,871	10,350	54,207
22p	31,740	41,299	10,350	59,508
32	31,740	40,980	10,350	59,280
32p	31,740	49,967	10,350	65,693
13	31,740	27,446	10,350	49,622
13p	31,740	33,465	10,350	53,918
23	31,740	33,871	10,350	54,207
23p	31,740	41,299	10,350	59,508
33	31,740	40,980	10,350	59,280
33p	31,740	49,967	10,350	65,693

* Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

the maximum value for public forage changes depending upon the precipitation conditions and the use of the dispersion project. For the median rain and price model, an extra 7,428 AUDs of forage consumption are supported with improved distribution between riparian and upland areas. This yields enough forage to support an additional 34.5 animal units for seven months.

In all states of nature, the dispersion project increases the ranch's annual gross margin less annual dispersion project costs. Table 6.4 illustrates the change in annual ranch gross margin realized when cattle are provided off-stream water and salt during a month and half of summer grazing. Increases of \$3,820 - \$13,008 are found by implementing the dispersion project, depending upon precipitation and price conditions. Even in low price and drought conditions, an additional \$3,820 in annual gross margin is generated from implementing the dispersion project. This indicates a rather rapid payback period for the project[13].

An analysis of the increased \$7,289 in annual gross margin for the median price and precipitation state of nature shows approximately half (\$3,752.50) is from the increased weight gain of cattle grazing in pastures with the dispersion project. The remaining amount of increase can be attributed to the income from the sale of the extra twenty calves, two heifer yearlings and five culled cows that are produced by the larger herd. This is illustrated in Figure 6.1, a comparison of cattle activity levels for a ranch not employing the dispersion project and for one that is providing off-stream water and salt.

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[13] Initial investment costs for the dispersion project are approximately \$2,400 which in this analysis is spread over its useful life of ten years.

Table 6.4. Change in annual gross margin less dispersion costs when dispersion project is implemented under scenario A (penalty for exceeding 35 percent utilization of riparian vegetation on public lands) at seven percent discount rate.

	Precipitation		
Price	Dry	Median	Wet
Low	+ $3,820	+ $4,526	+ $5,303
Median	+ $6,595	+ $7,289	+ $11,737
High	+ $9,327	+ $11,075	+ $13,008

To compensate for the reality of imperfect information, economists often calculate the expected value of a project. Expected value is determined by assigning probabilities to the different states of nature. The crop year precipitation data has a normal distribution with a standard deviation of 2.6 inches. The probability of precipitation being equal to or less than the low value is twenty percent[14]. The probability of the rain being greater than or equal to the high value is seventeen percent[15]. This yields a sixty three percent chance that the value will be near the median value (within plus or minus one standard deviation). Cattle prices exhibit autocorrelation because of their tendency to follow a trend in the price cycle. In other words, cattle prices do not generally jump from a low price in one year to a high price in the following year. Therefore, the probability of switching between low, median and high values is extremely low. To compensate for this fact, three expected values of the dispersion project, one for each price level, are calculated according to the probability of the precipitation states.

[14] The method used for expected value overestimates the expected value in dry years.
[15] The method used for expected value underestimates the expected value in wet years.

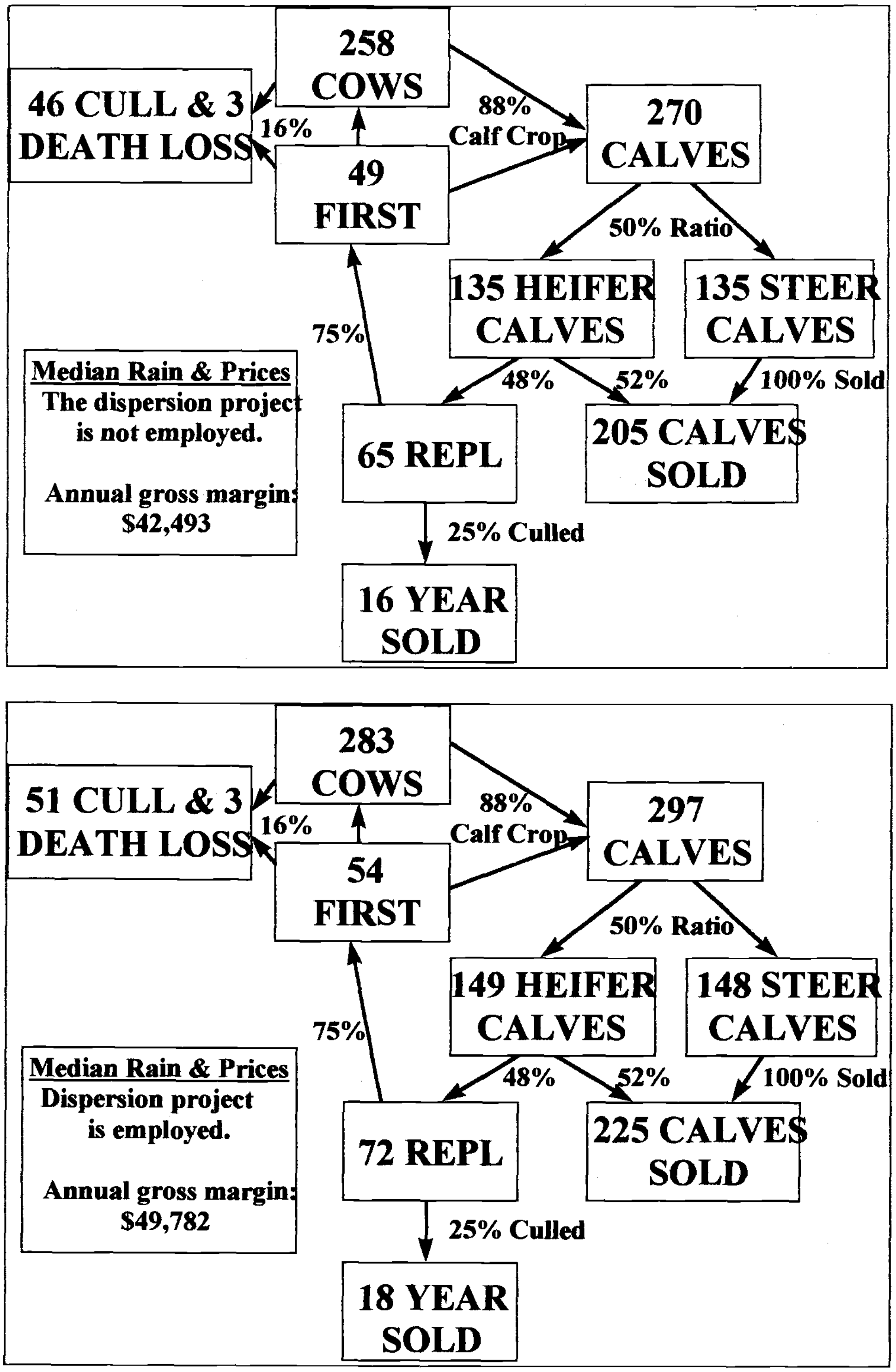

Figure 6.1. Flowchart for marketing decisions for median precipitation and price conditions when dispersion project is not employed (top) and when dispersion project is employed (bottom).

Table 6.5 is the payoff matrix for the expected value of the off-stream water and salt project. During the low period of the cattle price cycle, which Oregon ranchers were facing during the study, the project has an expected value of $4,517 in increased annual gross margin less the annual cost of implementing the dispersion project. As cattle prices increase, the expected value increases to $7,358 and $11,054 for median and high prices.

Table 6.5. Expected value for off-stream water and salt in terms of change in annual gross margin less the dispersion project costs under scenario A (penalty for exceeding 35 percent utilization of riparian vegetation on public lands) at seven percent discount rate. (Expected value determined by multiplying the change in gross margin for that state of nature by the probability of that precipitation state occurring).

	Precipitation			
Price	20% probability of a dry year	63% probability of a normal year	17% probability of a wet year	Expected value
Low	20% *$3,820	63% * $4,526	17% * $5,303	+ $4,517
Median	20% * $6,595	63% * $7,289	17% * $11,737	+ $7,358
High	20% * $9,327	63% * $11,075	17% * $13,008	+ $11,054

Table 6.6 shows the reduced costs and shadow prices for the various state of nature models run at a seven percent discount rate. Notice that in Table 6.3 during the low cattle price runs of the model, privately leased forage is not in solution. The reduced costs, or the decrease in price necessary for it to be in solution, is $0.03/AUD for non-dispersion project herd size and $0.02/AUD for dispersion project herd sizes. This means the current rate of $8.66/AUM for privately leased pasture would have to fall to $7.76/AUM and $8.06/AUM respectively to be used at low cattle prices.

The shadow prices of the solution provide the rancher information on the marginal value of increasing a limited resource. A prime example is the initial herd size since the model does not allow for the purchase of cows. The shadow price assigned to the cow provides information on the additional gross margin that an additional cow in year one would earn and are listed in Table 6.6. The shadow price for an initial cow in the model with median precipitation and prices and the employment dispersion project is $850.30. Therefore, if it is possible to purchase a cow for less than this value, it would be beneficial to the rancher's gross margin to do so in the first year.

Table 6.6. The value of an additional cow or the amount the price of private lease (AUD) must decrease before it is in solution.

	Shadow price	Reduced cost
Model	Initial number of cows	Private lease per AUD
11*	$548.68	-$0.03
11p	$670.76	-$0.02
12	$735.81	
12p	$845.48	
13	$997.03	
13p	$1,112.31	
21	$668.41	-$0.03
21p	$677.12	-$0.02
22	$846.50	
22p	$850.30	
23	$1,107.71	
23p	$1,112.31	
31	$668.41	-$0.03
31p	$711.86	-$0.02
32	$846.49	
32p	$928.12	
33	$1,107.71	
33p	$1265.98	

* Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

Scenario B. Project on Own Pasture with no Penalty

The dispersion project's expected value can also be calculated for situations in which the rancher is allowed a higher utilization level. For example, many range managers graze their own riparian lands at a 50 percent utilization level. The model is modified to reflect this type of situation to determine if the project would increase annual gross margin. This is accomplished by removing the penalty in the forage equation of motion (eq. 5.17) and increasing the allowable utilization percentages that are found in Table 5.3. Table 6.7 illustrates the calculated expected change in annual gross margin less dispersion project costs when the project is implemented under these conditions. The expected value of providing off-stream water and salt is $2,424, $3,312 and $3,976 under low, median and high price levels, respectively. These increases in expected gross margin are created from the additional weight gain of the culled cows and sold calves.

Table 6.7. Expected value for off-stream water and salt in terms of change in annual gross margin less the dispersion project costs under scenario B (riparian utilization of vegetation set at fifty percent on public lands) at seven percent discount rate. (Expected value determined by multiplying the change in gross margin for that state of nature by the probability of that precipitation state occurring).

	Precipitation			
Price	20% probability of a dry year	63% probability of a normal year	17% probability of a wet year	Expected value
Low	20% *$2,122	63% * $2,428	17% * $2,764	+ $2,424
Median	20% * $3,476	63% * $3,314	17% * $3,699	+ $3,312
High	20% * $3,191	63% * $4,109	17% * $4,536	+ $3,976

Objective Two: Importance of Discount Rate and Planning Horizon

In resource economics, both the discount rate and the planning horizon are important parameters since they influence the present value of future gains and losses. The discount rate is used to account for opportunity cost, risk and inflation. The planning horizon is the length of time for which the benefits and costs are estimated. The choice of the discount rate and planning horizon is often subject to debate due to intergenerational equity questions.

Discount Rate

The models of scenario A (riparian penalty) are run at both three, seven and ten percent discount rates to test the sensitivity of model results to the discount rate. The results of the sensitivity analysis are presented in Table 6.8 that compares the optimal herd size under each discount rate. At the median cattle price level, the discount rate does not affect herd size under any of the precipitation condition states. This is consistent with Throsby (1967) who stated that the steady state decision variables were independent of the discount rate. However, the model is sensitive to discount rates when prices are at the low end and high end of the price cycle. When the price is at a high level, at the three percent discount rate, the optimal herd size (412 cows) is the largest herd numbers allowed by ranch resources. The larger herd size is supported by feeding hay to the cattle for a longer period than required by the winter forage constraint. This result occurs because at a low discount rate, the present value of future income is not discounted as

Table 6.8. Number of cows at long run equilibrium with changing discount rates for ranches providing off-stream water and salt.

	Discount Rate		
Model	3%	7%	10%
11p*	307	269	193
12p	307	307	307
13p	412	306	306
21p	337	295	208
22p	337	337	337
23p	412	337	337
31p	373	331	225
32p	373	373	373
33p	412	373	373

* Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

severely. To maximize total gross margin, less dispersion project costs over sixty years, the ranch should support the largest herd possible to receive the greater revenue associated with high cattle prices.

Referring to Table 6.8, the models 11p, 21p and 31p (all three precipitation states at low cattle prices and using the dispersion project) are sensitive to the discount rate. As the discount rate increases, herd size decreases. As herd size changes, so do the forage supplies that enter in solution. At a three percent discount rate, hay, privately owned, privately leased and public lease pastures enter in the optimal long run solution. At a seven percent discount rate, the privately leased pastures no longer enter, which results in a decreased herd size of 38 cows. The model's optimal forage supply mix also does not use privately leased pastures at the ten percent discount rate. It does, however, choose to graze beyond the desired 35 percent riparian use. This enacts the penalty, reducing the amount of forage from public pastures that can be purchased.

The choice to receive the penalty may be due to two possible reasons. First, the penalty imposed in later years is worth relatively less. Second, the model's objective function is designed to maximize the present value of *total* gross margin. Table 6.9 demonstrates how the objective to maximize the present value of total gross margin causes the model at the ten percent discount rate to sell large amounts of cattle from the herd in the first several years before it is heavily discounted. As shown in Table 2.1, by year ten, the ten percent discount rate coefficient is 0.39, almost half the discount coefficient for the seven percent discount rate. Thus, a model maximizing present value of total gross margin at a high discount rate would seek to generate large amounts of revenue in the first several years, even though long run equilibrium levels are lower.

Table 6.9. Initial adjustment period, under a seven and ten percent discount rate for a ranch providing off-stream water and salt when crop year precipitation is at a median level and cattle prices are low.

	7% Discount Rate				10% Discount Rate			
Year	Cows	Sold Calves	Gross Margin	Public Lease Utilization	Cows	Sold Calves	Gross Margin	Public Riparian Utilization
1	300	213	$32,740	above 35%	300	264	$56,509	above 35%
2	297	187	$21,381	35%	252	261	$57,657	above 35%
3	297	192	$25,202	35%	249	177	$29,511	above 35%
4	296	198	$26,010	35%	209	139	$20,545	above 35%
5	295	197	$26,010	35%	175	139	$19,602	above 35%
Long Run*	295	197	$26,010	35%	208	139	$20,398	above 35%

* Long run indicates the variable levels when the model reaches steady state (long run equilibrium).

Planning Horizon

To test how decisions would change under a short term planning horizon, the forage equation of motion is removed. This will cause the forage available from public lease pastures to lose the penalty linkage between years. The model is run for a single year time horizon and repeated for a number of years. The forage loss due to the penalty for exceeding desired utilization levels in the previous year is inserted as a static parameter in each year. Table 6.10 lists the comparison between this short term planning and the long run equilibrium results for model 21p (median crop year precipitation, low cattle prices and employment of the dispersion project). The first year's decision is to stock the pastures with 326 cows. This is 31 more cows than the steady state equilibrium. These extra grazing cows increase the first year's gross margin by $3,822 over the long run equilibrium level. While the steady state's gross margin remains constant, the second year short term gross margin diminishes by $4,953 due to the forage loss associated with the utilization penalty. In the second year and every subsequent year, the decision is to keep exceeding the utilization limit at the highest level possible. If the short term planning ranch continued to operate, it would always have reduced gross

Table 6.10. Number of cows and gross margin under different planning horizons.

	Year 1		Year 2		Long Run	
Time Horizon	Cows	Gross Margin	Cows	Gross Margin	Cows	Gross Margin
Yearly Planning	326	$29,826	264	$24,873	264	$24,873
Long Term Planning	295	$26,004	295	$26,004	295	$26,004
Difference	31	$3,822	-31	-$1,131	-31	-$1,131

margins compared to a ranch that did not overstock in the first year. The model only restricted public land forage use based upon exceeding the previous year's utilization standard rather than a cumulative effect. When the model is run with a cumulative penalty, the rancher would lose all of his permitted AUMs by the fourth year.

A ranch manager would have to be economically irrational under the conditions of this model to follow the scenario of repeatedly exceeding utilization standards without regard to next year's production. However, the example points to the importance of equations of motion and for planning horizon lengths that cover biological time lags. As was shown by Pope and McBryde (1984), there may be cumulative effects on carrying capacity and weight gain caused by the level of grazing. At this time the data on the cumulative effects are not available to incorporate into this model but should be pursued in future research.

Objective Three: Employing the Model for Land Management

Scenario A considers the impact of a riparian utilization standard on public lands when the penalty for exceeding that level results in a loss of forage for the next year. At the seven percent discount rate, none of decision rules for the nine states of nature include exceeding the riparian forage utilization standard. When there are no repercussions for exceeding the standard (short term planning horizon example), the model maximizes present value of total gross margin by grazing to the highest level of AUD available from forage production yields. Thus, the penalty in scenario A is an effective deterrent for the profit maximizing producer under the assumptions of this model.

A properly constructed model can be used to answer "what if" questions. For example, if the agency wants to change from a loss of forage to a monetary fine, the model can be modified to calculate the necessary fine. To determine the price needed to be set, one can look at the reduced cost of exceeding the utilization standard when a high cost is assigned to forage consumed above desired levels and the penalty is removed from equation (5.17). Table 6.11 shows how high a monetary fine would have to be set in order to induce a profit maximizing rancher to not exceed the desired riparian utilization level. It ranges from \$16.20 per AUM in low cattle price years to \$27.00 in times of high cattle prices. Neither the existence of the dispersion project nor changes in precipitation conditions influence these values. For comparison purposes, the cost (including the lease fee and other expenses) of public and private leases per AUM are shown[16]. Agencies often double or triple the private lease rates when levying a fine against trespass use on public lands.

Table 6.11. Fine (\$/AUM) that effectively limits riparian area utilization to the desired level on public lands compared to actual public and private leasing costs.

Cattle price	Effective Monetary Fine	Public Lease Cost	Private Lease Cost
Low	\$16.20	\$5.25	\$8.66
Median	\$20.10	\$5.25	\$8.66
High	\$27.00	\$5.25	\$8.66

[16] The listed price for privately leased AUMs is during a low cattle price cycle. As cattle prices increase, the cost for a privately leased AUM would also be likely to increase.

The model can also be modified to calculate the change in ranch profits when the public lease riparian utilization levels are changed. Again, Table 5.3 is altered to reflect the desired utilization levels and the penalty for exceeding this level is a loss in forage for the next year. When utilizing the dispersion project, riparian forage accounts for three percent of the summer forage at the 35 percent riparian to 50 percent upland use ratio. Table 6.12 shows the change in annual gross margin less dispersion project costs when riparian utilization levels are decreased from fifty to thirty five percent. The model presented here finds it more profitable to reduce herd size since the only alternative for supplying lost forage is to purchase hay. Decreases in annual gross margin are in the range of $159 to $733 depending upon precipitation and price levels.

Table 6.12. Annual gross margin for 300 cow ranch changing from a 50% to a 35% riparian utilization standard on public lands.

	Riparian Utilization Level		Change in
Model	50%	35%	Gross Margin*
11p**	$23,644	$23,485	- $159
12p	$43,249	$42,977	- $272
13p	$77,201	$76,710	- $491
21p	$26,206	$26,010	- $196
22p	$50,135	$49,782	- $353
23p	$85,130	$84,524	- $606
31p	$26,550	$26,335	- $215
32p	$55,244	$54,817	- $427
33p	$93,903	$93,170	- $733

* Change in gross margin does not include costs for excluding cattle from riparian areas.
** Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

Tables 6.13 and 6.14 present the change in annual gross margin when cattle are excluded from the riparian area on public lands when previous utilization levels were fifty percent and thirty five percent, respectively. These tables do not include the costs of excluding cattle which is an estimated cost of $1,815 per mile per year when spread over the fence's 10 year life (OSU, 1996). Losses in annual gross margin are estimated to be in the range of $528 to $2,443, depending upon precipitation and cattle prices when previous utilization was at fifty percent. When riparian utilization is restricted from thirty five percent to zero, annual gross margin decreases by $369 to $1,638, depending upon the state of nature. This analysis assumes a low dependency (three percent) upon riparian public lands as a forage supply. If the dependency had been higher, then associated gross margin losses would also be higher.

Table 6.13. Annual gross margin for 300 cow ranch changing from a 50% to a 0% riparian utilization standard on public lands.

	Riparian Utilization Level		Change in
Model	50%	35%	Gross Margin*
11p**	$23,644	$23,116	- $528
12p	$43,249	$42,344	- $905
13p	$77,201	$75,565	- $1,636
21p	$26,206	$25,553	- $653
22p	$50,135	$48,959	- $1,176
23p	$85,130	$83,111	- $2,019
31p	$26,550	$25,835	- $715
32p	$55,244	$53,821	- $1,423
33p	$93,903	$91,460	- $2,443

* Change in gross margin does not include costs for excluding cattle from riparian area.
** Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

Table 6.14. Annual gross margin for 300 cow ranch changing from a 35% to a 0% riparian utilization standard on public lands.

	Riparian Utilization Level		Change in
Model	50%	35%	Gross Margin*
11p**	$23,485	$23,116	- $369
12p	$42,977	$42,344	- $633
13p	$76,710	$75,565	- $1,145
21p	$26,010	$25,553	- $457
22p	$49,782	$48,959	- $823
23p	$84,524	$83,111	- $1,413
31p	$26,335	$25,835	- $500
32p	$54,817	$53,821	- $936
33p	$93,170	$91,460	- $1,638

* Change in gross margin does not include costs for excluding cattle from riparian areas
** Model number refers to crop year precipitation and prices where 1 = low, 2 = median, 3 = high and "p" indicates whether the dispersion project is employed.

Chapter 7: Conclusions

Rangelands produce clean air, food, water and shelter that sustain life. As humans extract resources to drive their economy, they must remember the larger connection of each element to the ecosystem. The research data collected here should also be examined for its contribution to the holistic vision of managing natural resources. The Hall Ranch dispersion study, where off-stream water and salt are provided to cattle during a month and a half of summer grazing, was undertaken to provide information to enable better management of livestock grazing in riparian areas. Specifically, this thesis represented the economic analysis toward this goal. The following sections emphasize the major points of the research from the economic view and its potential impact on rangeland policy.

Economic Feasibility

Regardless of precipitation, price conditions and regulatory penalties, the upslope water source and salt dispersion project examined in this study has a positive net return for ranches dealing with riparian grazing concerns. Better distribution of cattle allows for more upslope forage to be consumed before reaching desired riparian utilization levels. The cows and calves also show higher weight gains when given access to off-stream water and salt. The initial costs of the hydraulic ram system and salt are estimated to be $2,400. It has an annual operating expense of $156.40 when used for one and a half months. The expected annual value of the project is $4,517, $7,358 and

$11,054 with low, median and high cattle prices, respectively, if an effective punishment for exceeding desired riparian utilization is enacted. The project has an expected net return of $2,424, $3,312 and $3,976 with low, median and high cattle prices when the only benefit is increased weight gain.

The model also shows with current market prices in a low period, the "typical" 300 cow rancher in northeast Oregon would be trying to maintain a herd size larger than optimal under the assumptions made here. The model finds that without the dispersion project only 266 cows can be supported by privately owned range and public pastures when cows are removed after 35 percent utilization of the riparian vegetation. The dispersion project allows the addition of thirty cows to a herd size of 296 because of the increased amount of forage that can be grazed from the uplands. Thus, providing off-stream water and salt may be a way in which traditional grazing levels can remain while environmental objectives (reduced livestock impacts in the riparian area) are also obtained.

Indirect Benefits of the Dispersion Project

There are also indirect economic benefits of the dispersion project that are not captured by the model. The only captured economic value of the increased weight gain is with the sale of cull cows and calves. This weight gain can also be associated with the improved health of cows and better calving success rates (Hart et al., 1988b). As riparian areas recover, they also can provide the rancher with higher quality and quantity of forage (Elmore and Beschta, 1987). More biological research needs to be conducted in riparian lands on the interaction of grazing levels and future forage production yields.

The social benefits of properly functioning riparian lands such as decreased flooding risk, improved wildlife and fisheries habitat, improved water quality, more recreational opportunities and aesthetic values are likely to be higher than the benefits that accrue to the land owner. Lant and Tobin (1989) found that Midwest farmers make "socially inappropriate" decisions concerning floodplain uses because water quality and recreational opportunities are public goods. Market failure occurs in the production of public goods because of their characteristics of being nonexcludable and indivisible for consumption (Tietenberg, 1992). This results in a free rider problem. The public enjoys the benefits of a healthy riparian system but does not pay the cost of its protection. Instead the burden falls to the individual who owns the land or operates an enterprise on it, that may result in less than optimal levels of public goods being generated.

The last section of chapter six examined the loss in ranch gross margin when riparian utilization on the public lands was set at various riparian utilization standards. As riparian utilization is decreased from 50 percent to 35 percent, annual gross margin is reduced by $159 to $733 depending upon the state of nature (precipitation and price conditions). When the riparian area that was open for 50 percent utilization is excluded from use, annual gross margin declines by $528 to $2,443 depending upon the state of nature. If riparian feed accounts for four percent of summer forage, Oregon State University estimated a two percent reduction in gross revenue when accounting for replacement feed and the fencing costs of one mile of stream for one year (OSU, 1996). The riparian forage calculations within this thesis are based on the assumption that the pastures used for grazing are in a three percent riparian to ninety-seven percent upland ratio. This results in a three percent reliance on public land riparian area forage. Other studies conducted in the northeastern Oregon have found the reliance on riparian meadows to be much greater (Kauffman, 1982; Roath and Krueger, 1982). The negative impacts of riparian utilization restrictions on ranch income would increase as the reliance on it as a forage supply increases. The analysis included here also does not consider the expenses associated with fencing riparian areas, which Oregon State University estimated to be $1,815 per mile per year when spread out over the fence's 10 year lifetime.

Sixty percent of Americans agreed that livestock grazing should be limited if it endangers wildlife habitat, even if it meant higher prices for meat (Ohmart and Anderson, 1986). Since beef is a global product, it would be difficult to keep American beef competitive if its price increased. A more favorable solution would be to create incentives to induce voluntary changes in land management. These incentives could include tax credits and subsidized loans for implementing riparian improvements. Other types of cost sharing programs may be a way to encourage ranches to participate in this and other riparian enhancing activities. One example is the Bonneville Power Administration/Oregon Department of Fish and Wildlife's fish habitat improvement plan that was implemented on the John Day River in central Oregon (Wightman and Eisgruber, 1994). The program pays for the initial investment costs and the rancher is responsible for the maintenance of the improvements.

Education is also an important part in the management of natural resources. Ranchers, whose experience on the ground gives them a unique perspective of the situation, can be a valuable source of information. The only way for livestock grazing to change in regard to the management of riparian areas is to involve the rancher. By educating them on the environmental objectives that need to be achieved, they in turn can educate the policy makers into ways those objectives can be achieved without undue hardships to cattle operations. In addition, sharing information on projects such as off-stream water and salt is important. The project has the direct benefit of better cattle weight gains, which results in increased gross margin for the ranch.

Problems with Utilization

The dispersion project analysis demonstrates that regardless of the social benefits that may accrue from better cattle distribution in pastures, the rancher can pay for the initial investment in two years under the conditions of the model. Part of the dispersion returns comes from the assumption that riparian utilization is a key factor in determining when cattle are removed from public lease pastures. However, criticism about utilization as a management tool must be considered. First, the vegetation sampling for utilization analysis is often done after cattle are removed. This means that a rancher will not know until after the fact that riparian utilization has exceeded the standard. To avoid this, a rancher would have to dedicate additional labor to periodic sampling during the grazing season. In addition, the correct method for utilization analysis is subject to debate as mentioned in the literature review. There will continue to be conflict between the ranching industry and public agencies if utilization becomes the measuring stick for management.

Another assumption made in this model is that the utilization ratio between upland and riparian areas remains constant throughout the season. From the preliminary GIS statistical analysis, this appears to be true for cattle within the dispersion project pastures. However, does the same result occur if the project is implemented in different seasons? The quality of forage changes throughout seasons (Vavra and Raleigh, 1976), which could influence the weight gain benefit seen in this project. The riparian area also responds differently to the timing of the grazing (Burkhardt, 1997). It would be beneficial to expand the Hall Ranch dispersion project to examine whether the benefits of off-stream water and salt can be achieved in other seasons.

Public Lands

There are many who feel that the federal government is an inefficient manager of the nation's resources (Gardner, 1997). In regard to livestock grazing on public lands, this criticism arises from the use of utilization standards that have been portrayed as a simple concept for agencies to employ (Burkhardt, 1997). A government can use sticks (penalties) or carrots (incentives) to achieve management objectives. Currently, the Forest Service is planning to use a stick in the form of forfeited forage when ranchers exceed desired riparian utilization levels[17]. As shown earlier, there are a variety of punishments such as losses in forage and monetary fines that would translate into a loss in profits for the rancher. Whether this new stick will be an effective means of achieving riparian recovery remains to be seen.

[17] Johnson, C. Gregory. 1996. Forest Service communication to grazing permittee.

One of the problems with the implementation of a thirty-five percent riparian utilization standard is that with the conditions shown here, it would force ranchers to decrease herd size by approximately thirty cows from the traditional 300 cows that have been able to graze. The dispersion project presented here may be a profitable method for distributing cattle out of the riparian areas to allow current grazing levels to continue, but without the negative impacts of heavy use of riparian areas. Although the ecological assessments have not been determined, the economic feasibility of this project may open the minds of land managers to the concept that being a good steward of the rangeland can have positive net returns. Instead of carrying sticks, providing incentives may yield better results in achieving management goals.

Future Research

It is clear that livestock grazing practices that endanger the integrity of riparian areas will no longer be tolerated. How to change livestock practices so that they are in harmony with the ecosystem is not as clear. More interdisciplinary studies like the one conducted at Hall Ranch in the summer of 1996 and 1997 are needed so that all aspects, ecological, economic and social, are included in finding a solution. The research presented in this thesis is incomplete without the ecological assessments that correspond with the dispersion study[18].

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[18] At the time of this writing, those ecological assessments are in the process of being analyzed.

The level of livestock grazing in riparian areas that is sustainable remains an unanswered question. Riparian ecosystems are highly complex and science will never be able to provide an exact answer. However, it can provide the general direction necessary for changes that will result in better grazing management in riparian areas. Many opinions have been generated that will need scientific validation before they will be accepted by the entire community. However, during this period of data collection, inactivity is not warranted. The greatest tragedy will occur if fighting among ourselves distracts us from improving the health of our riparian ecosystems.

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Appendices

Appendix A: GAMS Model Code

```
* Thesis Model - Amy M. Stillings
* Dept. of Agricultural and Resource Economics
* Oregon State University
* Fall 1997

* Statements used in the model vary according to the state of nature (precipitation and
* cattle price conditions) and if the dispersion project is employed.

* The model is set up to run with median precipitation and cattle prices when the
* dispersion project is implemented.

****Set Section****
 Set  T          Time periods /1*60/
      L          Forage supplier /L1 Spring & fall range, L2 Public lease, L3
                 private lease, L4 Hay, L5 Public beyond desired levels/
      G          Forage location /G1 riparian, G2 upland/
      P          Summer pastures /P1 non project, P2 water project/

****Data Section****
 Scalar
      CLF        Calving % (conception birth rate and death loss) /.88/
      LEASELMT   Limit to amount of AUD off private lease /10350/
      OWNLMT     Limit to amount of AUD off own rangeland /31740/
      CULL       Minimum cull cow rate /.15/
      DEATH      Cow death rate /.01/
      COWCST     Variable cost of cow no forage per month /14.41/
      RHO        Discount rate /.07/

* The following line is used for all models that use the dispersion project.  For all other
* runs, a * is placed in front of it.
      PCST       Pump cost /438.4/
* The following line is used for all models that do not use the dispersion project.  For all
* other runs, a * is placed in front of it.
*     PCST       Pump cost when project not employed /0/


*****Precipitation Parameters - change depending upon desired precipitation state
      Precp      Median precipitation of crop year /12.59/

**Low precipitation condition
* The following statement is used when the model is in a low crop year precipitation
```

* state. For all other models, a * is placed in front of it.
*   Rain /10.43/

**Normal precipitation condition
* The following statement is used when the model is in a median crop year precipitation
* state. For all other models, a * is placed in front of it.
        Rain /12.59/

**Wet precipitation condition
* The following statement is used when the model is in a wet crop year precipitation
* state. For all other models, a * is placed in front of it.
*   Rain /14.98/

*****Market parameters
        YEARWT   Selling weight of yearling heifer /8.0/
* The following lines are used for all models that use the dispersion project. For all other
* runs, a * is placed in front of them.
        COWWT   Selling weight of a cow with dispersion project /11.27/
        CALFFWT   Selling weight of heifer calf with dispersion project /5.38/
        CALFMWT   Selling weight of steer calf with dispersion project /5.88/

* The following line is used for all models that do not use the dispersion project. For all
* other runs, a * is placed in front of it.
*   COWWT   Selling weight of a cow /11.0/
*   CALFFWT   Selling weight of a heifer calf /5.25/
*   CALFMWT   Selling weight of a steer calf /5.75/

****Beef cattle prices - change depending upon desired price state

**Low prices
* The following statement is used when the model is in a low cattle price state.
* For all other models, a * is placed in front of it.
*   MKTCOW /54.82/
*   MKTCALF /86.12/;

**Median prices
* The following statement is used when the model is in a median cattle price state.
* For all other models, a * is placed in front of it.
        MKTCOW /59.81/
        MKTCALF /100.13/;

```
**High prices
* The following statement is used when the model is in a high cattle price state.
* For all other models, a * is placed in front of it.
*       MKTCOW /72.13/
*       MKTCALF /120.32/;

Parameters
 C(L) Cost of Forage Supply in AUD
       / L1 .0833, L2 .175, L3 .284, L4 .84, L5 .0/
 YIELD(G) The normal yield of forage dry lb per acre
       / G1 1158.8, G2 722.5/


 Table ACRE(G,P)  3% area riparian - summer pastures
          P1     P2
     G1  55      32
     G2  1725    1024 ;

* The following lines are used for all models that use the dispersion project.  For all
* other runs, a * is placed in front of it.
   Table UTIL(G,P)  Utilization when dispersion project employed
          P1    P2
     G1  .35   .35
     G2  .5    .5 ;

* The following line is used for all models that do not use the dispersion project.  For all
* other runs, a * is placed in front of it
*    Table UTIL(G,P)  Utilization when dispersion project not employed
*         P1    P2
*    G1  .35   .35
*    G2  .5    .25;

Parameter DF(T) Discount Factor;
      DF(T) $ (ORD(T) GE 1) = (1+RHO)**(-1*(ORD(T)));
Parameter CP(T) Control Period;
      CP(T) = ORD(T)$(ORD(T) GT 1);


****Variable Section****
 Variables
      Z                  Total gross margin less dispersion project costs
      SELLCALFF(T)       Number of heifer calves sold in each year
      SELLCALFM(T)       Number of steer calves sold  in each year
      SELLCOW(T)         Number of cows culled in each year
      SELLYEAR(T)        Number of yearling heifers culled
```

```
        COW(T)                  Mature cows in each year
        HERD(T)                 Herd size
        REPL(T)                 Number of calves in replacement
        TERM                    Terminal value
        NR(T)                   Yearly gross margin less dispersion project costs
        VARCST(T)               Total variable costs per year
        INCOME(T)               Income for the year
        X(L,T)                  Forage
        FIRST(T)                First calf heifers
        AVAILFOR(G,P,T)         Available Forage
        OVER(G,P,T)             Utilization Rate
        OVERFOR(G,P,T) Forage in L5;

  Positive Variable SELLCALFF, SELLCALFM, SELLCOW, SELLYEAR, COW,
        HERD, REPL, AVAILFOR, X, FIRST, OVER, OVERFOR;

****Equation Section****
  Equations
        Profit                  Objective function - Maximize total gross margin
        Inc(T)                  Income equation
        Vari(T)                 Variable costs
        Resource(T)             Resource constraints on ranch
        Forage(T)               Forage S_D
        Permit(T)               Permit land
        Summer(G,P,T)           Available forage from public lease within utilization limit
        Summer2(G,T)            Forage available from public lease over utilization limit
        Permit2(T)              Forage consumed over level
        Utillmt(G,T)            Utilization can not be over 75%
        Pen2(T)                 Utilization ratio between upland and riparian vegetation
        Own(T)                  Land constraint
        Private(T)              Limit to amount of leased AUDs
        Winter1(T)              Feeding hay constraint
        TermV                   Terminal value (Net R infinitely discounted)
        GM(T)                   Gross margin less annual dispersion costs
        Initial                 Initial mature cow number
        Initial2                Initial number of first calf cows
        Initial3                Number of replacement cows in herd
        FCalves(T)              Heifer calf crop
        MCalves(T)              Steer calf crop
        Yearling(T)             Yearling decision
        Cowsell(T)              Mature cow culling rate
        Herds(T)                Number of cows
        Oldcow(T)               Heifer are less than a third of herd
        Year(T)                 Cull part of the yearlings
        Herd1                   Herd size;
```

```
****Objective Equations

 Profit..  Z=E=Sum(T,(INCOME(T)-VARCST(T)-PCST)*DF(T))+TERM;
 Inc(T)..  INCOME(T)=E=((SELLCOW(T)*COWWT+SELLYEAR(T)*YEARWT)
               *MKTCOW)+(SELLCALFF(T)*CALFFWT+SELLCALFM(T)*
               CALFMWT)* MKTCALF;
 Vari(T).. VARCST(T)=E=12*COWCST*(COW(T)+FIRST(T))+Sum(L,X(L,T)*C(L));
 TermV..  TERM=E=((COW('60')+FIRST('60')-SELLCOW('60'))*181.42)/RHO*
               (1-1/((1+RHO)**60));
 Net(T)..  NR(T)=E=INCOME(T)-VARCST(T)-PCST;
 Resource(T).. HERD(T)=L=500;

 ****Forage Equations

 Summer(G,P,T)..  AVAILFOR(G,P,T)=E=((rain/precp)*111-10.6)/100*YIELD(G)
                    /25*ACRE(G,P)*(UTIL(G,P)-2*OVER('G1','P2',T-1));
 Permit(T)..  X('L2',T)=E=SUM((G,P),AVAILFOR(G,P,T));
 Summer2(G,T)..  OVERFOR(G,'P2',T)=E=((rain/precp)*111-10.6)/100*YIELD(G)/
                    25*ACRE(G,'P2')*OVER(G,'P2',T);
 Permit2(T)..  X('L5',T)=E=Sum(G, OVERFOR(G,'P2',T));

* The following line is used for all models that use the dispersion project.  For all
* other runs, a * is placed in front of it.
 Pen2(T)..  OVER('G1','P2',T)=E=1.4*OVER('G2','P2',T);

* The following line is used for all models that do not use the dispersion project.  For all
* other runs, a * is placed in front of it.
* Pen2(T)..    .5*OVER('G1','P2',T)=E=.35*OVER('G2','P2',T);

 Forage(T)..   Sum(L, X(L,T))=G=365*(Cow(T)+FIRST(T)+.75*REPL(T));
 Winter1(T).. X('L4',T)=G=152*COW(T)+FIRST(T)+.75*REPL(T));
 Own(T)..      X('L1',T)=L=OWNLMT;
 Private(T)..  X('L3',T)=L=LEASELMT;
 Utillmt(G,T)..  UTIL(G,'P2')+OVER(G,'P2',T)=L=.75;

 ****Initial Values
 Initial..       COW('1')=E=255;
 Initial2..      FIRST('1')=E=45;
 Initial3..      REPL('1')=E=60;

****Marketing Decision Equations
 FCalves(T)..  (COW(T)+FIRST(T))*CLF*.5=E=SELLCALFF(T)+REPL(T+1);
 MCalves(T)..  (COW(T)+FIRST(T))*CLF*.5=E=SELLCALFM(T);
 Yearling(T)..  REPL(T)=E=FIRST(T+1)+SELLYEAR(T);
 Cowsell(T)..   SELLCOW(T)=G=(COW(T)+FIRST(T))*CULL;
```

```
Herds(T)$(CP(T) GT 1).. COW(T)=E=((COW(T-1)+FIRST(T-1))*(1-DEATH))
                                   -SELLCOW(T-1);
Oldcow(T).. FIRST(T)=L=.33*(COW(T)+FIRST(T));
Year(T)..   SELLYEAR(T)=G=.25*REPL(T);
Herd1(T)..  HERD(T)=E=COW(T)+FIRST(T)+REPL(T);


Model Comp /all/;
 option limrow = 0;
 option limcol = 0;
 option solprint = off;
 option iterlim = 2000;
 Solve Comp Using NLP Maximizing Z;

 Report(T,"Herd") = HERD.L(T);
 Report(T,"Cow") = COW.L(T);
 Report(T,"First Calf") = FIRST.L(T);
 Report(T,"Repl Calf") = REPL.L(T);
 Report(T,"Culled Cow") = SELLCOW.L(T);
 Report(T,"Sold Calf") = SELLCALFF.L(T)+SELLCALFM.L(T);
 Report(T,"Sold Year") = SELLYEAR.L(T);
 Report(T,"Gross Margin") = NR.L(T);
 Display Report;
 Display X.L, Z.L;
```

Appendix B: GAMS Solution Example

Production variables and corresponding gross margin for the model with median crop year precipitation and cattle market prices when dispersion project is used.

Year	Cow	First Calf Heifer	Repl. Calf	Culled Cow	Calves Sold	Gross Margin
****************************Adjustment Period******************************						
1	255.000	45.000	60.000	45.000	138.003	$12,098.67
2	252.000	45.000	125.997	44.550	198.000	$43,713.31
3	249.480	94.498	63.360	51.597	229.318	$50,753.24
4	288.941	47.520	73.382	50.469	224.308	$49,626.85
5	282.627	55.036	71.778	50.650	225.109	$49,807.08
6	283.638	53.834	72.035	50.621	224.981	$49,778.24
7	283.476	54.026	71.994	50.625	225.001	$49,782.85
8	283.502	53.995	72.000	50.625	224.998	$49,782.12
*************************Long Run Equilibrium*****************************						
9	283.498	54.000	71.999	50.625	224.999	$49,782.23
10	283.498	54.000	72.000	50.625	224.999	$49,782.22
11	283.498	54.000	72.000	50.625	224.999	$49,782.22
12	283.498	54.000	72.000	50.625	224.999	$49,782.22
13	283.498	54.000	72.000	50.625	224.999	$49,782.22
14	283.498	54.000	72.000	50.625	224.999	$49,782.22
15	283.498	54.000	72.000	50.625	224.999	$49,782.22
16	283.498	54.000	72.000	50.625	224.999	$49,782.22
17	283.498	54.000	72.000	50.625	224.999	$49,782.22
18	283.498	54.000	72.000	50.625	224.999	$49,782.22
19	283.498	54.000	72.000	50.625	224.999	$49,782.22
20	283.498	54.000	72.000	50.625	224.999	$49,782.22
21	283.498	54.000	72.000	50.625	224.999	$49,782.22
22	283.498	54.000	72.000	50.625	224.999	$49,782.22
23	283.498	54.000	72.000	50.625	224.999	$49,782.22
24	283.498	54.000	72.000	50.625	224.999	$49,782.22
25	283.498	54.000	72.000	50.625	224.999	$49,782.22
26	283.498	54.000	72.000	50.625	224.999	$49,782.22
27	283.498	54.000	72.000	50.625	224.999	$49,782.22
28	283.498	54.000	72.000	50.625	224.999	$49,782.22
29	283.498	54.000	72.000	50.625	224.999	$49,782.22
30	283.498	54.000	72.000	50.625	224.999	$49,782.22
31	283.498	54.000	72.000	50.625	224.999	$49,782.22
32	283.498	54.000	72.000	50.625	224.999	$49,782.22
33	283.498	54.000	72.000	50.625	224.999	$49,782.22
34	283.498	54.000	72.000	50.625	224.999	$49,782.22
35	283.498	54.000	72.000	50.625	224.999	$49,782.22

Year	Cow	First Calf Heifer	Repl. Calf	Culled Cow	Calves Sold	Gross Margin
36	283.498	54.000	72.000	50.625	224.999	$49,782.22
37	283.498	54.000	72.000	50.625	224.999	$49,782.22
38	283.498	54.000	72.000	50.625	224.999	$49,782.22
39	283.498	54.000	72.000	50.625	224.999	$49,782.22
41	283.498	54.000	72.000	50.625	224.999	$49,782.22
40	283.498	54.000	72.000	50.625	224.999	$49,782.22
42	283.498	54.000	72.000	50.625	224.999	$49,782.22
43	283.498	54.000	72.000	50.625	224.999	$49,782.22
44	283.498	54.000	72.000	50.625	224.999	$49,782.22
45	283.498	54.000	72.000	50.625	224.999	$49,782.22
46	283.498	54.000	72.000	50.625	224.999	$49,782.22
47	283.498	54.000	72.000	50.625	224.999	$49,782.22
48	283.498	54.000	72.000	50.625	224.999	$49,782.22
49	283.498	54.000	72.000	50.625	224.999	$49,782.22
50	283.498	54.000	72.000	50.625	224.999	$49,782.22
51	283.498	54.000	72.000	50.625	224.999	$49,782.22
52	283.498	54.000	72.000	50.625	224.999	$49,782.22
53	283.498	54.000	72.000	50.625	224.999	$49,782.22
54	283.498	54.000	72.000	50.625	224.999	$49,782.22
*******************Terminal Adjustment Period*****************************						
55	283.498	54.000	72.000	50.625	206.328	$39,724.43
56	283.498	54.000	90.670	50.625	148.499	$06,512.04
57	283.498	68.003	148.499	52.725	215.956	$31,480.28
58	295.261	111.374	93.365	60.995	269.436	$46,724.11
59	341.573	70.024	88.403	61.740	362.205	$96,207.29
60	345.742	66.302	0.000	61.807	362.598	$109,539.82

Yearly forage supply decisions for model with median crop year precipitation and cattle market prices when dispersion project is used.

Key for forage supply (AUD): L1 Spring & fall range, L2 Public lease, L3 Private lease, L4 Hay, L5 Public pasture beyond desired riparian utilization level

Forage Supply	Year: 1	2	3	4	5	6
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	445.99	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	52,440.00	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Key for forage supply (AUD): L1 Spring & fall range, L2 Public lease, L3 Private lease, L4 Hay, L5 Public pasture beyond desired riparian utilization level

Forage Supply	Year: 7	8	9	10	11	12
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 13	14	15	16	17	18
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 19	20	21	22	23	24
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 25	26	27	28	29	30
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 31	32	33	34	35	36
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Key for forage supply (AUD): L1 Spring & fall range, L2 Public lease, L3 Private lease, L4 Hay, L5 Public pasture beyond desired riparian utilization level

Forage Supply	Year: 37	38	39	40	41	42
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 43	44	45	46	47	48
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 49	50	51	52	53	54
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65	59,507.65
L5	0.00	0.00	0.00	0.00	0.00	0.00

Forage Supply	Year: 55	56	57	58	59	60
L1	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00	31,740.00
L2	41,299.01	41,299.01	41,299.01	41,299.01	41,299.01	37,986.71
L3	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00	10,350.00
L4	59,507.65	64,618.70	85,560.45	90,591.45	90,176.08	62,630.65
L5	0.00	0.00	0.00	0.00	868.16	7,688.60