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An Examination of the On-Ranch Economics of Riparian Grazing Management

by

Jamie David Miller ©

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Abstract

This study estimates on-ranch (or on-farm) costs and benefits of various riparian area management schemes for a ranch in Southern Alberta. A static NPV model and a stochastic simulation model were used to quantify the effects of these management strategies on a hypothetical ranch. Under the assumptions used, strategies that improve upland and riparian range health will make a rancher better off (financially) in later periods. Lower discount rates will favour strategies with lower initial stocking rates.

The stochastic model results suggests that, on healthy range, a conservative grazing strategy will give the most stable and favorable financial results. However, the right combination of prices and good weather conditions could make an overgrazing strategy financially superior. For range in poor condition, overgrazing will be chosen over regenerative strategies. Both the static and stochastic models are sensitive to the rates of pasture degradation and regeneration.

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Chapter 1

Introduction

Riparian areas are formed when water, soil, and vegetation interact with one another. Dickard (1998) stated that riparian areas are often described as groups of plant, animal, and aquatic communities whose presence is directly or indirectly attributed to factors that are related to streams, or stream-induced. Fitch and Adams (1998) noted that riparian areas have different vegetation than uplands. Because the riparian areas represent floodplains, soil moisture is normally higher than upland areas as well (Hawkins, 1994). The higher water table allows riparian areas to stay greener longer, and produce more forage (Fitch and Adams, 1998). If a drought occurred, these areas could serve as a stable source of forage for grazing animals.

This study will examine producers' knowledge of, and attitudes toward, riparian area management. The costs and benefits of various management scenarios intended to better manage riparian areas will be evaluated. A static Net Present Value (NPV) model will be used to quantify the effects of these strategies on the riparian area of a hypothetical Alberta ranch. This model will analyze on-ranch decision-making regarding the strategies. Sensitivity analysis and scenario analysis will be used to analyze results of the NPV model.

A stochastic whole ranch simulation model will follow the static model. This model will take the entire ranch (upland and riparian pastures) into consideration. It will introduce random price and weather effects. That is, changing weather and cattle prices through time will be incorporated into the analysis. Scenario analysis will be performed on the stochastic simulation model. Conclusions based on the questionnaire, static model, and stochastic simulation model will then be presented.

1.1 Grazing and Riparian Areas

The effects of grazing cattle in many riparian areas have greatly affected the associated landscapes over the past 100 years (Fitch and Adams, 1998). Stillings (1998) noted that, until recently, traditional ranch management practices did not take the specific needs of riparian areas into consideration. The riparian areas of streams and rivers provide numerous ecological services. The benefits of healthy riparian zones include shelter and forage for wildlife, control of the flow and volume of stream discharge, and filtering of chemicals and sediment in runoff from fields and pastures (Fitch and Adams, 1998).

The riparian zone is usually the most productive zone for forages, as a result of its higher water table (Fitch and Adams, 1998). The economic benefit to ranchers of using this zone can be considerable, and may be necessary for the economic viability of ranch operations. In Alberta, economic viability of ranches is important. In 1999, the provincial cow/calf and feedlot industry had cash receipts of over 3 billion dollars (AAFRD, 2000-c).

The use of riparian areas for grazing can lead to conflict between public and private interests. For example, in the U.S., questions surrounding the grazing of livestock have spawned legal challenges, political debates, and increased media attention (Adams and Fitch, 1998). Certain watersheds in Alberta exhibit definite damage to riparian zones in that their appearance and vegetation (plant species vigor) are not what would occur naturally (Willoughby and Alexander, 2000). Platts and Wagstaff (1984) stated that range management guidelines suggested separate management schemes for riparian areas. Special protection of these areas means treating them differently from other parts of a ranch's rangeland pasture. However, special treatment for riparian areas could be impractical (both technologically and financially), or difficult to implement (Platts and Wagstaff, 1984).

Sopuck (2001) analyzed the Department of Fisheries and Oceans Canada (DFO) guidelines for protection of fish habitat. Section 35 (1) of the Fisheries Act states that "no person shall carry on any work or undertaking that results in the harmful alteration, disruption, or destruction of fish habitat." DFO (2001) posted the second part of this section on their public website, which states that "no person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act." The federal government assumed full responsibility for protection of fish habitat after talks with the provinces failed (Sopuck, 2001). The question of whether provincial governments or local communities have control over their own natural resources has led to some uneasiness concerning possible restrictions placed on private farm operations.

1.2 The Literature

Kauffman and Krueger (1984) reviewed the results of over 100 papers on livestock impacts on riparian ecosystems published between 1940 and 1980. The four major categories outlined were: i) impacts causing changes in streamside vegetation, ii) impacts which changed the shape of the stream channel, iii) impacts which influenced water quality and flow rates, and iv) impacts which changed the soil portion of the streambank (Kauffman and Krueger, 1984). Platts and Wagstaff (1984) stated that the previous literature established the fact that grazing animals do have negative effects on riparian areas. The presence of grazing cattle can also negatively affect wildlife. Negative effects include direct competition and alterations to the habitat necessary to support wildlife (Kauffman and Krueger, 1984).

1.2.1 *Problems with the Literature*

Existing literature does provide good coverage of the physical effects of grazing cattle in riparian areas. However, recent work suggests that the quality of the science in the studies regarding cattle grazing impacts is insufficient. Larsen et al. (1998) compiled a literature review of over 1500 articles about livestock influences on riparian zones and fish habitat. The authors classified the articles into 3 groups; papers with original data, commentary papers, and reports about methodology. Of the total papers reviewed, 428 were directly related to riparian zones and fish habitat, but only 89 were classed as experimental. Larsen et al. (1998) concluded that many studies in this area have inadequate descriptions of grazing management practices, weak study designs, and lack of pre-treatment data.

There are also studies that outline actual or assumed changes to the environment when cattle grazing is modified, either by complete or seasonal exclusion. However, recent studies suggest that the environmental impacts from grazing are highly variable, and depend mainly on geographical location, the soil and water component of the range, and the grazing management system used (e.g., Clark, 1998). These studies rarely discuss environmental costs associated with overgrazing riparian areas. More information is also needed on the economic benefits to the environment, through the protection of riparian areas.

Literature on the economics of riparian management is scarce. Platts and Wagstaff (1984) outlined many of the costs involved in fencing riparian areas. However, management strategies in general have not been discussed in detail in the literature. Adams and Fitch (1998) make reference to a number of strategies in *Caring for the Green Zone*, the guidebook for managing riparian areas. Other authors make references to rotational grazing, without explaining the details of the strategy or strategies involved. General economic concepts are described, but actual costs and benefits, in terms that are of interest to producers, are left to further study. This study will address some of the missing economic information.

1.3 Research Problem

The purpose of this study is to analyze various riparian management strategies. Some analyses of producer costs and benefits will be performed through the use of Net Present Value calculations. Net Present Value calculations will facilitate discounting the net revenue of a cow/calf operation over a period of time. The purpose of these analyses is to determine whether or not suggested riparian management strategies will financially benefit beef producers in Alberta. If beef producers in the province have not yet adopted strategies designed to protect riparian areas, there may be a perceived economic barrier to adoption. That is, producers may perceive riparian management strategies as costly, with little or no economic benefit. This study estimates some on-ranch (or on-farm) costs and benefits of various riparian area management schemes.

In order to assess these schemes, two models will be used. A static model analysis will focus on incremental changes to the riparian area pasture itself. A stochastic simulation model is used to analyze whole ranch concerns. The stochastic model will simulate price cycles for steers, heifers, bred heifers, and cull cows over time. As well, the stochastic model simulates changing weather patterns, and the effects on forage growth, stocking rate, etc. The stochastic simulation model will be used to capture dynamic aspects of the whole ranch using decision rules based on grazing, prices and related ranch factors, with weather and cattle prices as the main sources of risk.

Chapter 2 will give the reader an introduction to Alberta's cattle industry. It will discuss rangeland management in the province. After discussing overall management, riparian area management will be discussed. A discussion of different riparian management strategies will be presented. The chapter will also include a brief discussion of the economics of range and riparian management. Chapter 3 will present the methodology of an initial questionnaire, presented to a group of beef producers in Southern Alberta. The purpose of this questionnaire was to analyze producer knowledge and perceptions of riparian area management. The results of the questionnaire, including an analysis of the factors underlying certain management decisions, will follow.

Chapter 4 will present the fundamentals of NPV analysis. The static NPV model used in this research to analyze riparian management strategies will be presented. The scenario and sensitivity analysis used for the model will be explained. Results and discussion of the model analysis will be presented in Chapter 5.

Chapter 6 will present the basics of the stochastic simulation model. This description will include models for price and weather information used in the simulation model. As well, assumptions for each case used in the model will be described. Scenario analyses used in the simulation model will be outlined. Chapter 7 will present the results of the stochastic simulation model. A brief discussion will accompany each results section.

Chapter 8 presents conclusions to the research. Conclusions for the questionnaire, static model, and stochastic simulation model will be discussed. These will be followed by a discussion of model limitations, policy implications, and further research.

Chapter 2

2.1 Alberta's Cattle Industry

2.1.1 *Alberta's Farms and Land Use*

According to the 1996 Census of Agriculture (Statistics Canada, 1997), there were 54,626 farms in Alberta, of which 24,718 were classified as cattle (beef) operations. Alberta has 16,347,251 acres of natural land for pasture, and 4,731,087 acres of tame or seeded pasture. Alberta farmers own 31,344,893 acres of land, and rent or lease 20,619,467 acres from others. Alberta farmers also rent or lease 10,131,862 acres of land from the provincial government (Statistics Canada, 1997).

2.1.2 *Types of Cattle Operations*

There are different types of commercial beef operations in Alberta. Some producers supply breeding stock to other commercial producers. These are *purebred* or *seedstock* operations (AAFRD, 1998-a). These producers market animals with specific traits. These traits can range from low birth weight to superior carcass quality. Some producers operate *cow/calf* farms. These operations maintain cows, and raise calves until they are weaned (generally at six to eight months of age, and 500-600 pounds of weight) (AAFRD, 1998-a). *Backgrounding lots* feed or pasture calves in order to add size and weight. Generally, they will send the calves to *finishing feedlots* at 800-950 pounds. *Finishing feedlots* feed yearling and backgrounded calves to weights of 1,000-1,400 pounds, when they are ready for slaughter. Cattle are sent to *packers* for slaughter, and the meat to *wholesalers* and *retailers* for sale to consumers (AAFRD, 1998-a).

2.1.3 *Alberta's Cow/Calf Operations*

This research will focus on cow/calf operations. In Alberta, these operations can be large ranches or mixed farms (AAFRD, 1998-a). Large ranches (herds larger than 300 cows) use extensive areas of grassland for pasture. Most of their revenue comes from the sale of cattle and calves (AAFRD, 1998-a). AAFRD (1998-a) stated that the average land base per operation was 562 hectares. Mixed farms (small herds under 300 head) often use marginal land, and crop residue. Revenue for mixed farms comes from the sale of both cattle and crops (AAFRD, 1998-a). Table 2.1 presents average herd characteristics of Alberta cow/calf operations. The information was obtained by AAFRD through a detailed study of Alberta cow/calf herds, production results, and management practices during the production periods from 1986/87 to 1988/89 (AAFRD, 1998-a).

In 1998, Alberta reported 5,760,000 cattle and calves on-farm (AAFRD, 2000-a). This included 103,000 dairy cows, and 1,900,000 beef cows. The number of bulls was 108,000. Of the 1,826,000 calves, 45,000 were dairy heifers, 318,000 were beef heifers for breeding, 609,000 were beef heifers for slaughter, and 851,000 were steers (AAFRD, 2000-a). Table 2.1 provides details on average herd characteristics for Alberta cow/calf producers.

In 1998, the average annual income for a beef farm operator was $35,513 (AAFRD, 2000-d). Table 2.2 shows the average price (per cwt) from 1976 through 1997. In 1998, the total receipts from the beef industry were $2,748,100,000 (AAFRD, 2000-b). In 1999, the figure was $3,042,200,000. These figures represented more than one third of the total farm cash receipts for Alberta agri-food industries in those years (AAFRD, 2000-c).

2.2 Rangeland Management

2.2.1 *Livestock Grazing*

Fitch and Adams (1998) stated that the ecosystems found on the Canadian prairies were shaped over thousands of years by large herbivores, such as bison. Willms et al. (1996) stated that bison grazed the range during winter months (when grasses were dormant), allowing the range grasses to flourish during the growing season. When Europeans settled the area, they brought a system of sedentary grazing (Adams and Fitch, 1998). Willoughby and Alexander (2000) noted that, in the late 1800's, livestock grazing was unregulated and open-range along the eastern slopes of Alberta's Rockies. Though barbed wire fences (which marked pasture units) defined later ranches, there were no range management guidelines at the time (Fitch and Adams, 1998).

2.2.2 *Stocking Rate*

According to Willms et al. (1985), the most critical decision that must be made by beef producers is the stocking rate they should use on their rangeland. Stocking rate is the number of animals per unit area of land per unit of time. Willms et al. (1985) expressed stocking rate in Animal Unit Months (AUM) per hectare. One animal unit month is generally regarded as the amount of dry matter (forage) needed to support one grazing cow and calf pair for one month (Range Management – Public Lands Division, 1990). The choice of stocking rate can be a difficult decision. Parsch et al. (1997) noted that producers must consider future weather patterns in their decisions. Weather patterns (specifically precipitation) can determine how much forage is available to livestock. In addition to weather, Parsch et al. (1997) noted that stocking rate also affects the amount of forage available.

2.3 Riparian Management

2.3.1 *What Is a Riparian Area?*

Riparian areas are the zones adjacent to streams, rivers, and wetlands (Wagstaff, 1986). Riparian areas have different vegetation than uplands, stay greener longer, and produce more forage (for grazing livestock) because of their higher water table (Stillings, 1997). Adams and Fitch (1998) noted that riparian areas play important roles as buffer zones. If a drought occurs, these areas, with their more reliable forage supply, serve as an "insurance policy" for ranchers. The effects of floods are lessened by deep-rooted riparian vegetation, which stabilizes stream banks (Stillings, 1997).

Riparian areas have higher humidity, higher rates of transpiration, and more shade (Fitch and Adams, 1998). Animals are attracted to riparian areas for water, shelter, and forages (Stillings, 1997). Wildlife supported by riparian areas can attract human use, including hunting and fishing (Hawkins, 1994). In Alberta and the northwestern United States, rivers and streams often flow through rangeland and support herds of beef cattle (Adams and Fitch, 1998).

2.3.2 *Physical Effects of Livestock on Riparian Areas*

Fitch and Adams (1998) listed the eight hydraulic variables most important to riparian form and function. They were: 1) stream discharge, 2) stream gradient, 3) sediment load, 4) bank and bed resistance to moving water, 5) vegetation, 6) temperature, 7) geology, and 8) human activity. This last variable is important because it includes agriculture. Throughout history, agriculture has been based in riparian ecosystems (Krueger, 1994). This is due to the availability of water and nutrients, as well as the reasons mentioned in the previous section. Inputs from agricultural activities can seriously degrade riparian systems' natural processes.

Clary and Kinney (2000) simulated trampling of stream banks by cattle to show that, in riparian areas, livestock cause significant physical damage. Degradation can also include pollution through deposition of animal wastes and leaching. Krueger (1994) reported that 64% of non-point pollution in US river systems was attributed to agriculture. Another effect of livestock grazing is a change in plant species number and composition. Livestock may consume species of plants eaten by other riparian species such as the beaver (Wuerthner, 1990). When forage on rangeland is scarce, livestock may compete for food with wild species such as antelope (Wuerthner, 1990). The human activity variable can affect the other seven variables, upsetting an existing equilibrium.

2.3.3 *Livestock Effects on Vegetative Ecology*

Another aspect of range health that livestock can influence is vegetative ecology. Willms et al (1985) described a study at the Agriculture Canada Research Substation at Stavely, Alberta. The study concerned the effects of stocking rate on Rough Fescue (*Festuca scabrella*) grassland. The pasture had been moderately grazed by cattle between 1884 and 1908, and by horses between 1908 and 1920 (Willms et al, 1985). The area was again used for summer grazing of cattle until 1943, with heavy grazing during the drought of the 1930's. In 1949, four fields were fenced to form enclosures (Willms et al, 1985). It was within these enclosures that the study was performed.

Using a recommended stocking rate for the area of 1.6 AUM per hectare, the study evaluated light stocking (1.2 AUM/ha), moderate stocking (1.6 AUM/ha), heavy stocking (2.4 AUM/ha) and very heavy stocking (4.8 AUM/ha) (Willms et al, 1985).

Initially, all test sites had Rough Fescue as the dominant species, with Parry Oat Grass (*Danthonia parryi*) as the co-dominant (Willms et al, 1985). The authors found that, with a move from light to moderate grazing, the amount of Parry Oat Grass increased. As grazing intensified, Rough Fescue declined (Willms et al, 1985). The composition of forbs generally increased with stocking rate, while no effect was noted on shrubs. In a similar study, Willoughby and Alexander (2000) noted that heavy grazing allowed Kentucky bluegrass (*Poa pratensis*) to become dominant. Invader species, like Kentucky bluegrass, can change the nature of plant community ecology.

Platts (1990) noted that improper livestock grazing could diminish plant vigor, and reduce or destroy streamside vegetative cover. This often leads to a change in species composition, as noted above by Willms et al. (1985). Platts (1990) stated that, on rangeland in the western United States, "high-quality fibrous root plants" were replaced by "shallow-rooted annual species, or tap-rooted forbs," which could survive in dry, prairie conditions. Platts (1990) suggested that managing riparian areas differently from uplands could result in a more stable plant community.

2.3.4 *Cows and Fish Project*

In 1992, the Alberta Riparian Habitat Management Project (also called Cows and Fish) was established (CWS, 1999, AAFRD, 2000-e). It was a partnership between the Alberta Cattle Commission, Trout Unlimited Canada, the Canadian Cattlemen's Association, Alberta Environmental Protection, Alberta, Agriculture, Food, and Rural Development (AAFRD), and Fisheries and Oceans Canada (AAFRD, 2000-e). Eleven southern Alberta ranches assisted with the project. They applied riparian grazing strategies to restore riparian condition, or developed existing successful practices to share with project coordinators (AAFRD, 2000-e).

The initiators of the project stated that the knowledge and experience existed to recognize and correct grazing impacts on riparian areas (Fitch and Adams, 1998). In order to realize progress, it was accepted that a number of partners would have to cooperate on the project (hence, the large number of collaborators above). The Cows and Fish Project was built on the basis that the functions of riparian systems must first be understood in order to develop suitable strategies for grazing (AAFRD, 2000-e). Range management principles were then applied to develop riparian grazing strategies. Thus, the point of the Cows and Fish Project was to create awareness and "understanding of the linkages between livestock grazing, riparian vegetation health, and stream channel dynamics." (Fitch and Adams, 1998)

Before the inception of Cows and Fish, the Alberta Cattle Commission and the Canadian Cattlemen's Association declared that cattlemen had ownership of the riparian grazing issue (CWS, 1999). Riparian areas had been identified as an area of concern by the Commission's environmental risk assessment. Once the aforementioned partners had come together, they consulted technical data and chose options for the project. Demonstration sites were set up on ranches, and workshops concerning riparian management were held (AAFRD, 2000-e). Local community leaders (including producers), land management agencies, and other groups and organizations disseminated riparian management knowledge (Fitch and Adams, 1998).

2.4 Riparian Management Strategies

The following section reviews different riparian management strategies. Adams and Fitch (1998) described many of these strategies in the Cows and Fish guide book "*Caring for the Green Zone: Riparian Areas and Grazing Management*". These strategies have been applied to various test ranches and landscape areas in Alberta where ranching is common. The strategies range from low cost (herd distribution practices), to high cost (corridor fencing). The strategy chosen depends very much on the individual ranch and its associated strengths and weaknesses.

Strategies for managing riparian areas cannot be generalized due to the site-specific nature of riparian areas (Krueger, 1994). A site that is naturally stable will be able to respond well to stress. In fact, Krueger (1994) stated that riparian systems must have disturbance at some point to maintain natural processes. Disturbances can be natural (fire, flooding) or man-made (grazing). A lack of disturbance reduces the ability of a riparian system to provide clean water, good fish and wildlife habitat, etc. (Krueger, 1994). However, excessive removal or alteration of riparian vegetation can cause riparian area degradation (Adams and Fitch, 1998).

2.4.1 *Season-Long Grazing*

Continuous (or season-long) grazing represents the status quo. AAFC (2001-c) stated that this is still the most common grazing strategy in use by many cow/calf producers. If the number of grazing animals exceeds a pasture's carrying capacity, this type of grazing is considered to be a poor management choice for rangelands (Fitch and Adams, 1998). AAFC (2001-b) stated that livestock usually prefer to graze and loiter in riparian areas. A longer grazing season can lead to damage, as the animals remain in the riparian area unless moved. AAFC (2001-c) noted that animals would be more selective under this strategy, choosing only the most palatable vegetation. As well, when grazing is intense, there is no rest period for the vegetation, and it will be grazed through its vulnerable periods (AAFC, 1999).

2.4.1.1 Holding Pasture

A variation on this theme is the *holding pasture.* According to Adams and Fitch (1998), a holding pasture is usually a field in which livestock are held for prolonged periods of time. There could be valid reasons for this practice, including winter feeding and calving. Holding pastures can also refer to fields where animals are kept in high densities for short periods of time. Some of the problems with holding pastures in riparian areas include trampling of stream banks by livestock, and heavy use of herbaceous and woody plants (Platts, 1990). Adams and Fitch (1998) noted that woody plants are important to riparian health because they provide cover and shade, as well as bank stabilization.

2.4.1.2 Livestock Distribution: Placement of Water and Salt

Livestock distribution practices can be a low-cost method to relieve pressure on riparian areas. If animals prefer to graze in riparian areas, water should be placed outside of this area (Winward, 1994). Adams and Fitch (1994) noted that these upland "off-stream watering sites" could be effective in relieving grazing pressure on riparian areas. Piping, watering ponds, and troughs developed away from spring sources can provide off-stream water (Winward, 1994). The location of salt or minerals can also be important. Winward (1994) stated that ranchers must take care to locate supplements away from riparian watering sources, as that is where the animals would then be concentrated.

Dickard (1998) evaluated management strategies involving assessment of off-stream water and salt placement for improved cattle distribution (and subsequent riparian health). Sixty cow/calf pairs were allotted to three pastures, with three grazing strategies: 1) stream access, with access to off-stream water and salt; 2) stream access, with no access to off-stream water and salt; and 3) ungrazed control. No changes were noted for grazing activity, travel distances, forage utilization, or water quality in any of the three treatments (Dickard, 1998). However, Dickard (1998) found that cattle distribution was affected by the presence of off-stream water and salt. Water and salt located away from the stream were successful in relieving pressure on the riparian area.

2.4.2 *Grazing Systems*

Grazing systems specify livestock management and could be the most effective management technique for livestock in riparian areas (Wagstaff, 1986). Unfortunately, these systems are often the most difficult to implement (Winward, 1994). Winward (1994) pointed out that care must be taken to remove all animals from the area to be protected, as any remaining animals will focus on riparian vegetation. Grazing systems often involve increased fencing and herding costs for the producer (Wagstaff, 1986). Platts et al. (1989) noted that some grazing systems involve the deferral of animals from grazing specific pastures. This may have a direct effect on revenue for producers.

2.4.2.1 Rotational Grazing

According to AAFC (1999), rotational grazing allows for the best economic return on land, while managing the resource for future years. Normally, the range to be grazed is divided into different pasture units or cells (AAFC, 1999). However, Adams and Fitch (1998) stated that this management scheme could also work with existing pasture units, or through a change in herding practices. A rotational grazing system means that livestock will be grazing available range more evenly (AAFC, 2001-a). If grazing seasons are shorter, more rest can be provided to certain areas of the range. This can protect plants at young, vulnerable stages, by allowing them time to establish before grazing (AAFC, 2001-a).

Rest can be provided by deferring grazing (delaying early season grazing, for example), or by resting pastures after grazing. During spring runoff, stream banks are especially vulnerable to trampling (AAFC, 2001-a). Rotational grazing can help a rancher change the season of use, to keep livestock out of riparian areas at this time. When livestock overgraze an area, they have exhausted the young vegetation, and have turned to any forage available, including plant litter (AAFC, 1999). Rotational grazing allows some of this litter to be carried over into another season, which is better for overall range health.

2.4.2.2 Deferred Rotational Grazing

Platts et al. (1989) studied deferred rotation on a ranch on the Henry's Fork River, in Idaho. In 1986, a deferred rotational grazing system was implemented on the ranch. A deferred rotation means that no pasture unit in the rotation is ever grazed at the same time of year, two years in a row (Adams and Fitch, 1998). That is, the sequence of use changes from year to year. On the Henry's Fork pasture, the original pasture was divided into four units, with two chosen for deferral pastures. The animals entered late two years in a row, and another pasture unit was used during rest periods. On the ranch in question, the riparian area showed definite improvement under this regime (Platts et al., 1989). The authors reported that the producer could add 25% more livestock than he had before the management change, due to increased forage productivity.

2.4.2.3 Time-Controlled Grazing

Another grazing system is time-controlled grazing. This involves greatly shortening the grazing season on riparian pastures, and minimizing re-grazing of the required re-growth of plants (Adams and Fitch, 1998). Time-controlled grazing can be used at different stocking densities (light, moderate, or heavy). Adams and Fitch (1998) noted that heavy stocking densities could sometimes be effective in helping producers reach management goals. However, higher stocking densities can mean higher risk of overgrazing in the riparian area. If a rancher wants to restore woody vegetation to a riparian pasture, less selective grazing in riparian zones could hinder this goal (Adams and Fitch, 1998). A rancher must be prepared to move his or her animals, in order to achieve riparian area goals.

2.4.2.4 Rest-Rotation Grazing

Adams and Fitch (1998) described rest-rotation grazing as a conservative grazing strategy. This strategy can be used to assist a rancher in restoring woody vegetation to a riparian area, when it is needed most. Platts and Wagstaff (1984) stated that four or five years of rest could result in a gain of 75% of the original grazing benefits. If woody species do not have time to grow to a height where livestock can no longer browse them, no young trees will survive to replace old, dead trees (Adams and Fitch, 1998). Different types of trees will take longer to regenerate. This must be taken into consideration when planning rest periods.

2.4.2.5 Riparian Pastures

According to Adams and Fitch (1998) riparian pastures represent a landscape approach to riparian area management. This strategy involves defining pastures in such a way as to reduce variation within a field. To do this, a rancher could fence off a riparian area separately from an upland pasture (Adams and Fitch, 1998). Livestock should be grazed in a planned sequence, much like those in a rotational system. The main difference in a riparian pasture system is that pastures are separated according to their landscape type (Adams and Fitch, 1998). The riparian pasture strategy can also require more fencing than other strategies.

2.4.2.6 Corridor Fencing

Platts and Wagstaff (1984) noted that one method of grazing management is to fence the corridor that borders a riparian area. This method eliminates livestock grazing on a narrow fringe of the riparian area. Platts (1990) suggested this method for "high risk" riparian areas that have poor recovery potential. Platts and Wagstaff (1984) noted that this method could provide the most protection for damaged riparian areas. Corridor fencing is very expensive, and can be difficult to maintain (Winward, 1994). The type of fencing chosen will directly affect the costs associated with fencing as well (Platts and Wagstaff, 1984). Platts and Wagstaff (1984) also noted that annual maintenance costs per mile of fencing could be 1 – 3% of the initial fencing cost. Wagstaff (1994) stated that, while expensive, corridor fencing strategies could often be used to improve the management of riparian grazing areas.

2.5 Economics of Range and Riparian Management

2.5.1 *Economics of Range Management*

A rancher who owns a cow/calf operation receives revenue through the sale of market weight calves. Therefore, the amount of revenue received is dependent on the total number of market weight calves sold. In this study, the market weight of a calf is assumed to be 550 pounds. Increasing ranch revenue is not as simple as increasing the number of calves raised. There are a number of factors that must be taken into consideration.

According to Parsch et al. (1997), one of the key decision variables is the stocking rate. This is the number of animal unit months (AUM) of grazing per unit area of pasture. According to previous studies (Hart et al., 1988; Aiken and Brandsby, 1992), lower stocking rates lead to the highest animal weight gain (average gain per animal per day) (Parsch et al., 1997). Other studies (Willms et al., 1986; Bertelsen et al., 1993) noted that increasing stocking rates to medium or high levels leads to the maximum weight gain per unit area of pasture (Parsch et al., 1997).

Furthermore, empirical studies of stocking rate economics (Pearson, 1973; Hart, 1978) concluded that neither the highest weight gain per animal nor the maximum weight gain per unit area of pasture resulted in the highest profit for a ranch operation (Parsch et al., 1997). The economic optimum was found to be at a stocking rate between these two extremes (Parsch et al., 1997). Another study (Batabyal et al., 2001) considered the choice between stocking rate and the actual time animals spent grazing on pasture. A long-standing question was which of the choices was relatively more important in ranch decision-making. Batabyal et al. (2001) found that an optimally chosen stocking rate would result in lower long-run expected net unit costs than an optimally chosen grazing season.

Adding to the complexity of stocking rate choice is the effect of stocking rate on the rangeland being grazed by the cattle. Willms et al. (1985) noted serious declines in range condition as stocking rate increased from light (1.2 AUM/ha) to heavy (4.8 AUM/ha). As range condition deteriorates, herd numbers must be reduced, in order for there to be enough forage to raise calves to their full market weight. Another important influence on range condition is climate. Rainfall amounts below average (or extended dry periods) can also cause pasture deterioration (Parsch et al., 1997).

2.5.2 *Economics of Riparian Area Management*

The effect grazing animals have on pasture leads to another element of this study; the grazing of riparian areas. In previous sections, it has been noted that riparian areas can provide abundant forage resources for a ranch. However, it has also been noted that a stocking rate that is too high can damage these areas, and their forage production. A number of different grazing strategies have been proposed for managing the riparian area(s) of a ranch. Some of the costs involved with these strategies include fencing, such as those mentioned by Platts and Wagstaff (1984). There would also be inherent management costs, such as time required to rotate animals through grazing paddocks (rotational or rest-rotational grazing).

The economic discussion of riparian management might be thought of as improving on-ranch environmental quality. Other studies have looked at voluntary programs designed to reduce pollution, or conserve riparian areas. Norton et al. (1994) studied the role of voluntary programs in agricultural non-point pollution policy. The authors looked at a farmer who wished to maximize his or her utility (made up of a combination of a) a specified level of on-farm environmental quality and b) all other goods), subject to a budget constraint. This situation is graphically portrayed in Figure 2.1, and is briefly explained below.

In Figure 2.1, the indifference curves U^0 and U^1 represent the farmer's preferences and desired trade-off between farm profit (π) and on-farm environmental quality (q) (Norton et al., 1994). The farmer maximizes utility subject to a restricted profit function to determine optimal levels of π and q. This restricted profit function is $\pi = \pi(p,w,q;z)=p_h h$, where p and w represent input and output prices, respectively, z is a vector of farm field and climatic characteristics, p_h represents the price of "all other goods", and h is the quantity of "all other goods" (Norton et al., 1994). Profit is restricted such that a farmers expenditure on q and "all other goods", h, is equal to his or her income.

The optimal levels of profit and on-farm environmental quality are represented by π^{Opt} and q^{Opt}. These are shown in Figure 2.1 as the tangency point of U^0 (highest attainable utility level) and the profit function [$\pi = \pi(p,w,q;z)$] (Norton et al., 1994). Other combinations of profit and on-farm environmental quality will mean lower utility for the farmer. Norton et al. (1994) noted that though $q^{\pi Max}$ represents the maximum profit, the farmer is willing to reduce profit (by adopting new technology), in order to gain more q, due to his or her preference for on-farm environmental quality (preferences represented by shape of the indifference curves).

Norton et al. (1994) also presented a case where the aforementioned farmer's fertilizer use was polluting both off and on-farm water supplies (still using Figure 2.1). Therefore, by improving off-farm environmental quality, he or she also improves on-farm environmental quality. The producer changes his fertilizer application strategy to the point where on-farm environmental quality is at point q_1. This means that the farmer has suffered a loss in profits (shown in Figure 2.1 as the vertical distance, $\pi^{Opt} - \pi^1$) (Norton et al., 1994). His or her utility level is reduced to U^1.

However, because the increase in on-farm environmental farm quality has value, the compensation necessary to restore the farmer to his or her initial utility level, U^0, is less than the foregone profit (Norton et al., 1994). This is the farmer's Willingness To Accept (WTA), the vertical distance between the indifference curves, at the new level of on-farm environmental quality. Norton et al. (1994) stated that if the government were to offer a subsidy payment greater than or equal to the farmer's WTA, then the farmer would be willing to adopt the technology or strategy needed to reach q_1.

Kingsbury and Boggess (1999) went right to riparian landowners, and surveyed them on their willingness to participate in Oregon's Conservation Reserve Enhancement Program (CREP). This program means that producers would establish forested riparian buffer strips, and forego agricultural production on riparian areas for up to fifteen years. The authors stated that an annual government payment for program participation, equal to the foregone production on the riparian land greatly influenced the survey respondents' decisions to participate. Landowners with land dedicated to high-value crops were significantly less likely to participate (Kingsbury and Boggess, 1999). Farmers who irrigate, and use riparian areas for haying and grazing were also less likely to establish forested buffer strips.

Kingsbury and Boggess (1999) found that producers who felt that future flexibility of land use was important were less likely to participate (and may indicate that commitment periods were too long in the CREP). For irrigators, the importance placed on compliance with future regulations made them more likely to participate in CREP. Individuals who place an importance on the availability of cost-shared conservation practiced also showed more willingness to participate (Kingsbury and Boggess, 1999). Not surprisingly, those who perceived an environmental issue that has to be addressed on streamside property were also found to be more likely to participate in CREP.

Though the current study does not pursue the willingness of producers to participate in riparian management programs, some of the influences of producer's riparian management decisions in the Kingsbury and Boggess study surface in this study's initial riparian management questionnaire (see Chapter 3). Though this study does not attempt to discover a subsidy amount that will make producers more likely to adopt riparian management practices, it lays some of the groundwork necessary, by analyzing costs and returns associated with various strategies.

2.6 Chapter Summary

In Alberta, beef farming is a multi-billion dollar industry. In this industry's cow/calf operations, pasture is usually the major production input. Studies such as Clary and Kinney (2000) and Willoughby and Alexander (2000) have shown that degradation of riparian pastures occurs through trampling and overgrazing. However, recent studies have not addressed the economics of riparian area management. Specific costs and benefits have not been analyzed. Groups such as Cows and Fish have suggested a number of strategies to improve riparian health. These range from simple distributional changes, to more labour-intensive and costly fencing strategies. This study addresses the economic concerns associated with riparian area management strategies.

2.7 Tables for Chapter 2

Table 2.1 Average Herd Characteristics of Alberta Cow/Calf Producers (obtained from a detailed study of Alberta cow/calf herds, 1986/87 - 1988/89)

Number of herds surveyed	6,249
Cows and heifers in survey	519,979
Total land base per operation (hectares)	562
Cows in herd	72
Replacement heifers in herd	12
Breeding bull/herd	3

AAFRD, 1998-a

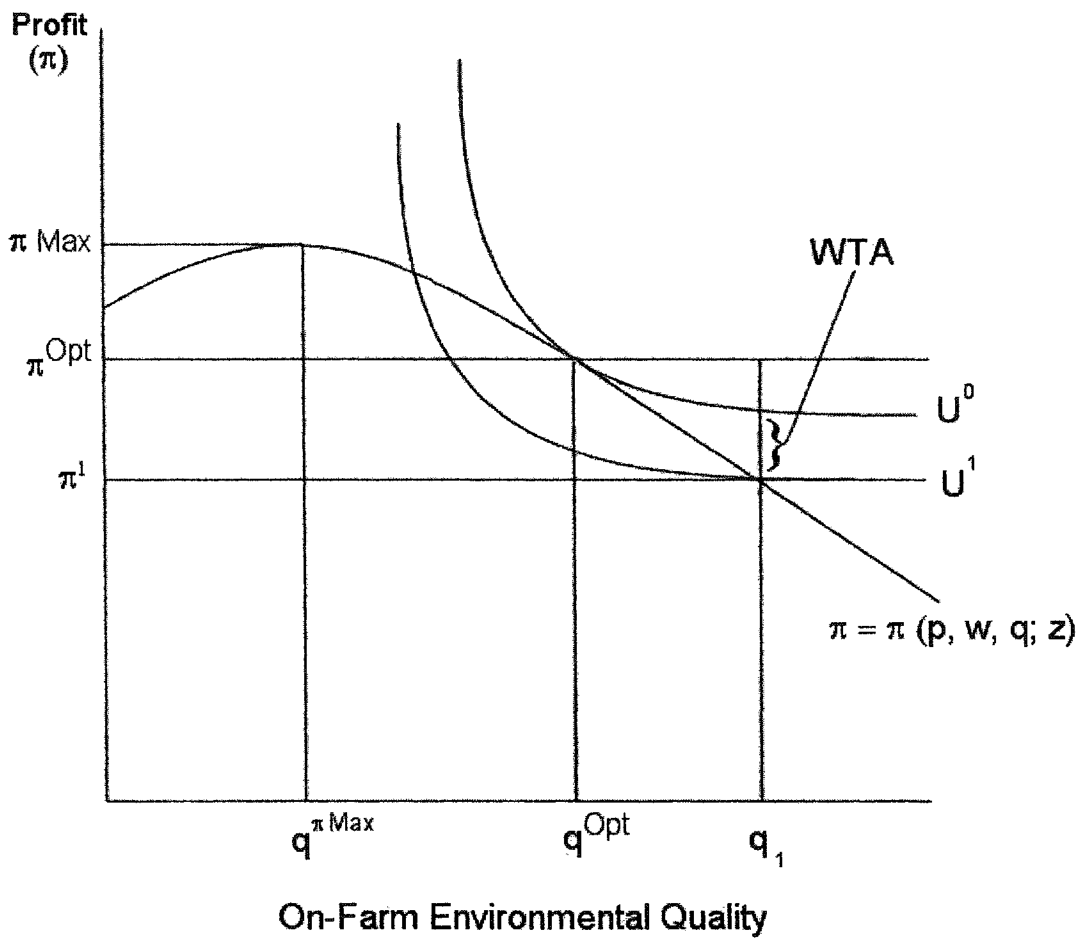
Table 2.2 Alberta Beef Cattle at July 1 (Thousands of Head)

Year	Beef Cows	Beef Heifers	Heifers for Slaughter	Calves	Steers	Bulls	Total Beef Cattle	5-600 pound Calves, May Prices, Adjusted for Inflation (1992=100) ($/cwt)
1976	1,530	270	368	1,435	770	88	4,461	116.87
1977	1,500	260	318	1,315	660	87	4,140	102.95
1978	1,400	240	320	1,239	645	82	3,926	159.63
1979	1,370	230	325	1,205	650	85	3,865	256.20
1980	1,400	245	306	1,290	600	90	3,931	150.23
1981	1,368	243	325	1,300	607	90	3,933	137.10
1982	1,394	227	320	1,260	580	90	3,871	125.47
1983	1,388	217	300	1,235	540	91	3,771	122.72
1984	1,368	233	298	1,255	540	91	3,785	116.03
1985	1,345	222	264	1,245	492	91	3,659	105.43
1986	1,315	232	255	1,252	426	91	3,571	113.11
1987	1,369	259	271	1,297	465	90	3,751	138.64
1988	1,444	283	287	1,351	526	91	3,982	134.36
1989	1,506	303	319	1,421	571	92	4,212	120.73
1990	1,567	305	320	1,478	568	94	4,332	115.09
1991	1,635	324	330	1,560	575	95	4,519	113.58
1992	1,667	335	348	1,581	631	97	4,659	106.83
1993	1,760	313	410	1,666	549	103	4,801	123.89
1994	1,917	400	359	1,818	567	112	5,173	131.63
1995	2,050	455	374	1,910	564	120	5,473	105.33
1996	2,023	320	459	1,945	653	119	5,519	70.29
1997	1,970	320	550	1,830	670	116	5,456	99.67

AAFRD, 1998-b (Cattle numbers) and Chase, 2001 (Price data)

2.8 Figures for Chapter 2

Figure 2.1 Willingness to Accept On-Farm Environmental Quality Programs*



* Adapted from Norton et al. (1994)

Chapter 3

3.1 Initial Questionnaire Methodology

3.1.1 *Introduction*

A questionnaire was developed to obtain a qualitative assessment of the knowledge level of producers, as well as their ideas about riparian management. Some questions probe the economic importance of management strategies to producers. This information will be tied to economic assessments in later chapters. The questionnaire was presented to producers at the 2000 Stockmen's Range Management Course in Maycroft, Alberta.

The Stockmen's Range Management series is sponsored by: the Alberta Cattle Commission, Alberta Agriculture, Food, and Rural Development, Agriculture and Agri-food Canada, the Prairie Farm Rehabilitation Administration, Alberta Environment, Cows and Fish, and others. This was not a random sample of the population of Alberta ranchers. It was biased in favour of those producers willing to attend the course. Forty-two producers and 2 non-producers filled out the questionnaire. The following section briefly describes the survey questions used. The full survey is found in Appendix 1.

3.1.2 *Survey Sections*

The questionnaire was divided into a number of sections. The first section involved an explanation of the various riparian management methods proposed by the Cows and Fish Program. These methods included Distribution Practices, Rotational Grazing, Deferred Rotational Grazing, Time-Controlled Grazing, Rest-Rotation Grazing, Riparian Pastures, Holding Pastures, and Corridor Fencing. As well, respondents were given an idea of the relative cost of each method. These methods are described in Chapter 2.

Part I

Part I of the survey presented two scenarios to respondents. Figure A (Scenario 1) showed a pasture that had been grazed season-long for 50 years. Figure B (Scenario 2) showed a pasture that demonstrated signs of recovery with a rotational grazing program. Both scenarios asked respondents to choose management strategies to manage the areas shown in the figures. They were asked to rank a list of choices from first to last (1 being the first choice, and 8 being the last). The choices were arranged as they have been discussed in the description section above (see Appendix 1). A section was also provided for respondents to give comments on the section.

The second part of Part I asked respondents how much their management choices were affected by certain factors. The respondents were asked to rate the factors from High Influence to Low Influence, on a Likert scale of 1 to 7 (1 being High Influence, 7 being Low Influence). The factors were arranged as follows:

a) Fencing and other capital costs
b) Management time required
c) Water quality for livestock
d) Water quality for downstream users
e) Effect on public perception
f) Changes in forage production
g) Changes in forage quality
h) Effect on fish and wildlife
i) Impact on short-term grazing
j) Impact on long-term grazing capacity
k) Cows and Fish recommendations
l) Effect on long-term ranch cash flow
m) Other (Examples: fish shelter, stable banks, etc.)

Parts II and III

The second part of the survey involved the respondents' choices of measurement units. That is, when the results of the survey were reported, which units of measurement would the respondents want to see used? The third and final part of the survey collected demographic information from respondents. These parts are presented in detail, in Appendix 1.

3.2 Initial Questionnaire Results

3.2.1 *Demographic Results*

The majority of respondents were ranchers or producers with grazing animals (Table 3.1). Many respondents have large-scale operations, with 90% of them being cow/calf operations. 80% of the respondents' operations had a riparian area on site. These are the producers who will be most affected by this study. 83% of respondents supported the objectives of the survey, and 76% of respondents thought that a survey was a good way to get information from ranchers. The two respondents who said no indicated that on-farm visits would be a better method.

3.2.2 *Figure A (Scenario 1) Badly Damaged Riparian Area Survey Response*

The badly damaged riparian area picture (Figure A in the questionnaire) can be seen in Figure 3.1. For this scenario, many producers favored Distributional Practices as a management choice (Table 3.2). More than half of the respondents ranked it as choice 1 or 2. Only one respondent ranked the Holding Pastures scheme as first choice, while 69% placed it at 7 or 8. Corridor Fencing received an interesting response; 52% of respondents placed it at 7 or 8, while 27% of respondents ranked it as their first choice.

The producers who responded to this questionnaire seemed to acknowledge the fact that overgrazing pastures can cause severe damage to riparian areas. Respondents recognized that the riparian area was damaged, and did not need increased grazing pressure. As well, there seemed to be a preference for the least expensive strategies. The response for Corridor Fencing was interesting, as it would be the most expensive strategy for beef producers. Even so, 27% of producers ranked it as a first choice. This may suggest that these producers felt that this riparian area was in need of a "last resort" fix. The producers may also have been exhibiting concerns regarding future environmental restrictions or legislation for riparian areas.

3.2.3 *Figure B (Scenario 2) Recovering Riparian Area Survey Response*

The recovering riparian area (Figure B in the questionnaire) can be seen in Figure 3.2. In this scenario, many producers favored Distributional Practices as a management choice (Table 3.3). More than half of the respondents ranked it as choice 1 or 2. Rotational Grazing was ranked as a high or "middle ground" choice (36% chose 1 or 2, 35% chose 3 or 4). Only three respondents ranked the Holding Pastures scheme between 1 and 5, while 93% placed it at 6, 7, or 8.

Corridor Fencing was biased toward the lowest rankings, with 87% of respondents choosing 6, 7, or 8. The producer responses to Scenario 2 were much like those for scenario 2. Least-cost scenarios were favoured. Producers seemed to know that this riparian area would not need Corridor Fencing to correct damage to the riparian area, as it was in a recovery stage.

The producers were then asked to rank the factors that would affect their decisions to use each management scheme. More information on the following results can be found in Appendix 2. The most important factors for producers appear to be

Changes in forage production, *Changes in forage quality*, *Effects on fish and wildlife*, and *Impact on long-term grazing capacity*. The effects on fish and wildlife will not be addressed in this study, but the other choices will have an impact.

These choices suggest that ranchers surveyed are looking to the future. They are concerned with the supply of quality forage for their livestock, and care about the other animals that inhabit parts of their ranches. These choices also suggest that ranchers also value long-term earnings, or income stability. The time factor will be addressed in our analysis, as we used 20 years of grazing in our ranch models.

The second part of the survey involved the respondents' choices of measurement units (See Appendix 2 for more information). Producers favoured Animal Unit Months (AUM) of grazing, when results are reported (69% of respondents). Many producers felt that Tonnes of Forage per Acre (47%) would also be a good way of showing results. These measurement units go hand in hand, as the amount of forage produced per acre will affect the number of AUM's of grazing possible. However, because AUM calculations can take cow size into account, AUM of grazing would be a better choice.

Choices featuring "dollars per acre" (benefit – 29%, cost – 38%, revenue – 24%, and profit – 22%) competed with "pounds of beef per animal" (27%) for the rest of the producers' choices. These go hand in hand as well, since pounds of beef per animal will translate to dollars for producers at the end of a grazing season. The total percentage of responses will not sum to 100%, as respondents were encouraged to choose more than one measurement unit.

3.3 Chapter Summary

Most of the respondents surveyed were ranchers with relatively large operations. Since large cow/calf operations will be modeled in this study, these producers would be most interested in the results. The responses to the initial questionnaire showed that most producers surveyed are knowledgeable about riparian area management. When choosing a strategy for their own ranches, producers would favour lower-cost solutions, such as distributional practices and rotational grazing.

However, in the case of a heavily degraded riparian area, many producers chose corridor fencing, the strategy with the highest capital costs. This may be a result of producers looking to the future, and selecting impacts on forage production and quality as the most important factors in their decision-making. This is further supported by the choices of long-term effects of riparian management on grazing capacity and ranch cash flow as important considerations.

3.4 Tables for Chapter 3

Table 3.1 Responses to Questions Relating to Characteristics of Ranches Managed by Respondents to the survey (N=44)

Questions asked	**Number**	**Percent of total sample**
Do you ranch or farm?	42	95
Do you have grazing livestock such as cattle?	41	98
Do you have a riparian area on your ranch?	33	80
Description of Cattle Operation		
Cow/Calf	37	90
Backgrounding	12	29
Finishing cattle	3	7
Other	7	17
Number of animals per operation		
<50	4	10
50-199	11	27
>200	26	63

Table 3.2 The number and percentage of the total respondents' ranks of various management practices to repair a damaged riparian area (Figure A – Scenario 1).

	Distributional Practices		Rotational Grazing		Deferred Rotational Grazing		Time Controlled Grazing		Rest Rotation Grazing		Riparian Pastures		Holding Pasture		Corridor Fencing	
Rank	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
1	9	22	3	12	4	10	2	5	3	7	9	22	1	3	11	27
2	12	30	5	15	3	8	6	15	7	17	6	15	0	0	2	5
3	4	10	6	20	11	27	8	20	6	15	2	5	0	0	4	10
4	5	12	8	22	10	24	4	10	6	15	5	13	2	5	1	3
5	3	7	9	12	5	13	4	10	9	22	9	22	2	5	0	0
6	3	7	5	7	5	13	10	23	7	17	3	8	7	18	1	3
7	2	5	3	5	2	5	7	17	1	2	4	10	16	39	4	10
8	3	7	2	7	0	0	0	0	2	5	2	5	12	30	17	42
Mean Rank	3		4		4		4		4		4		7		5	
Std Dev	2.21		1.86		1.60		1.92		1.86		2.24		1.41		3.13	

Rank of 1 is the highest ranking, rank of 8 is lowest ranking

 # refers to frequency of response, % refers to percentage of respondents choosing the rank

Table 3.3. Number and Percentage of the Total Respondents' Ranks of Various Management Practices to Maintain a Recovering Riparian Area (Figure B – Scenario 1).

	Distributional Practices		Rotational Grazing		Deferred Rotational Grazing		Time Controlled Grazing		Rest Rotation Grazing		Riparian Pastures		Holding Pasture		Corridor Fencing	
Rank	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
1	16	39	4	10	6	15	5	12	6	15	5	12	0	0	1	2
2	6	15	11	26	7	17	4	10	8	19	4	10	0	0	1	2
3	1	2	8	20	11	27	10	23	6	15	3	7	1	2	1	2
4	4	10	6	15	11	27	8	19	6	15	4	10	0	0	2	5
5	6	15	5	12	4	10	7	17	8	19	8	19	2	5	1	2
6	5	12	4	10	1	2	8	19	2	5	11	25	6	15	4	10
7	1	2	3	7	0	0	0	0	3	7	5	12	21	51	8	20
8	2	5	0	0	1	2	0	0	2	5	2	5	11	27	23	57
Mean Rank	3		4		3		4		4		5		7		7	
Std Dev	2.28		1.78		1.50		1.62		2.03		2.07		1.01		1.77	

Rank of 1 is the highest ranking, rank of 8 is lowest ranking

refers to frequency of response, % refers to percentage of respondents choosing the rank

3.5 Figures for Chapter 3

Figure 3.1 Badly Damaged Riparian Area

Figure 3.2 Recovering Riparian Area

Chapter 4

Introduction

This chapter presents simplified overviews of risk, discount rates, and Net Present Value analysis, as they relate to models used in this study. Section 4.1 is a technical discussion of investment analysis. Net Present Value (NPV) analysis, as it relates to cow/calf operations, is discussed. Next, the theory of risk premia and the Capital Market Line (CML) are presented. These concepts relate to the choice of a discount rate for a cow/calf operation. The key assumptions used in each of the model's range management cases are described in section 4.2. These assumptions determine the results from the static NPV analysis.

4.1 Theoretical Framework

4.1.1 *Capital Budgeting: Net Present Value (NPV)*

Farm models developed in this part of the study are analyzed using an incremental Net Present Value (NPV) analysis. This type of analysis is often used to analyze capital investments. A producer may invest in capital that will have value for more than one period. That is, the time value of money must be taken into consideration. The time value of money is one of the most important concepts in farm (and corporate) finance (Ross et al., 1999). Money received today is more valuable than money received tomorrow (AAFRD, 1995). That is, the longer a person must wait for money, the less it is worth to that person today.

The *future value* or *compound value* of money is the value of a sum after investing for one or more periods (Ross et al., 1999). For example, if one were to invest 10,000 dollars today at a 12% interest rate (annual compound rate), it would be worth 11,200 dollars after one year [10,000 x 1.12 = 11,200], and 12,544 dollars after two years [11,200 x 1.12 = 12,544]. That is, the future value is written as:

$$FV = C_0 \times (1 + r)^T \qquad \textbf{4.1}$$

where C_0 is the cash invested at time 0, r is the interest rate, and T is the number of periods over which the cash is invested (Ross et al., 1999).

Another way to show the time value of money is *present value*. This type of analysis tells an investor how much money he or she must invest today, in order to make a specific amount in the future (Ross et al., 1999). Using numbers from the above example, the present value of 11,200 dollars one year from now, at a 12% rate, is 10,000 dollars. An investor would know the amount of money to invest today, at a 12% rate, in order to receive 11,200 dollars in one year [11,200 / 1.12 = 10,000]. In the case of present value, the interest rate is referred to as the *discount rate* (Megginson, 1997). The equation for Present Value can be written as:

$$PV = \frac{C_t}{(1+r)^t} \tag{4.2}$$

where C_t is the cash flow at time period t and r is the interest (discount) rate.

Damodaran (1997) described a *discount rate* as a rate at which present and future cash flows are traded off. This rate calculates the present value of future cash flows (Ross et al., 1999). The discount rate includes the following elements:

1) preference for current consumption
2) uncertainty in future cash flows.

That is, if there is higher risk, there will be a higher discount rate. As well, if one has greater preference for current consumption, the discount rate is higher (Damodaran, 1997). The discount rate is discussed further in section 4.13.

The expected net cash flow produced by an investment can be presented as a single figure, known as the Net Present Value (NPV) (AAFRD, 1995). The NPV is adjusted for risk, inflation, and the time value of money. In order to understand the computation of a NPV, a simple example adapted from Ross et al. (1999) will be used. A company has the choice of investing $100 in a riskless project. The project has a cash flow of $107 after one period. The company can choose to invest the $100 today, and pay the $107 as a dividend after one period. On the other hand, the company can forego the project, and pay out the $100 as a dividend now. If the interest (discount) rate is 6%, the NPV of the project would be the $107 dividend, divided by 1.06 (interest rate), minus the $100 initial payment (107 ÷ 1.06 – 100). The result is $0.94. When an NPV is positive, a company will generally accept a project (Ross et al., 1999).

The above example could be applied to many situations. An agricultural producer faces a variety of investment decisions that affect his or her operation. The NPV method has three main attributes. The first attribute is that NPV uses cash flows. Other methods use earnings, which are artificial accounting constructs (Ross et al., 1999). Earnings do not represent cash, as cash flows do. NPV also uses all of the cash flows of a project, instead of ignoring cash flows after a specific period (as other methods, such as Payback do). NPV analysis also discounts cash, relying on the time value of money (Ross et al., 1999). These elements can be seen in the NPV formula, for multiple periods, shown below:

$$\mathrm{NPV} = C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^n} = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i}$$

(4.3)

where C_i represents the net cash flow for each period i, n represents the life of the project (last period), and r represents the risk-adjusted discount rate.

Other than NPV, there are a number of methods (rules) used to analyze investments. The first of these rules is the *Payback Period Rule*. The payback period is the amount of time required to recover the initial investment in a project, taking into account projected cash inflows (Megginson, 1997). When the amount to be received exceeds the initial investment, then the investment is recovered. In the case of a two-year cutoff period, an investment project that has a payback period of two years or less will be accepted (Ross et al., 1999).

There are some problems with the payback period method. First, the timing of the cash flows is not considered. That is, they are not discounted properly (as they would be in NPV analysis) (Ross et al., 1999). A second problem is that the method does not include payments that occur after the payback period (Megginson, 1997). A project that has a positive cash flow after the payback period would definitely be preferred to one that does not. There is also a problem with the choice of a payback period. Using the Payback Period Rule, the choice is arbitrary (Ross et al., 1999). A method such as NPV has a standard for choosing important aspects of financing, such as discount rates.

Another rule noted by Ross et al. (1999) is the *Average Accounting Return* (AAR). This method is defined as "the average project earnings after taxes and depreciation, divided by the average book value of the investment during its life" (Ross et al., 1999). Projected net incomes for each year in the life of the project, divided by its life span, are summed to find average net income (Ross et al., 1999). The expected values of an investment over the life span are summed, then divided by the life span to get average investment (Ross et al., 1999). The AAR can then be calculated by dividing the average net income by the average investment. The resulting percentage is the AAR (Ross et al., 1999).

One major flaw of the AAR method is the fact that accounting values (net income, book value of investment) are used to judge the value of the investment. A better analysis of the investment could be performed using the cash flows associated with a project (as in NPV) (Ross et al., 1999). Also, as in the case of the Payback Period Rule, the AAR method does not take timing of cash flows into consideration. The AAR method also requires an arbitrary cutoff date to be chosen (Ross et al., 1999).

The *Internal Rate of Return* (IRR) method (the most important alternative to the NPV approach) is used to find a single number that explains the benefits of a project (Ross et al., 1999). The number is an *internal* rate of return because it does not depend on the prevailing interest rate in the capital market. If NPV for a one-period project is written as:

$$NPV = Initial\ Investment + \frac{First\ Period\ Cash\ Flow}{1+r} \tag{4.4}$$

where r is the discount rate, the IRR is the rate r at which NPV will equal zero (Ross et al., 1999). The company or producer will accept the project if the discount rate is above the IRR, and vice-versa. This is the standard IRR rule (Ross et al., 1999).

Problems associated with IRR are not as apparent as problems with other methods. Consider two types of project. If a company pays money first, and receives money later, this is an investing-type project. If a company receives money first, and pays money later (e.g., conference attendees paying fees in advance), this is a financing type project (Ross et al., 1999). A financing-type project can reverse the standard IRR rule (see above). This can be a problem, unless it is fully understood (Ross et al., 1999). A project's cash flows may also exhibit two or more changes of sign for the net cash flows in different periods (e.g., -\$100, \$200, -\$150). A project such as this may exhibit more than one IRR, due to the "flip-flops" in sign (Ross et al., 1999).

Aside from the mathematical properties mentioned above, Megginson (1997) pointed out that NPV analysis uses a more conservative and realistic investment rate. The NPV approach implicitly assumes that intermediate cash flows generated by an investment will be reinvested at the discount rate (Damodaran, 1997). The IRR approach assumes reinvestment at the IRR of the project (Megginson, 1997). Megginson (1997) noted that the IRR rate is often higher than the discount rate (which is often a reasonable reinvestment rate).

Theoretically, NPV is a better approach for investment analysis (Megginson, 1997). However, many businesses (including farm businesses) often use the accounting approach or IRR to evaluate choices. This may be because the IRR can summarize a project into a simple rate of return (Ross et al., 1999). Freeze et al. (1999) used an accounting approach to evaluate beef feedlot composting. Unterschultz and Quagrainie (1996) used investment analysis in their study of agri-food ventures. However, Mumey and Unterschultz (1996) used concepts of NPV analysis in a study of risk premia in combines and tractors. Risk premia are discussed in section 4.1.3. Applying the reasoning discussed above, future analyses of riparian management would benefit from NPV analysis.

In order to use NPV analysis in our riparian management model, certain information is needed. Production data and relationships are needed for the model, a cow/calf operation. These provide a function for converting raw materials into a finished product. In the case of a cow/calf operation, it is the conversion of forages into 500-600 pound beef calves. As well, the revenue generated by the sale of finished products is needed. Capital and operating costs for the operation are needed in order to calculate of net cash flow (revenue – cost). Incremental analysis evaluates the changes between different competing scenarios. This simplifies the analysis while maintaining the rigour of NPV analysis.

4.1.2 *Project Risk*

Every project will have a certain amount of uncertainty associated with it. This uncertainty is referred to as risk. Megginson (1997) stated that investors wish to maximize returns for a given amount of risk. According to Unterschultz and Quagrainie (1996), investment projects can have two types of risk associated with them. These risk types are termed *unique risk* and *systematic risk.* Unique risk is risk that is specific to the investment project. Systematic risk is covariance risk between the investment project and the total market (Unterschultz and Quagrainie, 1996). If an investor can diversify his or her investment portfolio (i.e., hold more than one investment in a portfolio at one time), unique risk could be reduced to the point that it will not affect the overall value of a portfolio (Damodaran, 1997).

The standard financial approach to portfolio risk and diversification can be seen in Figure 4.1. It shows that as securities or assets are added to a portfolio, the total portfolio risk decreases. Total portfolio risk is measured as the standard deviation of portfolio returns. However, businesses such as cow/calf operations are often non-diversified. Therefore, both unique and systematic risk (total portfolio risk) must be considered when analyzing a farm's financial situation.

4.1.3 *Finding a Risk Premium and Discount Rate for an NPV analysis*

In this study, we wish to obtain a risk measure (discount rate) to use in the Net Present Value analysis of non-diversified investments. First, risk as it applies to diversified investment portfolios will be discussed. Though unique risk can be eliminated in most investment situations through diversification, systematic risk will continue to affect investors. According to Megginson (1997), this means that investors will demand a premium for holding more risky assets. The higher the systematic risk, the higher the expected rate of return will be. Investors must find a trade-off between risk and return. Damodaran (1997) stated that, if an investor specifies the amount of risk he or she is willing to accept, then the portfolio is optimized when expected returns are maximized subject to this level of risk. The dual approach suggests that, if an investor specifies his or her desired level of return, then the portfolio is optimized when variance (risk) is minimized, subject to this level of return (Damodaran, 1997).

Risk minimization can be written as:

$$\text{Min}: \sigma_p^2 = \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} w_i w_j \sigma_{ij} \tag{4.5}$$

Subject to:

$$E(R_p) = \sum_{i=1}^{i=n} w_i E(R_i) \geq E(\hat{R})$$

(4.6)

Where σ^2_p is the variance of the portfolio, w_i and w_j are portfolio weights on assets, σ_{ij} is the covariance between returns, $E(R_p)$ is the expected return on the portfolio, n is the number of assets, w_i is the profile weight on an asset, $E(R_i)$ is the expected return on an asset, and E(R) = Investor's desired expected returns.

The elliptical line shown in Figure 4.2 is referred to as the Efficient Frontier. This line is the result of varying E[R] in equations (4.5) and (4.6). Standard Deviation of Returns, σ_p, represents risk. Risk increases from left to right in the figure. The points on the efficient frontier represent combinations of risk (X-axis) and expected return (Y-axis). For example, point M would have a risk associated with it of σ_B and an expected return of $E[R_B]$.

Megginson (1997) stated that investors could choose to invest in risky assets (i.e., common stocks) or risk-free (riskless) assets (i.e., government treasury bills). With risky assets, the returns vary depending on the assets. A riskless asset has an actual return equal to the expected return (Damodaran, 1997). That is, the investor knows what the return will be at the time of the investment. Damodaran (1997) noted that, when investors have the choice of a riskless asset to invest in, the absence of variance in this asset makes it uncorrelated with the returns on any risky assets. Combinations of risky assets with a riskless one will give linear results for the standard deviation (Damodaran, 1997).

The linear relationship that exists between the standard deviation of the overall portfolio and the proportion invested in a risky asset is depicted in Figure 4.2. Megginson (1997) refers to the line from R_f through point *M* as the Capital Market Line, or CML. This line represents portfolios formed by combinations of the risk-free asset and the portfolio of risky securities, *M,* on the efficient frontier. *M* could be a portfolio composed of 30% in Bell Canada Enterprises (BCE), 45% in Canadian Imperial Bank of Commerce (CIBC), and 25% in Canadian Marconi (Ross et al., 1999). *M* is usually considered to be a large portfolio of financial assets. The CML is the efficient set of both risky and riskless assets. Points between R_f and *M* are portfolios in which some money is invested in the riskless asset and the rest is invested in *M*. Points past *M* are obtained by borrowing at the riskless rate, in order to buy more of *M*.

In this example, σ_A, σ_B, and σ_C represent the risk levels of projects. The standard deviation of returns (risk) increases from left to right (Megginson, 1997). That is, the Standard Deviation (X-axis) gives a Total Measure of Risk. Investor A could choose to invest in *A*, a point on the CML between R_f and M. Ross et al. (1999) stated that a more risk-averse investor might choose this point. A person with less risk aversion might choose a point closer to, or even beyond *M*, like point C. The return is maximized at a combination of the riskless asset and the risky portfolio at *M*, tangent to the riskless asset (Damodaran, 1997).

Portfolios on the CML dominate all other possible portfolios (Megginson, 1997). Ross et al. (1999) noted that, with riskless borrowing and lending, an investor's portfolio of risky assets would always be at point M. An investor would never choose another point on the efficient frontier, regardless of his or her tolerance for risk. In the same manner, the investor would also choose not to invest in a portfolio within the feasible region, below the efficient frontier (Ross et al., 1999). The more risk-averse investor would combine the securities of *M* with riskless assets. The less risk-averse investor would borrow the riskless asset to invest more in *M* (Ross et al., 1999). The insight that investors will always choose some combination of the riskless asset and the tangent portfolio is referred to as the *separation theorem*, or *two-fund separation* (Damodaran, 1997).

The CML provides an investment alternative, or a comparison to other investments for non-diversified investment portfolios. The equation for the Capital Market Line would be:

$$R_f + \sigma_B\left[\frac{R_M - R_f}{\sigma_M}\right] = E[R_B] \tag{4.7}$$

where R_f is the risk-free rate, σ_B is the risk associated with the asset B, R_M is the expected market return, σ_M the market risk, and $E[R_B]$ is the individual expected asset return. The Capital Market Line can lead to the choice of a discount rate for a project that is a large portion of the investor's portfolio. Mumey and Unterschultz (1996) stated that the discount rate is composed of a *riskless (risk-free) base rate* and a *risk premium*. A *risk-free rate* is the current rate of return for a one-year Treasury bill (Ross et al., 1999). Changes in capital supply and demand, as well as inflationary expectations can cause this rate to rise and fall (Mumey and Unterschultz, 1996).

A *risk premium* is the difference between the rate of return on a risky investment and the interest rate. In Figure 4.2, the difference between the expected return on the market portfolio, $E(R)_M$, and the risk-free rate gives the market risk premium and this premium can be used to calculate the risk premium for the risky investment. Rearranging equation 4.7 above, the risk premium would be:

$$E[R_B] - R_f = \sigma_B \left[\frac{R_M - R_f}{\sigma_M} \right] = \text{Risk Premium} \tag{4.8}$$

This means that $E[R_B]$ in equation (4.7) is a combination of a risk-free rate plus a risk premium. Therefore, the expected rate of return would become the discount rate.

According to Ross et al. (1999), the standard deviation of annual returns on a market portfolio (1948-1997) was 16.45% for Canada. From 1973 –1997, the standard deviation of Canadian Common Stocks was 16.36% (Ross et al., 1999 p.254). The market risk premium was calculated to be 7.04% (Ross et al., 1999). Munro (1993) calculated the risk on an Alberta calf feeding operation's annual returns. With a routine hedge, the risk for 550-pound calf enterprise was calculated to be 14.63%. The current (August 22, 2001) 91-day average Treasury Bill rate in Canada is 3.95% (Royal Bank, 2001). This is used as the risk-free rate. The calculation of the Capital Market Line, using equation 4.7 would be:

$$3.95 + 14.63 \left[\frac{7.04}{16.45} \right] = 10.21 \tag{4.9}$$

The result of this equation is the expected return on the cow/calf operation, given the risk level on the cow-calf portfolio. This expected return is the discount rate chosen for the cow/calf operation. In this case, the discount rate was found to be approximately 10%. This was the discount rate used for the cow/calf analysis in the static ranch model, described below. Bauer (1997) analyzed the costs and returns associated with the use of

Crown grazing dispositions in Stavely, Alberta. He analyzed a cow/calf operation from 1976 to 1996. The real rate of return for a Southern Alberta cow/calf operation was found to be 5.6%, with a standard deviation (risk) of 19.4%. Using this risk level in the above discount rate calculation, the discount rate would be 12.25%. Therefore, the 10% discount rate used in this study may understate the risk.

4.2 Static Ranch Model Assumptions

In this section, the static ranch models will be discussed. The discussion will present the key assumptions used in the NPV analysis of various riparian management strategies. These models deal with incremental analysis. Therefore, only the changes in the riparian area pasture were modeled. Income tax and other whole ranch considerations were not considered. The model involved the examination of a pasture containing one riparian area. Variables such as weather, calf prices, and land values were held constant. Once the base case was created, certain initial conditions were varied, to compare the costs of a status quo system to a new riparian management system. Model assumptions can be found in Table 4.1. Incremental changes are outlined in Table 4.2.

The main variable used in the model was the stocking rate, which was defined as the number of Animal Unit Months (AUM) per acre of pasture. In this model, an implicit assumption is that one AU is equivalent to a 1,000-pound cow, with a calf by her side (Range Notes, 1990). One grazing season amounts to 5.5 months in the case of the static model.

The carrying capacity, or sustainable carrying capacity, refers to the number of Animal Unit Months (AUM) a pasture can provide in one grazing season. An AUM refers to the amount of forage consumed by an Animal Unit (AU) in one month. This amount is approximately 1,000 pounds of dry matter (forage) (Range Management – Public Lands Division, 1990). Carrying capacity is also referred to as grazing capacity. If a pasture is overgrazed, carrying capacity is exceeded, and a lower future stocking rate must be chosen to restore range health (Wroe et al., 1988). In the model, if livestock degraded the pasture in a season, the number of AUM per acre in the following grazing season was reduced in accordance with the new, degraded carrying capacity. Various scenarios were designed based on variations in carrying capacity.

4.2.1 *Herd Assumptions*

The herd assumptions for all models were as follows. The gain per calf per day was assumed to be 2.2 pounds (1 kilogram) (Adams et al., 1991). The price for a 500-600 pound calf was $1.53 per pound (data provided by AAFRD). It was assumed that the market weight of a calf would be 550 pounds (chosen from an AAFRD beef market report, listing 500-600 pound calf sales). The death rate for calves was assumed to be 2%.

4.2.2 *NPV Calculations*

NPV calculations for all models were as follows. A discount rate of 10% was chosen. The calculation of this rate was discussed in the section 4.1.3. Calculations for the model were made over 20 years. Each year will often be referred to as a grazing season (or simply a "season"). An adjustment was made to the model to include net revenue beyond year 20 (twenty[1]). The net cash flows were discounted, using the 10% discount rate. The equation for each period was:

$$DCF = NC / (1 + r)^t \tag{4.10}$$

where DCF is the discounted cash flow, NC is net cash, and r is the discount rate, and t is the season number. The discounted cash flow was calculated for each season in the model. The DCF values for the twenty seasons were then summed to get the Net Present Value (NPV) for the cow/calf operation. That is:

$$NPV = \sum_{i=0}^{20} (DCF_i) \tag{4.11}$$

4.2.3 *Base Case – Conservative Continuous Grazing from Good Condition*

In the base case, a producer grazes a sustainable level of animal units in a continuous grazing system. That is, the producer chooses a stocking rate which matches the sustainable carrying capacity for the pasture. The animals are continuously grazed for 5.5 months in each grazing season. There are 20 grazing seasons in total. This scenario was chosen to highlight a continuous grazing system in which pasture is not degraded.

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[1] A simple perpetuity calculation was added to capture all benefits beyond year 20.

That is, it does not need a change in management strategy in order to improve. All other scenarios used this base case, with modifications in management and fencing.

4.2.3.1 Field Assumptions

The base case assumed an 1800-acre pasture unit, hypothetically situated in the Porcupine Hills of Southern Alberta. This is an area of the province where many beef operations are situated. This pasture is part of a larger ranching operation. The pasture area was broken down into 500 acres of riparian area, and 1,300 acres of upland. 1,800 acres translates to 3 sections of land placed end to end, minus 120 acres. A section is measured as one square mile of land. It is equivalent to 640 acres. Assuming a rectangular shape, the pasture was 14,817 feet in length and 5,280 feet (one mile) in width. It was assumed that the outside perimeter of the pasture was previously fenced (Figure 4.3).

For convenience, the stream and accompanying riparian area ran down the center of the pasture. The maximum width of any one meander of the stream was 250 feet. In order to keep livestock well distributed, it was assumed that the producer had previously added two waterers to the pasture. Each waterer fed water to two watering sites, one on each side of the pasture. This assumption regarding the location of the riparian area, while simplifying the analysis, represents a very idealized type of riparian system. The list of key assumptions for this model is found in Table 4.1.

4.2.3.2 Grazing Capacity and Stocking Rate

It was assumed that the pasture was of the Foothills Grassland range type, in the 18-22 inch (annual) precipitation zone, and the range condition was in the "Good" class (Adams et al., 1991). Adams et al (1991) stated that upland pasture in Good condition could support a stocking rate of 80 AUM/quarter section (2 Acres per AUM). Adams and Ambrose (2001) suggested that the riparian area could support double this rate, or 160 AUM/quarter section (1 Acre per AUM). When the upland and riparian pasture areas (in quarter sections) were multiplied by the stocking rates, it was found that the upland pasture had a carrying capacity of 650 AUM, and the riparian pasture a capacity of 500 AUM.

This translated to an initial (Year 1) uplands stocking rate of 0.5 AUM per acre per grazing season (5.5 months), and a riparian area stocking rate of 1.0 AUM per acre per grazing season. The stocking rate is the carrying capacity in AUM (650 or 500), divided by the pasture size in acres (1,300 or 500). This equates to 118 cow-calf pairs on the uplands pasture and 91 cow-calf pairs on the riparian pasture each grazing season. Since these levels of grazing were sustainable for the pastures, the producer had no loss in grazing capacity over the 20 seasons.

4.2.3.3 Incremental Revenue

Incremental revenue was derived from the weight gain of calves while they were on pasture. It was referred to as the total value of calves attributed to pasture. The total weight gain per calf attributed to pasture was found by multiplying the daily gain per calf (in pounds) by the grazing season (in months) by 30 days in one month. The total value of calves produced (attributed to pasture) was calculated by multiplying the total weight gain per calf by the price of a finished 5-600 lb calf by the total number of animal units grazed (minus the death loss). All incremental changes are found in Table 4.2. The daily rate of calf gain remained constant among scenarios.

4.2.3.4 Incremental Costs

In the base case, the stocking rate was assumed to be sustainable for each of the 20 seasons. As no new management strategies were needed to maintain the health of the riparian area, there were no incremental costs incurred in this scenario.

4.2.4 *Case 2 – Unsustainable Continuous Grazing from Good Condition*

The second case is one in which the pasture is overgrazed and the range starts in an initially good pasture condition. The stocking rate exceeds the sustainable carrying capacity for the pasture. This case is used to illustrate the incentive (if any) to overstock a pasture. It illustrates the effects of unsustainable stocking rates on pasture. Animals are still grazed for 5.5 months per year, for twenty years.

4.2.4.1 Field Assumptions

The pasture in case 2 is the same as the one used in the base case. It appears in Figure 4.3. Assumptions for this case can be found in Table 4.1.

4.2.4.2 Grazing Capacity and Stocking Rate

Initially, as in the base case, the pasture is in the Good range condition class. The initial stocking rates are 30% higher than in the base case. The uplands are stocked at 0.65 AUM per acre per season (154 AU per season), and the riparian area at 1.3 AUM per acre per season (118 AU per season). That is, the stocking rate exceeded the sustainable grazing capacity by 30%. The stocking rate was decreased slightly over time, as the carrying capacity was reduced, to simulate lost grazing potential through range deterioration. The overgrazed pasture had an assumed capacity decrease of 6% per season on the uplands (i.e., $AUM_t = (1-0.06)\ AUM_{t-1}$), and 3% per season on the riparian area, until Season 14.

After Season 14, it was assumed that stocking rate in the uplands reached a steady state of 0.273 AUM/acre, or 65 AU grazed per season. The riparian area, with its lower degradation rate did not reach the steady state. In Season 20, the riparian area had a stocking rate of 0.729 AUM/acre, or 66 AU grazed per season. Adams et al. (1991) and personal communication with Adams (2000) were used as a basis for the choice of deterioration rate. Rates in the literature varied from pasture to pasture. The rate in this model was chosen because it would reduce the pasture's carrying capacity by slightly more than half after twenty grazing seasons (assuming the steady state for upland range after season 14).

4.2.4.3 Incremental Revenue

Incremental revenue was found in the same manner as in the base case. Incremental changes are found in Table 4.2. Incremental revenue in case 2 is higher in earlier seasons than the in the base case. However, in later seasons, it falls below that of the base case, due to degradation of pasture and lower stocking rates.

4.2.4.4 Incremental Costs

Though the carrying capacity of the pasture was allowed to decrease in this model, no new management strategies were put in place. Therefore, no incremental costs were incurred. Note that only incremental costs on the riparian pasture are included. Potential costs (of reduced carrying capacity) to the whole ranch are not included.

4.2.5 *Case 3: Unsustainable Continuous Grazing from Poor Condition*

The third case is one in which a previous owner overgrazed an initially Good condition pasture for ten years, as in the first ten grazing seasons of Case 2. This assumed overgrazing has left the pasture in Poor range condition class (initially). Subsequently, the producer in Case 3 overgrazes it. This model is used to set up a comparison for Case 4, rotational grazing.

4.2.5.1 Field Assumptions

The pasture in Case 3 is the same as the one used in the base case. However, it is in poor pasture condition when the overgrazing begins in this model. The pasture appears in Figure 4.3. Assumptions for this model are found in Table 4.1.

4.2.5.2 Grazing Capacity and Stocking Rate

Adams et al. (1991) stated that in order to sustainably graze pasture in poor condition, 50% fewer AUM per quarter section should be grazed than the stocking rate for good condition grassland. As we wanted to simulate overgrazing on this pasture, the stocking rates used were the rates from Season 11 in Case 2. That is, the initial uplands stocking rate in Case 3 was 0.35 AUM per acre, or 83 AU grazed per season. On the riparian area, the rate was 0.959 AUM/acre, or 87 AU grazed per Season. As in Case 2, the stocking rate was decreased slightly over time (because the sustainable carrying capacity was reduced) to simulate lost grazing potential through range deterioration.

As in Case 2, the overgrazed uplands pasture had an assumed capacity decrease of 6% per season. The riparian area had a capacity decrease of 3% per season. Because the pasture begins in a degraded condition, the uplands pasture reaches a steady state (0.273 AUM/acre per season, 65 AU grazed per season) by Season 5. The riparian area degrades to a stocking rate of 0.537 AUM/acre, or 49 AU grazed per season, by season 20. The Sensitivity Analysis (Section 4.42) includes a variation on this scenario.

4.2.5.3 Incremental Revenue

Incremental revenue was found in the same manner as in the base case. Incremental changes are found in Table 4.2.

4.2.5.4 Incremental Costs

Though the carrying capacity of the pasture was allowed to decrease in this model, no new management strategies were put in place. Therefore, no incremental costs were incurred.

4.2.6 *Case 4: Rotational Grazing from Poor Condition*

Case 4 has the same initial pasture conditions as Case 3. Ten years of overgrazing by a previous owner is assumed. The pasture is in poor condition. In this case, the rancher implements a rotational grazing strategy. Rotational grazing strategies were ranked highly by respondents to the initial questionnaire, when asked what riparian management strategies should be used to repair damage to riparian areas (Chapter 3). For this case, it was assumed that management time was available in order to change the riparian management strategy. As well, no additional management costs are added in this case. This model presented an alternative for comparison to the overgrazing strategy seen in Case 3.

4.2.6.1 Field Assumptions

This rotational scheme changed the original pasture. The pasture was divided into four units, by adding three cross fences of one mile in length. Each pasture unit was 5,280 feet in length by 3,705 feet in width. If each new fence addition (assuming the outside area was previously fenced) was 5,280 feet long, then an additional 15,840 feet of fencing was required. As well, in order to ensure good livestock distribution, an additional two waterers were added. This pasture can be seen in Figure 4.4. All key assumptions for this model are found in Tables 4.1 and 4.2.

4.2.6.2 Grazing Capacity and Stocking Rate

As in the previous case, the pasture started in poor condition due to overgrazing. Because all pasture units were not going to be used at once, the grazing capacity was reduced by a further one third on both the uplands and riparian area. That is, the uplands have an initial stocking rate of 0.273 AUM/acre (65 AU grazed per season). The riparian area has an initial stocking rate of 0.671 AUM/acre (61 AU grazed per season). If it is assumed that the animals were rotated through the pastures, grazing is expected to be more uniform in each pasture they graze. It was assumed that the forage resources in the pasture would begin to regenerate. That is, the rotational system would be better for forage re-growth than the original continuous grazing system.

Correspondence with Barry Adams (2000) and Adams et al. (1991) suggested some pasture regeneration times. Each of these examples involved different ranches and many different restoration strategies. Regeneration in these examples ranged from 3.5% per year to almost 10% per year in one case. However, in another case, Adams (2000) suggested that complete regeneration might take more than a ten to fifteen year period. The grazing capacity in this model was assumed to increase by 2 percent each year on the uplands, and 6% per year on the riparian area. By season 8, the riparian area had leveled off at its sustainable steady-state level, 1 AUM per acre, or 91 AU grazed per season.

The uplands pasture had been regenerated to a stocking rate of 0.398 AUM/acre (94 AU grazed per season).

4.2.6.3 Incremental Revenue

Incremental revenue was found in the same manner as in the base case. In this case, the gradual increase in carrying capacity means a similar increase in stocking rate, to match the sustainable carrying capacity. This translates to a gradual increase in incremental revenue. Incremental changes for this model are found in Table 4.2.

4.2.6.4 Incremental Costs

This strategy involves adding new fencing to the riparian area. Saskatchewan Agriculture and Food's fencing cost calculator (SAF, 2001) provided costs per mile for different fencing types (barbed, 3- and 4-strand and high tensile, 4- and 5-strand), using new materials prices from UFA. These costs included tractor and post-pounder use, as well as hourly labour. According to the calculator, four lines of standard barbed, 2-strand, all-post fencing would cost a rancher $0.69 per foot. 5 lines of high-tensile, one-strand, all-post fencing would cost $0.65 per foot.

The cost per foot was multiplied by the amount of fencing needed in each scenario, in order to determine total fencing costs for each of the fencing types. The cheaper high-tensile fence was chosen for this model. This scenario required 15,840 feet of additional fencing, at a cost of $10,296. Maintenance costs per season were set at 2.5% of the original cost of fencing. This number was adapted from Platts and Wagstaff (1984). In the rotational scenario, maintenance cost per year was $257. Note that these fencing and maintenance costs could vary depending on the pasture and riparian area in question.

In a conversation with Adams and Ambrose (2001), it was suggested that a watering site, using water from a ranch well, could be put in place for approximately $3,500. In the base case, it was assumed that two waterers (serving both sides of the pasture) had been installed previously. In the rotational scheme, there are four pastures in total. That is, another two waterers were needed to improve livestock distribution. The extra cost of these watering sites ($7,000) was reflected in the initial costs for this model.

Incremental costs were the differences in costs due to the changes in management strategies. Incremental Costs were divided into Operating Costs and Capital Costs.

Operating costs reflected annual payments for such things as upkeep. Capital costs were fixed, one-time costs (in this case in Season 0), such as fencing and waterers. These were updated for each season, depending on when each change took place. In this example, a producer added fencing and waterers in season zero. These capital costs were not repeated in the following season, as no new fencing or water were needed.

However, the 2.5% maintenance cost appeared as an operating cost in the seasons following fence construction, as fencing must be kept in good condition each season. Total Incremental Costs were calculated by summing Operating Costs and Capital Costs. Costs are considered a Cash Outflow to a producer. Net Cash for a producer was calculated by subtracting Total Costs from Total Revenue (value of calves produced in a season). Incremental changes for this model are found in Table 4.2.

4.2.7 *Case 5: Corridor Fencing from Poor Condition*

In this case, the producer implements a corridor fencing strategy, after 10 years of overgrazing by a previous owner (as in Cases 3 and 4). In the responses to the initial questionnaire, 42% of respondents ranked this as choice 1 or 2 for riparian restoration in a highly degraded pasture. The degraded riparian corridor was fenced off, in order to allow for rehabilitation. This case was used as an alternative to the overgrazing strategy of Case 3, and the rotational grazing strategy of Case 4.

4.2.7.1 Field Assumptions

The new corridor fencing takes 100 acres of pasture out of production. That is, the pasture now contains 10 quarter sections, plus 5/8 of another (10.625 quarter sections). The excluded corridor divides the former pasture into two grazeable pastures. By design, this new pasture system also incorporates a rotational strategy, as livestock graze one pasture unit at a time. In order to provide water for the animals, the waterers mentioned in the base case serve the two pastures. The pastures used can be seen in Figure 4.5.

4.2.7.2 Grazing Capacity and Stocking Rate

As in the previous case, the pasture started in poor condition. The stocking rate for the uplands was the same as that for Season 1 in Case 4 (0.273 AUM/acre) to simulate ten prior years of overgrazing. However, because the riparian area is almost taken completely out of production, its initial carrying capacity is half of the initial capacity of

Case 4. Its initial stocking rate is 0.336 AUM/acre, or 31 AU grazed per season. The animals are rotated between the two upland pastures, so grazing is assumed to be more uniform in each pasture they graze. Animals are allowed to minimally graze the riparian corridor, when it begins to regenerate.

As in Case 4, it was assumed that the forage resources in the pastures would begin to regenerate. The grazing capacity on the uplands is assumed to increase by 2% per year. On the riparian pasture, the lighter stocking rate contributes to a faster regeneration time, of 10% per season. The corridor fencing reduces the grazeable pasture area, so the stocking rates are slightly lower than in case 4. By Season 13, the riparian area has been regenerated to its base case stocking rate of 1 AUM/acre (91 AU grazed per season). By Season 20, the uplands have been regenerated to 0.398 AUM/acre (94 AU grazed per season).

4.2.7.3 Incremental Revenue

Incremental revenue is calculated in the same manner as in the base case. The increase in incremental revenue follows the trend of the rotational grazing system. Incremental changes for this model are found in Table 4.2.

4.2.7.4 Incremental Costs

The fencing costs incurred by this strategy are higher than those for the rotational system, as two lines of fencing, 14,817 feet in length, must be constructed. This additional 29,634 feet of fencing added an additional $19,262 of initial cost. The maintenance cost per season was approximately $482 (Table 4.2).

4.2.8 *Case 6: Rest Rotational Grazing from Poor Condition*

In this case, the producer implements a rest rotation strategy, after 10 years of overgrazing by a previous owner (as in Cases 3 and 4). In the responses to the initial questionnaire, more than a third of respondents ranked this as choice 1 or 2 for riparian restoration in a highly degraded pasture. In this case, the pasture is fenced off for rotational grazing, as in Case 4. For the first 8 years, one pasture is completely rested (no grazing) each season, while the others are grazed. This means that each of the four pastures will be rested twice in the first eight years. After eight years, a regular rotational strategy is employed. This case, like Case 4 and Case 5, was used as an alternative to the overgrazing strategy of Case 3.

4.2.8.1 Field Assumptions

For the first 8 years, one quarter of the original pasture is completely rested each season. Therefore, the grazeable area was reduced by one quarter in both the upland and riparian pastures. The new upland area was 975 acres. The new riparian area was 375 acres. After eight grazing seasons, the pasture is restored to its full grazing area. As in Case 4, two additional waterers are needed for this strategy, as the pasture has four grazeable areas. The pasture is the same as that for Case 4, rotational grazing, and can be seen in Figure 4.4.

4.2.8.2 Grazing Capacity and Stocking Rate

As in the previous case, the pasture started in poor condition. The initial grazing capacities for the uplands and riparian area were the same as those for Season 1 in Case 4 (rotational grazing) (0.273 AUM/acre and 0.671 AUM/acre, respectively) to simulate ten prior years of overgrazing. The animals are rotated through the pastures, so grazing is assumed to be more uniform in each pasture they graze.

It was assumed once more that the forage resources in the pastures would begin to regenerate. Under rest-rotation grazing, the grazing capacity on the uplands was assumed to increase by 4% per year. On the riparian pasture, it was assumed to increase at 8% per season. After the first eight years, the regular rotational strategy results in the uplands pasture being regenerated at 2% per season. The riparian area regenerates at 6% per season under regular rotation. By Season 7, the riparian area has been regenerated to its base case stocking rate of 1 AUM/acre (91 AU grazed per season). By Season 20, the uplands have been regenerated to their base case level of 0.5 AUM/acre, or 118 AU grazed per season.

4.2.8.3 Incremental Revenue

Incremental revenue is calculated in the same manner as in the base case. The increase in incremental revenue follows the trend of the rotational grazing system. Incremental changes can be found in Table 4.2.

4.2.8.4 Incremental Costs

Incremental costs for this case were the same as those for case 4 (Table 4.2).

4.3 Graphical Summary of Grazing Scenarios

Figure 4.6 presents a graphical summary of the grazing scenarios (in AU grazed per Season) discussed above. The Base Case (Conservative Continuous Grazing) is a flat line at 209 AU grazed per season, as there are no changes in carrying capacity. The Unsustainable Continuous Grazing of Case 2 begins at a higher level (272 AU grazed per season), but falls to a final rate of 131 AU grazed per season. Continuously grazing pasture in poor condition at an unsustainable rate (Case 3) causes a decrease from 170 AU grazed per season to 113 AU grazed per season, a level below that of Case (Case 2 began on pasture in good condition).

Using the assumptions of the static NPV model, Rotational Grazing (Case 4) would improve grazing from 126 AU grazed per season to 185 AU grazed per season over a twenty-year time span. Corridor Fencing (Case 5) would improve grazing to 185 AU grazed per season. Case 6, Rest Rotational grazing, improves from 94 AU grazed per season to the Base Case level of 209 AU grazed per season in Season 20.

4.4 Other Scenarios and Sensitivity Analysis

4.4.1 *Indifference Point Analysis (Scenario Analysis)*

The static models are sensitive to the key assumptions. Some of these assumptions are stocking rate, calf price, and degeneration/regeneration rates. The model results were analyzed for sensitivity to changes in price and initial stocking rate. A rancher would be financially indifferent to implementing a rotational grazing strategy over a continuous grazing system at the point where neither system would make the rancher financially better off in the long run. The long run results in the static model relied on incremental NPV as an indication of financial well-being. The "financial indifference point" was the point where the 20- season NPVs of both scenarios were equal.

4.4.1.1 Scenario 1 – Base Case vs. Case 2

The initial uplands stocking rate in Case 2 is allowed to change to the point where the NPV in Case 2 = NPV in Base Case. The riparian area stocking rate was made to increase or decrease proportionally. All other assumptions in the Base Case and Case 2, including pasture degradation rates and subsequent stocking rates, remained unchanged. This determines the point at which a rancher is financially indifferent between a sustainable continuous grazing strategy and a higher (though unsustainable) initial stocking rate. That is, how high must the initial stocking rate in Case 2 become before the unsustainable strategy is the best financial choice? In subsequent discussion, this point is referred to as the "financial indifference point." Calf prices were then allowed to vary (between $0.80/lb to $1.60/lb), to see how the financial indifference point changed.

4.4.1.2 Scenarios 2, 3, and 4 – Case 3 vs. Cases 4, 5, and 6

Similar to Scenario 1, the financial indifference point is evaluated by finding the initial stocking rate in Case 3 that will equate the NPV in Case 3 to the NPV in Case 4. This is the financial indifference point between unsustainable continuous grazing (Case 3) and implementing a rotational grazing strategy (Case 4). As in Scenario 1, different calf prices ($0.80/lb to $1.60/lb) were used to analyze how the financial indifference point changes. Again, all other assumptions were held constant.

Similar to Scenario 2, the financial indifference point for Scenario 3 is evaluated by finding the initial stocking rate in Case 3 that will equate the NPV in Case 3 to the NPV in Case 5, implementing a corridor fencing strategy (Case 5). Scenario 4, similar to scenarios 2 and 3, will equate the NPV in Case 3 to the NPV in Case 6.

4.4.1.3 Additional Background on Scenarios 1 through 4

Some of the underlying equations are as follows: In order to determine the value of calves attributed to pasture, a price per pound for 5-600 lb beef calves, P_B, was multiplied by the total pounds of gain per calf attributed pasture, WG_t. The symbol t represents the season number. The equation for the value of all calves attributed to pasture over time was:

$$P_B \cdot \sum_{t=0}^{20} \frac{WG_t}{(1+i)^t}$$

(4.12)

This was the equation for all continuous grazing systems (sustainable and unsustainable, including the base case). In Scenario 1, Equation 4.12 would represent both spreadsheets. This is because there are no incremental costs added to sustainable grazing from good condition (Base Case) or to unsustainable continuous grazing from good condition (Case 2). This means that, regardless of the price per pound of calf ($0.80 - $1.60), the same initial stocking rate for Case 2 will be returned at the point of financial indifference.

For the rotational system, the equation was similar, except that fencing and watering costs, C_t, were included. The equation was:

$$P_B \cdot \underbrace{\sum_{t=0}^{20} \frac{WG_t}{(1+r)^t}}_{Benefits} - \underbrace{\sum_{t=0}^{20} \frac{C_t}{(1+r)^t}}_{Incremental\ \ Costs} \tag{4.13}$$

In Scenario 2, equation 4.12 represents Case 3 (no added costs) and equation 4.13 represents Case 4 (added fencing and watering costs). If calf price and weight gain were equal in both equations, the value of calves attributed to pasture would be reduced in equation 4.13 by the incremental costs. In the indifference point analysis, the NPVs of both cases are equated by allowing the stocking rate for Case 3 to change.

As the price of calves increases (in relation to an increase in the price per pound, in this case), the indifference point initial stocking rate is expected to increase, to offset the effect of fencing and watering costs, C_t, introduced in Case 4 (equation 4.13). That is, the initial stocking rate of the pasture in Case 3 would have to be higher for a producer to choose an overgrazing strategy; as higher calf prices will offset the costs associated with fencing and watering (incremental costs). The results of the financial indifference point analysis are discussed in the following chapter.

4.4.2 *Sensitivity Analysis*

4.4.2.1 Discount Rate Sensitivity

The model results on an appropriate discount rate for cow/calf operations are not clear. The initial scenarios used a discount rate of 10% (current risk-free rate plus a risk premium for cow/calf operations). In this analysis, the discount rates are changed, in order to see the effect on incremental NPV in each case. This analysis uses rates of 5% and 15%, and compared them to that of the initial scenarios. All other assumptions are held constant. The results are presented in the following chapter.

4.4.2.2 Pasture Degradation Rate Sensitivity

The research literature on pasture degradation rates varies with the scenario and pasture conditions chosen (Adams et al., 1991 and Adams, 2000). An analysis was performed to analyze the sensitivity of cases 2 and 3 to different pasture degradation rates. Initially, both scenarios used degradation rates of 6% (uplands) and 3% (riparian area) per grazing season. For this analysis, rates of 2% (uplands), 1% (riparian area); and 10% (uplands), 5% (riparian area) are used, and compared to the 6% and 3% rates. All other assumptions are held constant. The results are presented in the following chapter.

4.5 Chapter Summary

The static model is analyzed using Net Present Value (NPV) analysis. NPV models are often used in investment analysis. A cow/calf operation involves investment on the part of a producer, in both time and money. Using risk premia for cow/calf operations in Alberta and the concept of the Capital Market Line (CML) a discount rate for cow/calf operations was chosen. This discount rate is used in the static ranch model.

The static ranch model compares six cases. A Base Case represents the ranch in a sustainable grazing strategy, where extra management is not needed to keep range in good condition. Cases 2 and 3 represent overgrazing strategies. Initial pasture conditions are good in Case 2 and poor in Case 3. Cases 4 through 6 represent strategies to improve riparian health. Though costs are higher, these strategies may be needed to keep range productive and healthy. Incremental NPV is used as an indicator of ranch well-being.

Scenario analyses will be performed to determine the point at which a rancher will be financially indifferent between grazing strategies. The indifference point will be the initial stocking rate at which a producer will be no better off financially, regardless of the grazing strategy chosen. Sensitivity analyses will then be performed to determine how sensitive the model is to changes in the discount rate and pasture degradation rate.

4.6 Tables for Chapter 4

Table 4.1 Model Assumptions for NPV Analysis

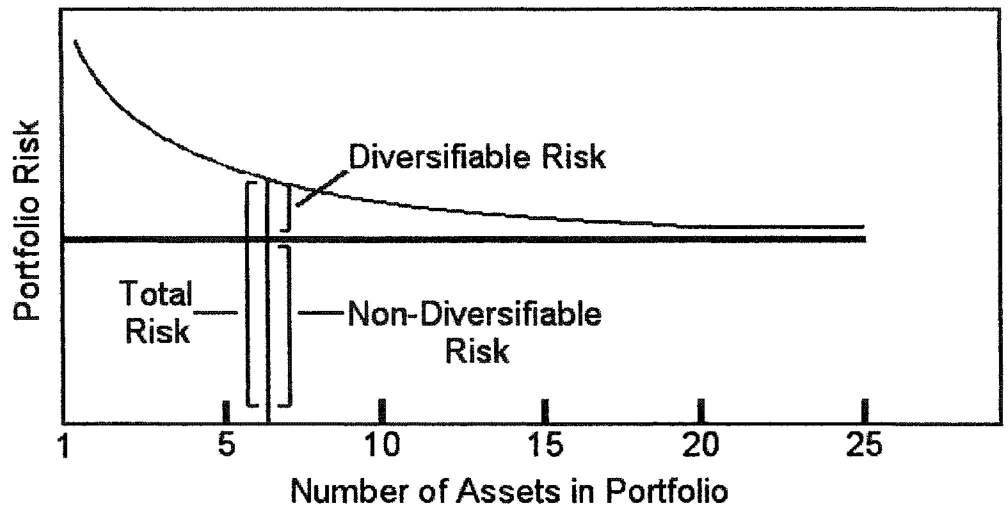
	Base Case: Sustainable Continuous Grazing (from good condition)	Case 2: Unsust. Continuous Grazing (from Good Condition)	Case 3: Unsust. Continuous Grazing (from Poor Condition)	Case 4: Rotational Grazing (from Poor Condition)	Case 5: Corridor Fencing (from Poor Condition)	Case 6: Rest Rotational Grazing (from Poor Condition)
Initial Upland Pasture Size (acres)	1,300	1,300	1,300	1,300	1,300	1,300
Initial Riparian Pasture Size (acres)	500	500	500	500	500	500
Outside perimeter fenced	Yes	Yes	Yes	Yes	Yes	Yes
Initial Pasture Condition	Good	Good	Poor	Poor	Poor	Poor
Grazing season (months)	5.5	5.5	5.5	5.5	5.5	5.5
Gain per Calf per Day (lbs)	2.2	2.2	2.2	2.2	2.2	2.2
Price per Pound (5-600 lb calf)	1.53	1.53	1.53	1.53	1.53	1.53
Market Weight of Calf (lbs)	550	550	550	550	550	550
Death Loss of Calves (%)	2	2	2	2	2	2
Discount Rate (%)	10	10	10	10	10	10
Uplands Degradation Rate (% per season)	NA	6	6	NA	NA	NA
Riparian Degradation Rate (% per season)	NA	3	3	NA	NA	NA
Uplands Regeneration Rate (% per season)	NA	NA	NA	2	2	4/2
Riparian Regeneration Rate (% per season)	NA	NA	NA	6	6	8/6

Table 4.2 Grazing Scenarios for NPV Analysis

	Base Case: Sustainable Continuous Grazing (from good condition)	Case 2: Unsust. Continuous Grazing (from Good Condition)	Case 3: Unsust. Continuous Grazing (from Poor Condition)	Case 4: Rotational Grazing (from Poor Condition)	Case 5: Corridor Fencing (from Poor Condition)	Case 6: Rest Rotation Grazing (from Poor Condition)
Uplands Pasture Used (acres)	1,300	1,300	1,300	1,300	1,300	975/1,300
Riparian Pasture Used (acres)	500	500	500	500	400	375/500
Season 1 Uplands Stocking Rate (AUM/acre)	0.500	0.650	0.350	0.273	0.273	0.273
Season 1 Uplands Stocking Rate AU/grazing season)	118	154	83	65	65	48
Season 20 Uplands Stocking Rate (AUM/acre)	0.500	0.273	0.273	0.398	0.398	0.456
Season 20 AU/grazing season	118	65	65	94	94	108
Season 1 Riparian Stocking Rate (AUM/acre)	1.00	1.30	0.959	0.671	0.336	0.671
Season 1 Riparian AU/grazing season	91	118	87	61	31	46
Season 20 Riparian Stocking Rate (AUM/acre)	1.00	0.729	0.537	1.00	1.00	1.00
Season 20 Riparian AU/grazing season	91	66	49	91	91	91
Uplands Regeneration (Degeneration) Rate (%/yr)	NA	(6)	(6)	2	2	4/2
Riparian Regeneration (Degeneration) Rate (%/yr)	NA	(3)	(3)	6	10	8/6
Extra Fencing Used (feet)	0	0	0	15,840	33,858	15,840
Capital Cost of Fencing	0	0	0	$10,296	$22,007	$10,296
Extra Watering Sites Used	0	0	0	2	0	2
Capital Cost of Watering Sites	0	0	0	$7,000	0	$7,000

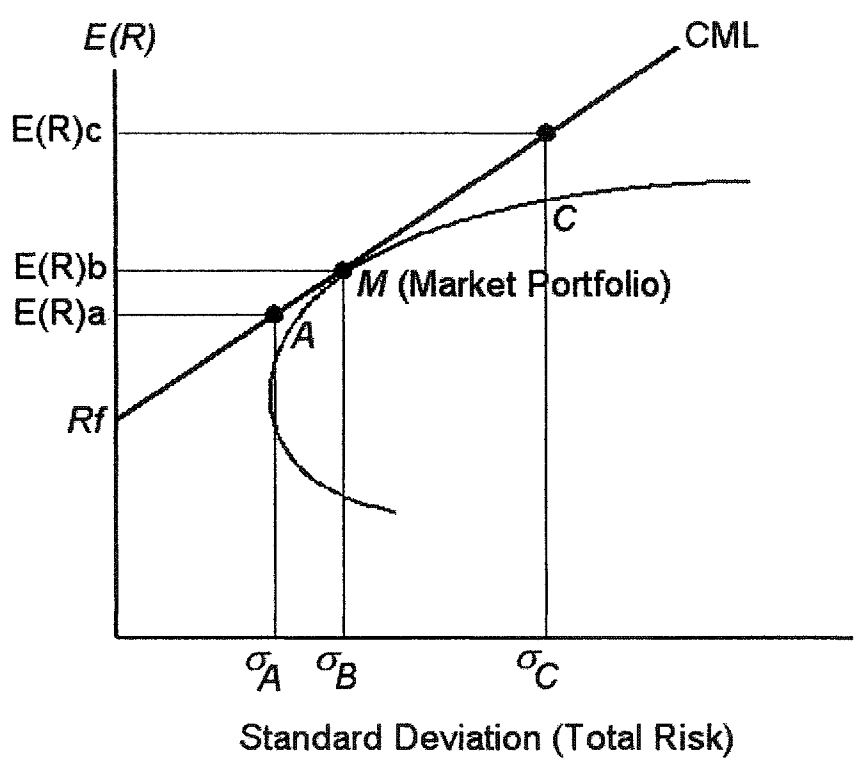
4.7 Figures for Chapter 4

Figure 4.1 Portfolio Risk and Diversification*



*adapted from Megginson (1997)

Figure 4.2 Capital Market Line (Risky Portfolio with Riskless Asset)*



*adapted from Damodaran (1997)

Figure 4.3 Hypothetical Pasture and Riparian Area (not to scale)

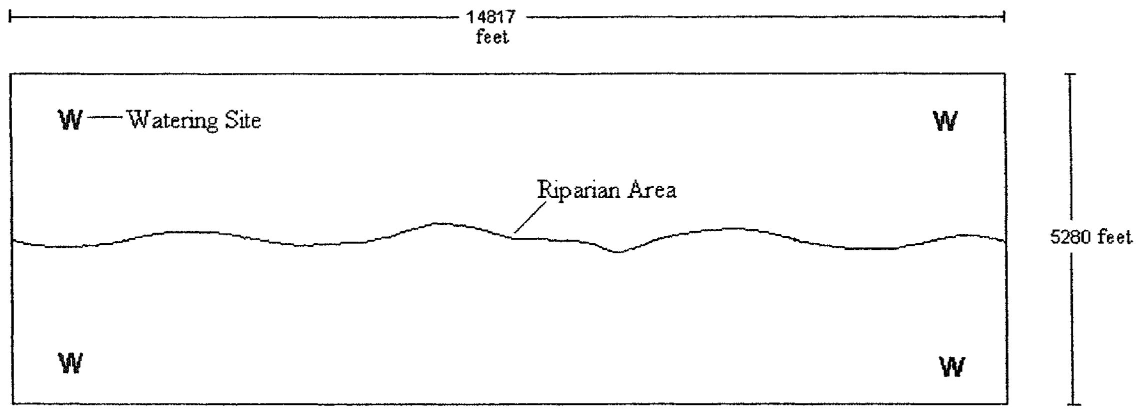


Figure 4.4 Hypothetical Pasture with Rotational Grazing (not to scale)

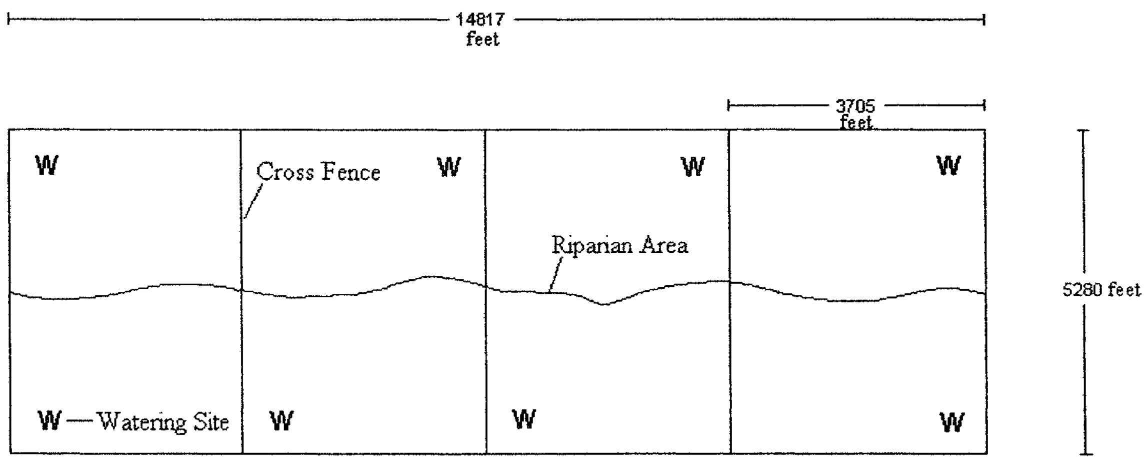


Figure 4.5 Hypothetical Pasture with Corridor Fencing (not to scale)

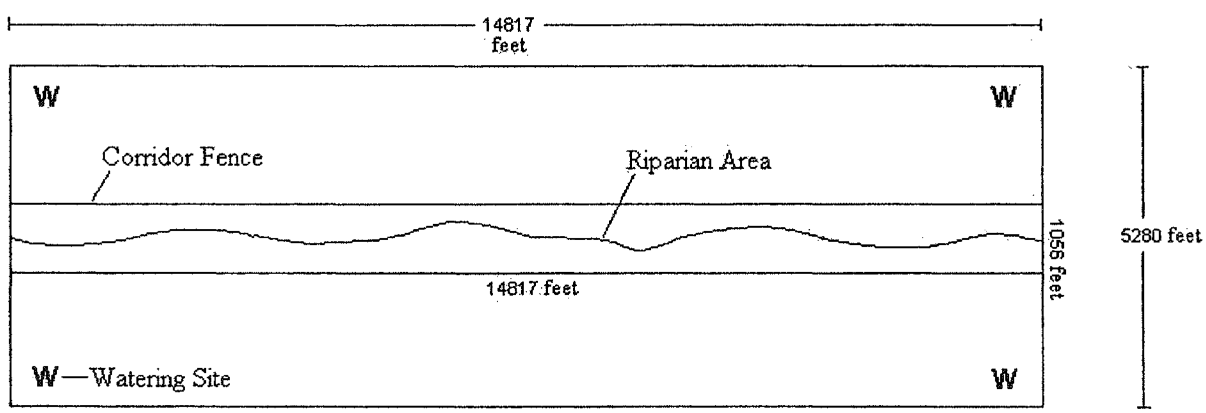
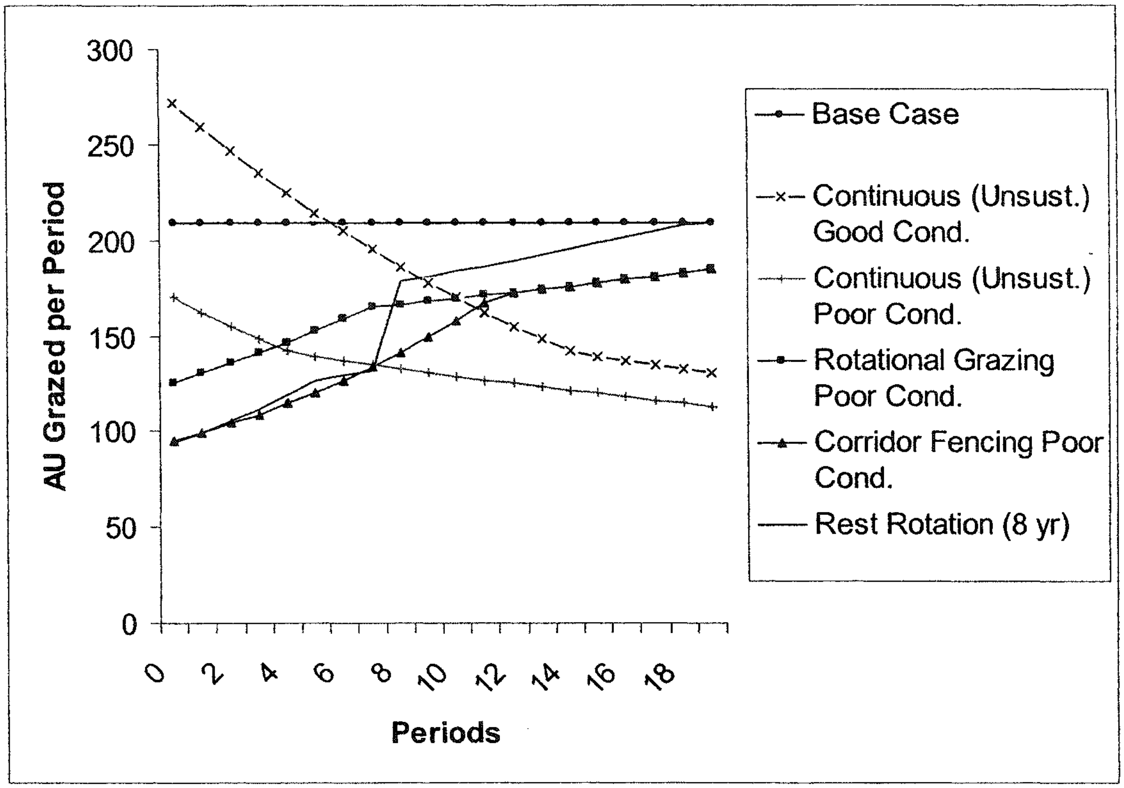


Figure 4.6 Grazing Scenario Summary for NPV Analysis



Chapter 5

5.1 Static NPV Model Results

The following section presents results for the static NPV model. Note that the NPV is not the same as ranch profit. It is a method to compare scenarios. However, higher NPVs indicate improved economic benefits for the ranch.

5.1.1 *Base Case Versus Case 2 – Sustainable Continuous Grazing Versus Unsustainable Continuous Grazing from Good Condition*

In the base case, a producer continuously stocked a pasture at its sustainable long-run carrying capacity. In this case, the sustainable carrying capacity was 650 AUM per season on the uplands and 500 AUM per season on the riparian area. This translated to a stocking rate of 0.5 AUM per acre, or 118 AU per grazing season on the uplands. On the riparian area, the initial stocking rate was 1.00 AUM per acre, or 91 AU per grazing season (Tables 4.1 and 4.2).

The value of the 209-calf production attributed to the pasture each grazing season was $113,804. This value was the same each season, holding calf prices constant. As no riparian management changes were made, there were no additional costs borne by the producer. The model assumes that initial costs remain constant across different cases. Recall that costs are those for the 500 acre riparian area and 1,300 acre upland area only. The resulting Incremental Net Present Value after twenty seasons was $1,138,044 (Table 5.1).

In Case 2, the producer grazed the pasture at a stocking rate 30% higher than the field's sustainable carrying capacity level (Section 4.2.4). This resulted in an initial uplands stocking rate of 0.65 AUM per acre, or 154 AU per season. On the riparian area, the initial stocking rate was 1.3 AUM per acre, or 118 AU grazed per season. In the first season, the value of calves attributed to pasture was $147,945. However, as the stocking rate was reduced each season to match the loss in grazing capacity, this value fell as well. Degradation rates were 6% per season on the uplands, and 3% per season on the riparian area. At Season 14, it was assumed that the uplands pasture would reach a steady state of 0.273 AUM per acre, which continued through season 20.

The ending uplands stocking rate (grazing seasons 15 through 20) was 0.273 AUM per acre, or 65 AU per grazing season. On the riparian area, the stocking rate fell to 0.729 AUM per acre, or 66 AU per grazing season. The value of calves attributed to the pasture in season 20 was $71,182. The resulting incremental Net Present Value after twenty seasons was $1,065,663, which was just over $70,000 less than that for the Base Case (Table 5.1).

5.1.2 *Case 3 Versus Cases 4, 5 and 6 – Unsustainable Continuous Grazing from Poor Condition Versus Regeneration Grazing Strategies*

In Case 3, the producer continuously grazed a previously degraded pasture. In order to simulate 10 years of prior overgrazing, the initial carrying capacity was the capacity in year 11 of Case 2 (overgrazing from good condition). That is, the initial upland stocking rate (Season 1) was 0.350 AUM per acre, or 83 AU per grazing season. On the riparian area, the initial stocking rate was 0.959 AUM per acre, or 87 AU grazed per season (Tables 4.1 and 4.2).

As in Case 2, the stocking rate was reduced by 6% on the uplands until it reached a steady state of 0.273 AUM per acre (65 AU per grazing season). The riparian area, degrading at 3% per season, reached a stocking rate of 0.537 AUM per acre (49 AU grazed per season) by Season 20. The incremental Net Present Value after twenty seasons was $746,207. This is just over $300,000 less than the incremental NPV found in Case 2 (Table 5.1).

The initial carrying capacity in Case 4, rotational grazing from poor condition, simulated a degraded pasture condition. The initial stocking rate from Case 3 was reduced by a further 30%, to allow the pasture to regenerate, through the implementation of a rotational grazing system. The initial uplands stocking rate was 0.273 AUM per acre, or 65 AU per grazing season. On the riparian area, the initial stocking rate was 0.671 AUM per acre, or 61 AU per grazing season. Each year, the uplands carrying capacity was assumed to increase by 2%. The riparian area had a regeneration rate of 6%. The stocking rate increased to match the increase in carrying capacity. By Season 8, the producer was grazing at the base case rate on the riparian area (1.00 AUM/acre, 91 AU per grazing season). By Season 20, the uplands had regenerated to a stocking rate of 0.398 AUM per acre, or 94 AU per grazing season.

The value of calves attributed to pasture in Season 1 was $68,325. The value in Season 20 was $100,644. The extra capital outlay for fencing in Season 0 was $10,296.

The two extra waterers added $7,000. A fence maintenance cost of 2.5% per season totaled $257 per season. The incremental Net Present Value after twenty seasons was $841,734 (Table 5.1), which is greater than that for Case 3.

Corridor fencing from poor condition, Case 5, modeled the initial uplands carrying capacity at 30% lower than in Case 3. The riparian area's initial capacity from Case 4 was cut in half, as grazing on the riparian corridor was very light, in order to encourage regeneration. As in the rotational grazing case, uplands pasture quality increased by 2% per season. However, on the lightly grazed riparian area, regeneration occurred at a 10% rate. Extra fencing costs in Season 0 totaled $19,262. The incremental NPV after 20 seasons was $732,792 (Table 5.1). This was more than $100,000 less than that for the rotational system and slightly lower than the incremental NPV in Case 3.

Case 6, the rest rotation strategy, had initial stocking rates for the upland and riparian pastures that were the same as those for Case 4, rotational grazing. For the first 8 grazing seasons, one quarter of the area was rested each year. The uplands regenerated at a 4% rate. The riparian area regenerated at a rate of 8%. After season 8, the regular rotational strategy was used again. The uplands then regenerated at a rate of 2%, and the riparian area at 6%. Extra fencing and watering costs were the same as those for Case 4, rotational grazing. The incremental NPV was $786,785. This is approximately $55,000 less than that for rotational grazing (Case 4), but greater than that for Case 3.

5.1.3 *Discussion of NPV Results*

In the static model, the Base Case NPV is the highest, and the number of AU grazed per season is assumed to be sustainable (Table 5.1). The number of grazing livestock does not decrease, as it does in the Case 2. The first two cases involve pasture in good condition in season 1. However, in Case 2, the pasture was stocked at an unsustainable rate, resulting in a loss of grazing capacity over time. Case 2 resulted in the second-highest NPV at the expense of pasture condition. Case 3 showed how the unsustainable Continuous Grazing system used in Case 2 would affect a pasture in initially poor condition. The result was a drop in incremental NPV of almost $400,000. This would suggest that, over the long-term, there is no long-run financial incentive to overgraze, given the model assumptions used here.

The Rotational Grazing system in Case 4 was implemented to improve the pasture in poor condition. Using the set of assumptions explained above, this system resulted in an increased grazing capacity over the twenty seasons. Its incremental NPV is almost $100,000 higher than that for Case 3. From this, it can be concluded that, in the long-run, it would be a better financial decision for the producer to implement a rotational grazing strategy on poor pasture. Initial capital costs are higher, but long-run benefits exceed those of an unsustainable continuous grazing strategy (like Case 3).

Though Corridor Fencing (Case 5) resulted in an NPV that was lower than that for overgrazing from poor condition (Case 3), the riparian area was rehabilitated to its Base Case grazing rate. Grazing livestock were only given limited access to the fenced riparian area at first. In a real-world case, this strategy would be used as a last resort, in order to return a riparian area to health. This goal was achieved in this strategy by season 13. It is important to note that, as in this case, riparian restoration may not take twenty entire seasons. Corridor fencing may also work as a risk management scheme, in case of a drought. This is because the riparian area holds moisture, and is expected to have better forage. The corridor system appears to have the capacity to give a rancher more financial benefit in the long run (more than 20 seasons), when compared to an unsustainable continuous grazing strategy. Higher initial costs (and less grazing capacity) are offset by increased sustainable stocking rates (and hence, increased value of calves attributed to the pasture).

Case 6 (Rest Rotational Grazing) resulted in an incremental NPV of approximately $40,000 more than that for Case 3. As in Case 5, higher initial costs are offset by increased stocking rates on both upland and riparian pastures in later time seasons. The riparian area was restored to full health by Season 9. Though the uplands pasture does not come back to the Base Case level, it ends at a higher level than the uplands pasture in Case 5 did.

5.2 Indifference Point (Scenario) Analysis Results

5.2.1 *Scenario 1 – Base Case vs. Case 2*

In this scenario, the producer could choose to graze a pasture at a sustainable level (Base Case), or overgraze the pasture (using a continuous grazing system – Case 2). The uplands stocking rate for Case 2 was allowed to change. The riparian area stocking rate changed in proportion to the uplands rate. The new stocking rates were evaluated at 500-600 lb calf price levels ranging from $0.80 per pound to $1.60 per pound. The resulting stocking rates for the first season of Case 2, represented the financial indifference point in grazing season 1 for each of the price points. If the uplands pasture in Case 2 could initially support 0.698 AUM/acre (165 AU per grazing season), and the riparian pasture 1.396 AUM/acre (127 AU per grazing season), the producer would be indifferent between sustainable strategies and overgrazing strategies, at all price points (Table 5.2). All other model assumptions, including the pasture degradation rates (Case 2) were held constant.

This suggests that if the pasture were capable of supporting a total of 292 AU per grazing season (or more) in grazing season 1, the producer would financially be better off by overgrazing the range. This would mean grazing at a rate of 20 AU above the initial level for Case 2 (272 AU), and 40% more than the sustainable (Case 1) level of 209 AU. If the rancher prefers to receive more economic benefits now, the overgrazing strategy would be chosen. If the pastures cannot initially support a total of 292 AU per grazing season or higher, the sustainable grazing strategy (Base Case) is the optimal strategy.

5.2.2 Scenarios 2, 3, and 4

In Scenario 2, the producer chooses between overgrazing a pasture with a continuous grazing plan (Case 3), and using a rotational grazing strategy (Case 4), with the expectation that the rotational strategy would rehabilitate the pasture. The uplands stocking rate for Case 3 was allowed to change. The riparian area stocking rate was made to move in proportion to the uplands rate. The new stocking rates for Case 3 were evaluated at 500-600 lb calf price levels ranging from $0.80 per pound to $1.60 per pound. Since there were added costs (fencing and watering) in the rotational grazing scenario, there was a slight increase in the financial indifference point in grazing season 1 as calf prices increased (Table 5.3).

In Scenario 2, higher calf prices provided slightly more incentive to continue the overgrazing strategy. At $0.80 per pound, the indifference point stocking rate was 0.4 AUM/acre (95 AU grazed per season) on the uplands, and 1.096 AUM/acre (100 AU grazed per season) on the riparian area (Table 5.3). This result suggested that, at $0.80 per pound, a beef producer would choose a continuous overgrazing stocking rate if the pastures could support more than 195 AU in grazing season 1. Below this carrying capacity, a beef producer choosing a rotational grazing system would be better off (financially) in the long run.

If calf prices increase from $0.80 per pound to $1.00 per pound, the initial stocking rate (uplands plus riparian area) must be approximately 2 AUM higher for the rancher to choose a continuous overgrazing strategy. This is because the slightly higher calf price, and increased carrying capacity through pasture regeneration, will offset the extra cash required for the fencing and watering of the rotational system. This trend continues through price changes to $1.60 per pound. However, the differences in stocking rate become slightly smaller as calf prices increase.

In Scenario 3, the producer chooses between overgrazing a pasture with a continuous grazing plan (Case 3), and using a corridor fencing strategy (Case 5), with the expectation that the corridor strategy would rehabilitate the pasture. The stocking rates for Case 3 were allowed to change in the same manner as in Scenario 2. Since there were added costs (fencing) in the corridor fencing scenario, there was a slight increase in the financial indifference point in grazing season 1 as calf prices increased (Table 5.4).

In Scenario 4, the producer chooses between overgrazing a pasture with a continuous grazing plan (Case 3), and using a rest rotation strategy (Case 6), with the expectation that the rest rotation strategy would rehabilitate the pasture. The stocking rates for Case 3 were allowed to change in the same manner as those in the previous scenarios. The results in Table 5.5 suggest that, at $0.80 per pound, a beef producer would choose a continuous overgrazing stocking rate if the pastures could support more than 177 AU in grazing season 1. Below this carrying capacity, a beef producer choosing a rest rotation system would be better off (financially) in the long run.

5.2.3 *Scenario Analysis Conclusions*

In Scenario 1, the financial indifference point was found at 165 AU per season in the uplands and 127 AU per season in the riparian area, at all calf price points. In the Base Case, it was noted that, in the assumed good pasture condition, the hypothetical pasture could support 209 AU per grazing season. In order for the producer to have financial indifference, the pasture would have to support a much higher initial stocking level (292 AU per season – addition of upland and riparian areas). This would suggest that, in the case of the good condition pasture (Base Case), the best strategy from a financial point of view would be a sustainable grazing strategy, where the stocking rate matched a pasture's long-run carrying capacity.

In Scenario 2, it was assumed that the pastures were in poor condition in year 1. This meant that the hypothetical pasture (upland plus riparian) was initially stocked at 183 AU per grazing season in Season 1, which was an unsustainable rate. At the initial calf price of $0.80 per pound, the financial indifference point was found where the uplands pasture supported 95 AU per season, and the riparian pasture supported 100 AU per season. Therefore, the producer would have to be able to stock the full pasture (riparian and upland) at an even higher rate than the initial one (183 AU per season – addition of upland and riparian areas), before considering the unsustainable continuous grazing strategy over the rotational strategy. Though the rotational strategy has higher initial capital costs, the pasture health is gradually restored. As average calf prices increase, the financial indifference point becomes higher as well. Higher calf prices, as well as pasture restoration, make the rotational grazing strategy appear to be the better choice for the pasture in poor condition at each calf price point.

In Scenario 3, it was again assumed that the pastures were in poor condition in year 1. This meant that the hypothetical pasture (upland plus riparian) was initially stocked at 183 AU per grazing season in Season 1, which was an unsustainable rate. However, the pasture was being compared to a highly degraded pasture in Case 5, which needed a drastic measure (corridor fencing) to restore it to health. In this scenario, at the initial calf price of $0.80 per pound, the financial indifference point was found where the uplands pasture supported 77 AU per season, and the riparian pasture supported 81 AU per season. The producer would consider the unsustainable continuous grazing strategy over the corridor strategy at a lower stocking rate than was originally chosen for Case 3 (Overgrazing from Poor).

However, for a seriously degraded pasture, like that in Case 5, a corridor strategy may be the only choice when a pasture cannot support stocking rates above this level. As in Scenario 2, as calf prices increase, the financial indifference point becomes higher as well. Higher calf prices, as well as pasture restoration, make the corridor fencing strategy appear to be a good choice for the seriously degraded pasture at each price point.

In Scenario 4, it was again assumed that the pastures were in poor condition in year 1. This meant that the hypothetical pasture (upland plus riparian) was initially stocked at 183 AU per grazing season in Season 1, which was an unsustainable rate. At the initial calf price of $0.80 per pound, the financial indifference point was found where the uplands pasture supported 86 AU per season, and the riparian pasture supported 91 AU per season. Again, this combined level was lower than the 183 AU per season used in Season 1 of Case 3. The pastures in Case 6 (Rest Rotational Grazing) started in a degraded condition (though not as serious as those in Case 5). Though the rest rotational strategy has higher initial capital costs, the pasture health is gradually restored, as in the previous two scenarios. As calf prices increase, the financial indifference point becomes higher as well. Higher calf prices, as well as pasture restoration, make the rest rotational grazing strategy appear to be the better choice for the pasture in poor condition at each calf price point.

5.3 Sensitivity Analysis Results

5.3.1 *Discount Rate Analysis*

When the discount rate was varied, it changed the incremental NPV (Table 5.6). It can be seen that lower discount rates result in higher incremental NPVs across cases. Higher discount rates reduce the incremental NPV for each case. Higher discount rates favour strategies that use higher initial stocking rates (Case 2), though these strategies lead to lower future stocking rates. Lower discount rates favour strategies with lower initial stocking rates and higher future cash flows in later time seasons (Case 4).

With higher discount rates, producers who favour early returns might look to the case of overgrazing from good condition (Case 2), where higher returns are seen in the early years of grazing. However, this case will lead to lower returns in the future, as pasture condition is degraded. With lower discount rates, producers with poor pasture might favour a system such as rotational grazing (Case 4), which has higher returns in the later years of grazing. Though a producer starts with a lower initial stocking rate, a rotational system will restore health to a pasture, resulting in higher stocking rates in the future.

5.3.2 *Pasture Degradation Rate Analysis*

Case 2 (overgrazing from good condition), at its initial 6% degradation rate, had its initial uplands stocking level of 154 AU grazed/season fall to its steady state rate of 65 AU grazed/season (Table 5.7). For the riparian area at 3%, the numbers were 118 AU grazed/season initially, and 66 AU grazed/season in Season 20. Sensitivities to different rates of pasture degradation are reported in Table 5.7. At a 2% rate for the uplands and a 1% rate for the riparian area incremental NPV increases from $1,065,663 to $1,305,035. At a 10% degradation rate for the uplands and 5% degradation rate for the riparian area, the incremental NPV decreases to $940,416. The incremental analysis is quite sensitive to changes in the rates of range degradation due to overgrazing. Similar analysis for Case 3 (overgrazing from poor condition) is reported in Table 5.7.

The incremental NPV changes are smaller in Case 3 versus Case 4. Case 3 pastures began in degraded conditions, while Case 2 pastures were in good condition in Season 1. For both Cases, pasture conditions can only degrade to a specific steady state (0.273 AUM/acre).

5.4 Chapter Summary / Summary of Results

In the incremental NPV analysis, sustainable continuous grazing on good condition pasture returned the highest value. However, under the assumptions used, selected strategies that improve riparian area health (such as rotational grazing) will make a rancher better off (financially) in the long run, when degraded pasture is being considered. Scenario analysis found the financial indifference points for a producer choosing between sustainable and unsustainable continuous grazing (Scenario 1), rotational grazing and unsustainable continuous grazing (Scenario 2), corridor fencing and unsustainable continuous grazing (Scenario 3), and rest rotational grazing and unsustainable continuous grazing (Scenario 4).

It was found that, in several cases, there is no long-run financial incentive to overgraze pasture. In Scenarios 1 and 2, a pasture would have to be able to sustain a much higher initial stocking rate than the proposed initial rate, in order for a producer to choose an unsustainable grazing strategy. Scenarios 2, 3, and 4 also showed higher stocking rates necessary to make a producer choose unsustainable continuous grazing over strategies that would improve riparian health (section 5.2.2).

Discount rate sensitivity analysis results show that higher discount rates favour strategies that use higher initial stocking rates, though these strategies lead to lower future stocking rates. Lower discount rates favour strategies with lower initial stocking rates, with higher future payoffs (Case 4 – rotational grazing from poor condition). Case 2 (overgrazing from good condition) is more sensitive to increases in the range degradation rate than Case 3 (overgrazing from poor condition).

The static NPV analysis looks at the riparian area (and a small portion of the uplands pasture area of a ranch). Weather conditions and cattle prices are assumed to be fixed for the 20 grazing seasons measured. In a dynamic whole ranch environment, a rancher would face risk associated with changing weather and cattle prices. As well, the riparian area would make up a small portion of the overall ranch area. The following chapter will present a stochastic ranch simulation model, which attempts to model some of the dynamism of a whole ranch.

5.5 Tables for Chapter 5

Table 5.1 Comparison of Static NPV Model Results

	Base Case: Sustainable Continuous Grazing (from good condition)	Case 2: Unsust. Continuous Grazing (from Good Condition)	Case 3: Unsust. Continuous Grazing (from Poor Condition)	Case 4: Rotational Grazing (from Poor Condition)	Case 5: Corridor Fencing (from Poor Condition)	Case 6: Rest Rotation Grazing (from Poor Condition)
Initial (Season 1) Uplands Stocking Rate (AUM/acre)	0.500	0.650	0.350	0.273	0.273	0.273
Initial (Season 1) Uplands AU/grazing season	118	154	83	65	65	48
Final (Season 20) Uplands Stocking Rate (AUM/acre)	0.500	0.273	0.273	0.398	0.398	0.456
Final (Season 20) Uplands AU/grazing season	118	65	65	94	94	108
Initial (Season 1) Riparian Stocking Rate (AUM/acre)	1.00	1.30	0.959	0.671	0.336	0.671
Initial (Season 1) Riparian AU/grazing season	91	118	87	61	31	46
Final (Season 20) Riparian Stocking Rate (AUM/acre)	1.00	0.729	0.537	1.00	1.00	1.00
Final (Season 20) Riparian AU/grazing season	91	66	49	91	91	91
Initial Value of Calves Attributed to Pasture (t=1)	$113,804	$147,945	$92,474	$68,325	$51,723	$51,243
Final Value of Calves Attributed to Pasture (t=20)	$113,804	$71,182	$61,713	$100,644	$100,644	$108,094
Incremental NPV	$1,138,044	$1,065,663	$746,207	$841,734	$732,792	$786,785

Table 5.2 Results of Indifference Scenario 1 (Base Case vs. Case 2)

Price ($/lb – 500–600 lb Calf)	Upland AUM/acre	Riparian AUM/acre	Upland AU per Season	Riparian AU per Season
0.80	0.698	1.396	165	127
1.00	0.698	1.396	165	127
1.20	0.698	1.396	165	127
1.40	0.698	1.396	165	127
1.60	0.698	1.396	165	127

Table 5.3 Results of Indifference Scenario 2 (Case 3 vs. Case 4)

Price ($/lb – 500–600 lb Calf)	Upland AUM/acre	Riparian AUM/acre	Upland AU per Season	Riparian AU per Season
0.80	0.4	1.096	95	100
1.00	0.405	1.109	96	101
1.20	0.408	1.118	96	102
1.40	0.41	1.124	97	102
1.60	0.412	1.128	97	103

Table 5.4 Results of Indifference Scenario 3 (Case 3 vs. Case 5)

Price ($/lb – 500–600 lb Calf)	Upland AUM/acre	Riparian AUM/acre	Upland AU per Season	Riparian AU per Season
0.80	0.325	0.891	77	81
1.00	0.332	0.909	78	83
1.20	0.336	0.921	79	84
1.40	0.339	0.929	80	84
1.60	0.342	0.935	81	85

Table 5.5 Results of Indifference Scenario 4 (Case 3 vs. Case 6)

Price ($/lb – 500–600 lb Calf)	Upland AUM/acre	Riparian AUM/acre	Upland AU per Season	Riparian AU per Season
0.80	0.365	0.999	86	91
1.00	0.37	1.013	87	92
1.20	0.373	1.022	88	93
1.40	0.376	1.029	89	94
1.60	0.377	1.033	89	94

Table 5.6 Results of Discount Rate Sensitivity Analysis

Incremental NPV	Base Case: Sustainable Continuous Grazing (from good condition)	Case 2: Unsust. Continuous Grazing (from Good Condition)	Case 3: Unsust. Continuous Grazing (from Poor Condition)	Case 4: Rotational Grazing (from Poor Condition)	Case 5: Corridor Fencing (from Poor Condition)	Case 6: Rest Rotation Grazing (from Poor Condition)
5% DR	$2,276,089	$1,864,609	$1,396,223	$1,809,368	$1,671,119	$1,800,133
10% DR	$1,138,044	$1,065,663	$746,207	$841,734	$732,792	$786,785
15% DR	$758,696	$767,800	$518,226	$531,858	$442,923	$473,243

Table 5.7 Results of Pasture Degradation Rate Sensitivity Analysis

Variables at Changing Degradation Rates (Degradation Rates in %)	Case 2*: Unsust. Continuous Grazing (from Good Condition)	Case 3*: Unsust. Continuous Grazing (from Poor Condition)
Initial Uplands Stocking Level (2%)	154 AU/Grazing season	83 AU/Grazing season
Initial Riparian Stocking Level (1%)	118 AU/Grazing season	87 AU/Grazing season
Final Uplands Stocking Level (2%)	105 AU/Grazing season	65 AU/Grazing season
Final Riparian Stocking Level (1%)	98 AU/Grazing season	72 AU/Grazing season
Incremental NPV (2% Up, 1% Rip)	$1,305,035	$830,502
Initial Uplands Stocking Level (6%)	154 AU/Grazing season	83 AU/Grazing season
Initial Riparian Stocking Level (3%)	118 AU/Grazing season	87 AU/Grazing season
Final Uplands Stocking Level (6%)	65 AU/Grazing season	65 AU/Grazing season
Final Riparian Stocking Level (3%)	66 AU/Grazing season	49 AU/Grazing season
Incremental NPV (6% Up, 3% Rip)	$1,065,663	$746,207
Initial Uplands Stocking Level (10%)	154 AU/Grazing season	83 AU/Grazing season
Initial Riparian Stocking Level (5%)	118 AU/Grazing season	87 AU/Grazing season
Final Uplands Stocking Level (10%)	65 AU/Grazing season	65 AU/Grazing season
Final Riparian Stocking Level (5%)	45 AU/Grazing season	33 AU/Grazing season
Incremental NPV (10% Up, 5% Rip)	$940,416	$691,709

* Original analysis used degradation rates of 6% upland and 3% riparian

Chapter 6

6.1 Stochastic Model Elements

In the previous two chapters, static NPV models were used to evaluate different riparian management strategies for a single riparian area. The model analysis was focused on incremental changes to the riparian area pasture, while upland grazing did not make a large contribution. In a whole ranch scenario, a riparian area would make up only a small part of the overall grazing area. At the same time, this small area can contribute more available forage per unit area. The stochastic model presented in this chapter models whole ranch concerns.

The incremental NPV model had a number of limitations that concerned grazing experts providing feedback on this project. The model did not account for over-wintering of cattle. When cattle numbers were reduced due to loss of grazing capacity, these cattle were taken out of the static model, without accounting for their whereabouts, sale price (cull cows), etc. The stochastic model developed in this chapter accounts for cattle wintered, culled, bought and sold and other dynamic business issues.

Beef prices and costs related to ranch operation in the static model were all fixed. The stochastic model simulates the price cycles for steers, heifers, bred heifers, and cull cows. That is, the effects of price changes over time will be captured. Another important variable in most farming situations is the weather. Changing weather will have important effects on forage availability and quality. The health of grazing areas has an important effect on the stocking rate. The static model assumed that the effects of weather were fixed at an average level over twenty grazing seasons. The stochastic model simulates changing weather patterns, and associated effects on forage growth, stocking rate, etc.

The cases for the stochastic simulation models presented in this chapter are loosely based on the static grazing scenarios from Chapters 4 and 5. The ranch operation will now include a larger upland grazing area, in addition to the riparian area. Models for weather and cattle prices will be developed and added to the NPV models. These will be used to capture dynamic aspects of the whole ranch using decision rules on grazing, prices, etc. Whole ranch concerns such as overwintering of cattle, heifer and bull purchases, and cull cow sales will also be added to the 20-season simulation.

This chapter describes the development of the whole ranch model and stochastic model elements. It explains the various differences between the stochastic and static models. The sources of risk in this stochastic simulation model are weather and cattle prices.

6.1.1 *Weather Model*

Precipitation amounts for southern Alberta were obtained from Walter Willms, of the AAFRD Lethbridge Research Station. Precipitation data were collected at Stavely, in the Porcupine Hills region of southern Alberta. Amounts were given in daily accumulation. The total precipitation amounts (May to October) for the years 1960 through 2000 were calculated. These precipitation data were used to create precipitation indices, using a model proposed by Sneva and Hyder (1962). From these precipitation indices, forage production indices were calculated for forty-one years.

First, a median crop year precipitation amount was determined from the precipitation record. The median precipitation amount was determined to be 320.7 mm. A precipitation index was calculated for the year being sampled by dividing the annual precipitation amount by the median crop year precipitation, and multiplying by 100. Median herbage yield indices were estimated using the following regression equation from Sneva and Hyder, 1962:

$$Y = 1.11X - 10.6 \tag{6.1}$$

Where Y is the forage yield index, and X is the precipitation index noted above. Forty-one forage yield indices were calculated in all. These are found in Table 6.1.

Though the growth of forage (or any plant) is dependent on precipitation, sunlight, temperature, and many other changing factors, precipitation data for the years 1960 to 2000 were readily available. As well, Sneva and Hyder (1962) created their forage yield index using precipitation as a proxy for all the elements contributing to forage growth in a range environment. It was decided that these would be used to determine forage growth for this hypothetical ranch in the Porcupine Hills of Alberta. The precipitation data allowed for forty-one sampling intervals. Each of the sampling intervals represented a different forage year, and hence different forage yield index.

It was assumed that each of the precipitation indices in Table 6.1 was independent through time and equally likely to occur in a given ranch year. These precipitation indices led to the corresponding forage yields for that year. To choose a forage yield index in the model, samples were drawn at random from a uniform distribution, drawing from 41 annual intervals. Thus, each forage index had an equal probability of being drawn.

The stochastic spreadsheet model was set up in such a way that the range year interval chosen resulted in the choice of the forage yield index associated with that crop year. For example, Interval 20 is associated with crop year 1980, and a forage yield index of 114.2. If the model randomly chooses interval 20 for grazing season 10, then the forage yield index in grazing season 10 will be 114.2. Forage yield indices were randomly drawn for each of the 20 years in the ranch model to simulate twenty consecutive years of weather. Stocking rates on the ranch are adjusted each season based on the grazing index.

6.1.2 *Price Models*

The whole ranch model incorporated elements such as the sale of cull cows and the purchase of bred heifers. A more complete set of prices was needed to explain these additions to the model. It was assumed that the prices of steers, heifers, bred heifers, and cull cows would be correlated through time. Simple econometric time series price models were used to forecast cattle prices over time. The price models incorporated three lagged time seasons. Each price in the present time season was dependent on the prices in the previous three seasons. The cattle prices obtained were biannual data. Therefore, each lagged time season represented 6 months. The price functions below represent this structure for each of the four cattle categories, where *S*, *H*, *B*, and *C* index steers, heifers, bred heifers and cull cows respectively:

$$\begin{aligned} P^S_t &= \alpha^S_0 + \alpha^S_1 P^S_{t-1} + \alpha^S_2 P^S_{t-2} + \alpha^S_3 P^S_{t-3} + \varepsilon_S \\ P^H_t &= \alpha^H_0 + \alpha^H_1 P^H_{t-1} + \alpha^H_2 P^H_{t-2} + \alpha^H_3 P^H_{t-3} + \varepsilon_H \\ P^B_t &= \alpha^B_0 + \alpha^B_1 P^B_{t-1} + \alpha^B_2 P^B_{t-2} + \alpha^B_3 P^B_{t-3} + \varepsilon_B \\ P^C_t &= \alpha^C_0 + \alpha^C_1 P^C_{t-1} + \alpha^C_2 P^C_{t-2} + \alpha^C_3 P^C_{t-3} + \varepsilon_C . \end{aligned} \qquad \textbf{(6.2)}$$

In these equations P_t represents the price in the present time period, P_{t-1} through P_{t-3} are the prices lagged 1, 2, and 3 half-year periods respectively, α_0 represents the intercept parameter, α_1 through α_3 are the parameters on the current and lagged prices, and ε represents the error term or residual associated with each price equation.

Darren Chase, Provincial Market Analyst (Livestock), for AAFRD provided prices (per head) for 500-600 pound steers and heifers, as well as for bred heifers and cull cows. These prices were obtained at Calgary, and converted to dollars per hundredweight ($/cwt) by dividing the dollars per head figures by 5.5. Prices for November and May for the years 1976 to 2000 were used. The prices were adjusted for inflation by using Consumer Price Index figures from Statistics Canada's CANSIM database. A CPI for All Products in Canada for each of the years 1976 to 2000 was used. Each of the November and May prices was divided by the year's CPI, and then multiplied by one hundred, in order to obtain CPI-adjusted prices. These prices can be found in Table 6.2.

The parameters for the four price models outlined above were estimated using a system of four equations. Since the error terms among the four equations may be correlated, the econometric technique employed was Seemingly Unrelated Regression (SUR). The SUR method allows one to obtain parameters for each individual price equation as well as the correlation coefficients among the four error terms (Griffiths et al., 1993).

To ensure that the functional form of the price equations was robust, SUR procedures were estimated for models containing prices lagged one, two, and three periods. Indicators of the goodness of fit (R^2) for the system, as well as for individual equations, increased with each additional lagged price added to the models. In the 3-lag specification chosen, the system R^2 was 0.9441. A Likelihood Ratio Test of the diagonal covariance matrix for the system of four equations had a chi-square value of 178.29 with 6 degrees of freedom, which is statistically significant at the 95% level. This information suggests that the form of the price system chosen is a reasonably good predictor of cattle prices.

Tables 6.3 and 6.4 provide the final parameter estimates and correlation coefficients among the errors for the cattle price system of equations. The estimation results from Table 6.3 are used to simulate prices for steers, heifers, cull cows and bred heifers through twenty years of time. Correlations from Table 6.4 are required to ensure the simulation draws for steer, heifer, cull cow, and bred heifer price in each period of the ranch model maintain the correlation found from the SUR estimates.

6.1.3 *Ranch Model*

The whole ranch differs from that used in the static model. Adams and Ambrose (2001) suggested that a riparian area would make up between 8 and 10 percent of total ranch area. The riparian pasture area in the whole ranch model has an area of 500 acres. The uplands area is now assumed to be 4,900 acres. The total ranch area of 5,400 acres is three times the area used for the static model. As in the static model, conservative stocking rates were chosen based on Adams et al. (1991). These were 0.500 AUM/acre for the uplands, and 1.000 AUM/acre for the riparian area. These rates translated to 445 and 91 animals, respectively, for a total animal unit (AU) number of 536 in a conservative continuous grazing strategy simulation.

6.2 Simulation Model

The simulation of a ranch in the whole ranch model is run in two parts. In the first part, Cases 1 and 2 are run simultaneously, using the same random price and forage yield (weather) draws. That is, the Conservative Grazing case (Case1 or Base Case) is compared to a case where the pastures are overgrazed from good condition (Case 2). The cattle prices and weather are the same for each strategy. This simulation was run to compare the costs and benefits of a conservative strategy (Case 1) to those of an overgrazing strategy (Case 2). The hypothesis was that conservative grazing would be a better long-term business strategy.

In the second part of the simulation model, Case 3 is one in which the pastures are already in poor condition (from previous overgrazing), and are then overgrazed further. This case is run simultaneously with Case 4 (Rotational Grazing), Case 5 (Corridor Fencing), and Case 6 (Rest Rotational Grazing), with the same random cattle price and weather draws. That is, the weather and cattle prices are the same for each strategy. This simulation was run to compare the costs and benefits of regenerative strategies (Cases 4, 5, and 6) to those of an overgrazing strategy (Case 3). The hypothesis was that the regenerative strategies would be the better long-term business strategies.

For each part of the simulation, the simulation model chooses random steer, heifer, bred heifer, and cull cow prices for each of twenty seasons. As well, random weather variables are chosen for each season. These weather variables translate to random forage yield indices for each of twenty seasons. As noted above, the random variables chosen for Case 1 are linked to Case 2, so each share the same weather and prices. The same is true for the simulation of Case 3 vs. Cases 4, 5, and 6. Weather variables affect the number of animals that can be placed on each pasture. In the stochastic simulation model, other ranch costs were added, and tied to the number of animals wintered. These were costs such as winter feed, bedding, veterinary costs, etc. The number of animal units (AU) wintered was multiplied by a specific cost per AU for each of these variable costs.

Each part of the simulation model was run using Palisades Decision Tools' @RISK program for Microsoft Excel. The settings were as follows. The simulations were run using a Monte Carlo algorithm. The simulation performed 5,000 iterations of the stochastic whole ranch model with each run. That is, @RISK simulated 20 years of ranching operations (conservative grazing and overgrazing from pasture in good condition or overgrazing, rotational grazing, corridor fencing, and rest-rotational grazing from pasture in poor condition) 5,000 times.

6.2.2 *Price Model*

Prices for cattle types were simulated each season using the models estimated for 6.2. In a single equation model, residuals would be sampled from an independent normal distribution. Residual samples would be distributed normally, with a mean of 0, and a standard deviation of σ_i. However, this model is a system of four equations. The distribution is assumed to be multivariate normal. Therefore the residuals between equations may be correlated, and not independent.

Drawing from a bivariate normal distribution is performed as follows. Independent samples x_1 and x_2 are found using the @RISK procedures. Then, samples ϵ_1 and ϵ_2 can be found using:

$$\epsilon_1 = x_1$$

$$\epsilon_2 = \rho x_1 + x_2\sqrt{1-\rho^2} \quad \textbf{(6.4)}$$

(6.5)

where ρ is the coefficient of correlation between the variables in the bivariate distribution (Hull, 1997).

For a multi-variate normal distribution, where the coefficient of correlation between variable *i* and variable *j* is $\rho_{i,j}$, n independent variables, $x_i (1 \leq i \leq n)$, must be sampled from univariate standardized normal distributions (Hull, 1997). The samples would be $\epsilon_i (1 \leq i \leq n)$, where

$$\epsilon_i = \sum_{k=1}^{k=i} \alpha_{ik} x_k$$

(6.6)

Hull (1997) stated that, in order for ϵ_i to have the correct variance and correlation with the $\epsilon_j (1 \leq j \leq i)$, we must have

$$\sum_k \alpha^2_{ik} = 1$$

(6.7)

and

$$\sum_k \alpha_{ik} \alpha_{jk} = \rho_{i,j}$$

(6.8)

The first sample, ϵ_1 is set equal to x_1. The equations for the α's can be solved in such a way that ϵ_2 is calculated from x_1 and x_2, ϵ_3 is calculated from x_1, x_2, x_3, and so on (Hull, 1997).

From (6.4) we know that:

$$\epsilon_1 = x_1$$

If

$$\epsilon_2 = \alpha_{21} x_1 + \alpha_{22} x_2$$

(6.9)

and

$$\alpha_{21} = \rho_{12} \text{ and } \alpha_{22} = \sqrt{1 - \rho_{12}^{\ 2}}$$

(6.10) and (6.11)

it leads to (6.5):

$$\in_2 = \rho_{12}x_1 + \left(\sqrt{1-\rho_{12}^{\ 2}}\right)x_2$$

In the same manner, if:

$$\in_3 = \alpha_{31}x_1 + \alpha_{32}x_2 + \alpha_{33}x_3$$

(6.12)

and

$$\alpha_{31} = \rho_{13} \text{ and } \alpha_{32} = \left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right) \text{ and } \alpha_{33} = \left[\sqrt{1-\rho_{13}^{\ 2} + \left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)^2}\right]$$

(6.13) and (6.14)

then,

$$\in_3 = \rho_{13}x_1 + \left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)x_2 + \left[\sqrt{1-\rho_{13}^{\ 2} + \left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)^2}\right]x_3$$

(6.15)

It also follows that if

$$\in_4 = \alpha_{41}x_1 + \alpha_{42}x_2 + \alpha_{43}x_3 + \alpha_{44}x_4$$

(6.16)

and

$$\alpha_{41} = \rho_{14} \text{ and } \alpha_{42} = \left(\frac{\rho_{24} - \rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right) \text{ and}$$

$$\alpha_{43} = \left\{\frac{\rho_{34} - \rho_{14}\rho_{13} - \left[\left(\frac{\rho_{24} - \rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)\left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)\right]}{\left[\sqrt{1-\rho_{13}^{\ 2} + \left(\frac{\rho_{23} - \rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{\ 2}}}\right)}\right]}\right\} \text{ and}$$

$$\alpha_{44} = \sqrt{1-\rho_{14}^{2} - \left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)^{2} - \left\{\frac{\rho_{34}-\rho_{14}\rho_{13} - \left[\left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\right]}{\left[\sqrt{1-\rho_{13}^{2} + \left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)}\right]}\right\}^{2}}$$

(6.17), (6.18), and (6.19)

It follows that:

$$\in_4 = \rho_{14}x_1 + \left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)x_2 + \left\{\frac{\rho_{34}-\rho_{14}\rho_{13} - \left[\left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\right]}{\left[\sqrt{1-\rho_{13}^{2} + \left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)}\right]}\right\}x_3 +$$

$$\sqrt{1-\rho_{14}^{2} - \left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)^{2} - \left\{\frac{\rho_{34}-\rho_{14}\rho_{13} - \left[\left(\frac{\rho_{24}-\rho_{14}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)\right]}{\left[\sqrt{1-\rho_{13}^{2} + \left(\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^{2}}}\right)}\right]}\right\}^{2}}\; x_4$$

(6.20)

The relationships above were used to correlate the prices for steers, heifers, cull cows and bred heifers through time using estimates for the equations in 6.2.

In each season, for each of the price variables, a random sample was drawn from a normal distribution. Each random draw was multiplied by its corresponding multivariate distribution sample, (Random Steer Price draw by $\in_1$, Random Heifer Price Draw by $\in_2$, and so on). These multivariate samples ($\in_1$ to $\in_4$) were found using the equations 6.4, 6.5, 6.15, and 6.20, outlined above. This multiplication was used to make the random normal draws multivariate normal.

From the price data and SUR, a mean price for each animal type was found and recorded. The choice of cattle prices for each grazing season was based on the assumption that the previous three seasons could help predict the current season price.

Initial prices for the first three seasons were developed using information found in the SUR and multivariate distribution calculations. Grazing Season 1 price calculations used the mean prices found in the SUR as the prices for all cattle types. The equation is explained in the following paragraph, using steer price as an example.

For steer price in Grazing Season 1, the price was developed as follows, using the results from Table 6.3. Starting with a mean steer price of 127.22/cwt, the equation for Season 1 Steer Price appears below.

$$P_S^1 = (49.447 + (0.44445 \text{ x } 127.22) + (0.55442 \text{ x } 127.22) + (-0.3839 \text{ x } 127.22) + \epsilon_1) \quad \textbf{(6.21)}$$

This equation was used for each of the other Season 1 cattle prices; heifers, bred heifers, and cull cows, using their respective price constants, lagged coefficients, mean prices, and multivariate samples. The equations were correlated based on the discussion above.

For the second season, the equation was the same. However, instead of multiplying their price coefficients (lagged one season) by the mean price from the SUR, they used the price found in grazing season 1 (i.e., the previous season). For steer prices, this meant that the price found using equation 6.5 became the price multiplied by the steer price coefficient (lagged one season) in the Grazing Season 2 steer price calculation. Therefore, in Grazing Season 4, mean cattle prices from the SUR were no longer used, as prices for steers, heifers, bred heifers, and cull cows depended on the prices found in the previous three grazing seasons. Thus, prices in the model were linked through time as well as across equations in each time period.

Using the equations outlined above, a price for each of steers, heifers, bred heifers, and cull cows was generated for each grazing season. This occurred for each of the twenty grazing seasons. In order to keep prices positive and within the range given by AAFRD, a MAX/MIN function was added to each price calculation. This limited the prices to just outside their maximum and minimum values. In order to determine the limits, the mean prices and standard deviations found in the SUR were used. The standard deviations were added to or subtracted from the mean until the results were at or just outside the maximum and minimum price values from AAFRD.

In the price simulation, the Steer Price minimum value was set at \$23/cwt (23 dollars per hundredweight), and the maximum at \$273/cwt (5 SD down, 7 SD up from mean). For Heifers the minimum and maximum prices were $26/cwt and $239/cwt, respectively (5 SD down, 7 SD up from mean). For bred heifers, the minimum and maximum prices were $64/cwt and $287/cwt (6 SD down, 8 SD up from mean). For cull cows, the minimum and maximum prices were $13/cwt and $132/cwt (5 SD down, 7 SD up from mean).

6.2.3 *Cow Replacement Program and Cull Cows*

In addition to random price and weather changes, and variable ranch costs that changed with cattle numbers, there was an additional element added to the ranch model simulation. This was a cow replacement program. It was assumed that a rancher would hold back some of his or her heifers for breeding. In each of the ranch model cases (fully explained below), the heifer retention rate was 10% (from AAFRD). Retained heifers were subtracted from the total heifer calf sales, to avoid double counting.

Along with the heifer retention, the ranch model also included bulls for breeding. AAFRD suggested one bull for every 25 cows. It was assumed that half of the bulls required would be purchased, and half would be culled from the existing bulls each year. This was done instead of replacing all the bulls required every second year. The price of a bull was assumed to be $2,000.

The ranch model simulation also accounted for cull cattle. AAFRD suggested a cull rate of 7%. The total cull cow number also included the culled bulls mentioned previously. The number of cattle culled each season was multiplied by the weight of a cull cow (assumed to be 1,200 pounds) or a culled bull (assumed to be 2,000 pounds). This number was multiplied by the cull cow price (per cwt) simulated for that season. If the number of heifers culled was greater than the number of heifers retained for the breeding program, it was assumed that the rancher would purchase the extra bred heifers needed. The number of bred heifers needed over and above those retained was multiplied by the randomly chosen bred heifer price (per cwt) selected for that grazing season, then by 7, to represent a 700-pound animal.

If the pasture in question is degraded in one grazing season, and the cow number must be reduced in the next season, the cattle are sold off as cull cows using the cull cow price that season. In the same manner, if pasture condition is improved, and cattle are added to the herd, the number of animals added is multiplied by the simulated bred heifer price, as mentioned above. In this manner, animals leaving the ranch, or being brought into the ranch, are all accounted for.

6.2.4 *Common Assumptions*

For all cases in the stochastic ranch model simulation, there were some common ranch assumptions. The grazing time used was 5.5 months. The gain per day for calves was assumed to be 2.2 pounds. Death loss for calves on the ranch was 4%. The rate of heifer retention was 10%, and cattle were culled from the herd at a 7% rate. The discount rate used for the ranch simulation was 10%, as in the static model. The calculation of the discount rate was explained in section 4.1.3. As in the static ranch model, Net Present Value is one of the results reported. Net Present Value calculations were explained in section 4.2.2.

In the stochastic ranch model, some variable costs not included in the static model were added. From AAFRD, a "cost per cow wintered" was obtained for such items as winter feed, veterinary expenses, etc. A full list of these variable costs (name and cost per cow wintered) can be found in Table 6.5. Though some animal units may have been pastured on rented land during the grazing season, wintering costs were applied to all of the ranch's animal units (as the rancher bore wintering costs for all animals grazed). A comparison of the different scenarios can be found in Table 6.6.

6.2.5 *Base Case 1 - Conservative Continuous Grazing from Good Condition*

In the base case, a producer grazes a sustainable level of animal units in a continuous grazing system. That is, the producer chooses a stocking rate that matches the sustainable carrying capacity for the pasture. The animals are continuously grazed for a period of 5.5 months in each grazing season. There are 20 grazing season periods in total. The simulation model chooses random cattle prices and precipitation/forage growth for each grazing season. This scenario was chosen to highlight a conservative continuous grazing system in which pasture is not degraded. That is, it does not need a change in management strategy in order to improve. All other scenarios used this base case, with modifications in management and fencing.

6.2.5.1 Field Assumptions

The base case assumed a 5,400-acre grazing area, hypothetically situated in the Porcupine Hills of Southern Alberta. The pasture area was broken down into 500 acres of riparian area, and 4,900 acres of upland. Assuming a rectangular shape, the pasture was 14,817 feet from west to east and 15,840 feet (three miles) from north to south. It was assumed that the outside perimeter of the pasture was previously fenced. The pasture would resemble that found in Figure 4.3 of the static model, except with a north-south dimension of 15,840 feet, instead of the previous 5280.

As in the static model, the stream and accompanying riparian area ran down the center of the pasture, from west to east. The maximum width of any one meander of the stream was 250 feet. In order to keep livestock well distributed, it was assumed that the producer had previously added two waterers to the pasture. Each waterer fed water to a watering site on both sides of the pasture. This assumption regarding the location of the riparian area, while simplifying the analysis, represents an idealized type of riparian system, as in the static model.

6.2.5.2 Grazing Capacity and Stocking Rate

As in the static model, it was assumed that the pasture was of the Foothills Grassland range type, in the 18-22 inch (annual) precipitation zone, and the range condition was in the "Good" class (Adams et al., 1991). Adams et al. (1991) stated that upland pasture in Good condition could support a stocking rate of 80 AUM/quarter section. Adams and Ambrose (2001) suggested that the riparian area could support double this rate, or 160 AUM/quarter section. When the upland and riparian pasture areas (in quarter sections) were multiplied by the stocking rates, it was found that the upland pasture had a total carrying capacity of 650 AUM, and the riparian pasture had a total carrying capacity of 500 AUM.

This translated to an initial uplands stocking rate of 0.5 AUM per acre per grazing season (5.5 months), and a riparian area stocking rate of 1.0 AUM per acre per grazing season. The stocking rate is the carrying capacity in AUM (650 or 500), divided by the pasture size in acres (4,900 or 500). This equates to 445 cow-calf pairs on the uplands pasture and 91 cow-calf pairs on the riparian pasture each grazing season. These levels of grazing represented maximum sustainable levels for the pastures. See Table 6.6.

6.2.5.3 Grazing Capacity and Stocking Rate Decision Rules

The following explanation is graphically portrayed in Figures 6.2 and 6.3. As Base Case 1 represented a conservative grazing strategy, there was a maximum stocking rate set for the ranch. The maximum rates were equal to the maximum number of animal units that could graze upland and riparian pastures without causing degradation of the forage resources. For the upland pasture, this maximum stocking rate was 0.500 AUM/acre. For the riparian area, it was 1.000 AUM/acre.

Stocking rates in the model were reduced in response to weather. For the uplands, an arbitrary range health cutoff was chosen at a forage yield index of 90. Below this level, deterioration would occur if stocking rates were maintained at the maximum. To determine the stocking rate in AUM for the first season, the spreadsheet model checked to see if the Season 1 forage index chosen was below 90. If so, the Base Case index was divided by 100, and the resulting percentage multiplied by the maximum sustainable carrying capacity for uplands (2,450 AUM in the Base Case). If not, the model chose the maximum sustainable carrying capacity as the stocking rate.

In Season 2, the calculation of the stocking rate was dependent on both the previous season and current season forage yield. If the previous season's forage yield index was below the cutoff, and the current season's was equal to or greater than the cutoff, the model chose the minimum of a) the average of the previous and current season's forage yield indices, or b) the maximum sustainable carrying capacity. If both the previous index and the current index were below the cutoff, then the model chose the current index multiplied by the maximum sustainable carrying capacity.

If the previous season's index was above the cutoff and the current index was below it, the model chose the current season's index multiplied by the maximum sustainable carrying capacity. If both indices were above the cutoff, the model chose the maximum sustainable carrying capacity. This was done for the remaining grazing seasons. The calculations for the riparian area were the same, except that a forage yield index cutoff of 70 was used, and the maximum sustainable capacity on the pasture was 500 AUM.

As in the static model, there was a lower level cutoff for stocking rate on pastures. This was the stocking rate where a pasture reached a steady state. That is, the pasture condition could not fall below this level. In the static model, the number chosen was 0.273 AUM/acre, representing the stocking rate an uplands pasture was reduced to from good condition after 15 years of overgrazing (static model Case 2 – Unsustainable

Continuous Grazing from Good Condition). In the static model, this translated to less than half of the initial (Season 1) stocking rate. For the stochastic model, 0.273 AUM/acre was chosen as the steady state grazing level for both upland and riparian areas. If a pasture begins Season 1 at this stocking rate, it is in very poor condition.

The Base Case was set up in such a way that the animal units wintered was always equal to the maximum sustainable number of animal units for the ranch (536 AU). If, due to poor weather, the sustainable number of animal units had to be reduced to protect carrying capacity, the animals pulled off the pasture were grazed on rented pasture during the grazing season (Figure 6.3). The animal unit months attributed to rented pasture was multiplied by a private pasture rental rate (Table 6.5), and the cost added to the net cash calculation. The rental charge was $16.81 per AUM. There were no additional watering or fencing costs added in this case.

6.2.6 *Case 2 – Unsustainable Continuous Grazing from Good Condition*

The second case is one in which the pasture starts in an initially good pasture condition and is subsequently overgrazed. Table 6.6 shows the comparison of this strategy to the Base Case, as well as to other grazing scenarios. The stocking rate exceeds the sustainable carrying capacity for the pasture. This case is used to illustrate the incentive (if any) to overstock a pasture. It illustrates the effects of unsustainable stocking rates on pasture. Animals are still grazed for 5.5 months per grazing season, for twenty years. The pasture in Case 2 is the same as the one used in the base case. As before, the pasture would be similar to that in Figure 4.3, except with a width of 15,840 feet.

6.2.6.1 Grazing Capacity and Stocking Rate

Initially, as in the base case, the pasture is in the Good range condition class. The initial stocking rates are 30% higher than in the base case. The uplands are stocked at 0.650 AUM per acre per Season (579 AU per season), and the riparian area at 1.300 AUM per acre per season (118 AU per season). That is, the stocking rate exceeded the sustainable grazing capacity by 30% (Table 6.6).

6.2.6.2 Grazing Capacity and Stocking Rate Decision Rules

Rates of range degradation varied with the forage index. The size of the cow herd each season was tied to the rate of range degradation. First, long term upland and riparian AUM capacities were determined. In the uplands grazing season 1, the model chose the unsustainable maximum carrying capacity (3185 AUM). In Season 2, the model based the expected carrying capacity on the previous season's weather. If the forage yield index chosen in the previous season was greater than or equal to 130, then the model chose the stocking rate from the previous season (0% degradation). If the index chosen was between 115 and 130, the model chose a degradation rate of 2%. If the forage yield index in the previous season was between 100 and 115, the model chose a degradation rate of 4%. If the index was between 85 and 100, the model chose a degradation rate of 6%. Finally, if the forage yield index chosen in the previous season was at or below 85, the model chose a degradation rate of 8%.

These rates allowed for a range of pasture degradation (or status quo) possibilities, depending on precipitation amounts (and hence forage yield indices) chosen randomly by the model for each grazing season. For the riparian area, the cutoffs were the same, but the degradation rates were cut in half. That is, they were 0%, 1%, 2%, 3%, and 4%, respectively. As in Base Case 1, the minimum stocking rate for both upland and riparian pastures was 0.273 AUM/acre. Because the maximum stocking rate that could be chosen by the model was the previous grazing level, there was no need for an upper grazing cut-off in this case.

Once the long-term grazing capacities were determined each season, a herd size for the year based on expected grazing capacity was calculated. The calculation chose the maximum of a) the long-term upland stocking rate chosen above, divided by the grazing time in months (5.5), or b) the minimum stocking rate on the uplands (0.273 AUM/acre) multiplied by the upland area (4900 acres), divided by the grazing time in months. The upland animal unit number was added to the riparian animal unit number that was calculated in a similar fashion. The cow herd size would remain the same or decrease each season depending upon the expected grazing capacity (Figure 6.4).

Actual stocking rates for the uplands and riparian areas were then determined using the upland and riparian forage yield index cutoffs of 90 and 70, respectively. To determine the stocking rate in AUM/acre for the first season, the spreadsheet model checked to see if the Season 1 index chosen was below 90. If so, the Base Case index was divided by 100, and the result was multiplied by the current season's long-term upland carrying capacity for uplands. If not, the model chose the current season's long-term upland carrying capacity as the stocking rate.

In Season 2 and beyond, calculation of the stocking rate (in AUM/acre) was dependent on both the previous season and current season forage yield. The calculation was identical to that used for the stocking rate in the Base Case, except the current season long-term carrying capacity was substituted for the maximum sustainable carrying capacity used in the Base Case. As in the Base Case, the uplands and riparian area calculations differ only in their choice of cutoff forage yield index, and long-term carrying capacity.

The total AUM/acre grazed on each of the uplands and riparian pastures was determined using the above stocking rate calculations. For the uplands, the model chose the maximum of a) the minimum stocking rate (0.273 AUM/acre), or b) the stocking rate divided by the total upland pasture area (4,900 acres). For the riparian area, the total riparian pasture area (500 acres) was used in the calculation. These AUM/acre numbers were then multiplied by the total pasture areas, and divided by grazing time in months (5.5), in order to determine the number of animal units grazed on each of the pastures. The total AU grazed on each of the pastures were summed to get the animal units grazed on own pasture.

The model now contains a herd size dependent on expected grazing capacity (through weather/forage calculations), and a current year grazing capacity influenced by current season weather. If the current season herd size falls below the ranch's current season grazing capacity (albeit at an unsustainable level), the difference is made up through pasture rental. That is, the herd size based on expected grazing capacity is always maintained for that season (Figure 6.5). As pasture quality is degraded through overgrazing, the base herd size decreases over time. The current season's herd size is subtracted from the previous season's herd size, to obtain the permanent herd reduction due to overgrazing. These animals are sold off at cull cow prices. The variable ranch costs in Case 2 were the same as those for Base Case 1 (see Table 6.5). No new fencing or watering costs were added to this case.

6.2.7 *Case 3 –Unsustainable Continuous Grazing from Poor Condition*

The third case is one in which a previous owner overgrazed an initially Good condition pasture for ten years, as in the first ten grazing seasons of Case 2. This assumed overgrazing has left the pasture in Poor range condition (initially). Subsequently, the producer in Case 3 overgrazes it (Table 6.6). This model is used to set up a comparison for Case 4, Rotational Grazing, Case 5, Corridor Fencing, and Case 6, Rest-Rotational Grazing. The pasture in Case 3 is the same as the one used in the previous cases. However, it is in poor pasture condition when the overgrazing begins in this model.

6.2.7.1 Grazing Capacity and Stocking Rate

Adams et al. (1991) stated that in order to sustainably graze pasture in poor condition, 50% fewer AUM per quarter section should be grazed than the stocking rate for good condition grassland. Therefore, in order to portray an overgrazing situation, the initial sustainable herd is reduced by only one third. That is, the initial uplands stocking rate in Case 3 is 0.350 AUM per acre, or 312 AU grazed per season. On the riparian area, the rate is 0.700, or 64 AU grazed per season (Table 6.6).

6.2.7.2 Decision Rules and Other Ranch Model Costs

The decision rules for grazing capacity, stocking rate, etc. are the same as those used in Case 2, except with lower initial grazing values. The variable ranch costs in Case 3 are the same as those for Base Case 1 (see Table 6.5). No new fencing or watering costs are added to this case.

6.2.8 *Case 4: Rotational Grazing from Poor Condition*

Case 4 begins with an even poorer initial pasture condition. Initial carrying capacities for both upland and riparian pastures are one third of the initial capacities for Case 3 (Table 6.6). The low initial capacities were used to measure regenerative capabilities of rotational grazing, which the rancher implements in this case. Rotational grazing strategies were ranked highly by respondents to the initial questionnaire, when asked what riparian management strategies should be used to repair damage to riparian areas (Chapter 3). For this case, it was assumed that management time was available in order to change the riparian management strategy (add fences, and rotate animals through the pastures during the grazing season). As well, no additional management costs are added. This model presented an alternative and comparison to the overgrazing strategy in Case 3.

6.2.8.1 Field Assumptions

This rotational scheme changes the original pasture. The pasture is divided into four units, by adding three north-south cross fences of three miles in length (each). Each pasture unit is 15,840 feet in length by 3,705 feet in width. If each new fence addition (assuming the outside area was previously fenced) is 15,840 feet long, then an additional 47,520 feet of fencing is required. As well, in order to ensure good livestock distribution, an additional two waterers are added, to give watering sites to each of the two new grazing areas. This pasture is similar to the one in Figure 4.4, except with a north-south dimension of 15,840 feet.

6.2.8.2 Grazing Capacity and Stocking Rate

The pasture starts in poor condition due to previous overgrazing. As noted above, the initial grazing capacities are the ones used for Case 3, but reduced by a further one third on both the uplands and riparian area. That is, the uplands have an initial stocking rate of 0.273 AUM/acre (243 AU grazed per season). The riparian area has an initial stocking rate of 0.469 AUM/acre (43 AU grazed per season). If it is assumed that the animals are rotated through the pastures, grazing is expected to be more uniform in each pasture they graze. It was assumed that the forage resources in the pasture would begin to regenerate. That is, the rotational system would be better for forage re-growth than the original continuous grazing system.

6.2.8.3 Grazing Capacity and Stocking Rate Decision Rules

First, long term upland and riparian AUM capacities were determined. In the uplands grazing season 1, the model chooses the initial carrying capacity (one third of Case 3's capacity). In Season 2 and beyond, the model bases the range carrying capacity on the previous season's weather. However, in Case 4, the model chooses regeneration rates, instead of degeneration rates.

If the forage yield index chosen in the previous season is less than or equal to 85, then the model chooses the stocking rate from the previous season (0% regeneration). If the index chosen is between 85 and 100, the model chooses the stocking rate from the previous season, plus a regeneration rate of 2%. If the forage yield index in the previous season is between 100 and 115, the model adds a regeneration rate of 4% to the previous season's stocking rate. If the index is between 115 and 130, the model adds a regeneration rate of 6%. Finally, if the forage yield index chosen in the previous season is equal to or greater than 130, the model chooses the previous season's stocking rate, plus a regeneration rate of 8%.

These rates allow for a range of pasture regeneration (or status quo) possibilities, depending on precipitation amounts (and hence forage yield indices) chosen randomly by the model for each grazing season. For the riparian area, the cutoffs are the same, but the regeneration rates are doubled. That is, they are 0%, 4%, 8%, 12%, and 16%, respectively. In this regenerative system, the stocking rate cutoffs are the same as those for Base Case 1. That is, the minimum stocking rate on the uplands and riparian pastures is 0.273 AUM/acre. The maximum rates are set to 0.500 AUM/acre on the uplands, and 1.000 AUM/acre on the riparian area.

Once the long-term grazing capacities are determined, a herd size based on expected current grazing capacity is calculated. The calculation chooses the maximum of a) the long-term upland stocking rate chosen above, divided by the grazing time in months (5.5), or b) the minimum stocking rate on the uplands (0.273 AUM/acre) multiplied by the upland area (4900 acres), divided by the grazing time in months. The upland animal unit value is added to the riparian animal unit value (chosen for the riparian area with a similar "maximum" calculation, except using a riparian area of 500 acres and the long-term riparian AUM capacity).

Stocking rates for the uplands and riparian areas each season are then determined using the upland and riparian forage yield index cutoffs of 90 and 70, respectively. The calculations for Season 1 are the same as in previous cases. The calculations for Season 2 are identical to those used for the stocking rate in previous cases, except using Case 4's current season long-term carrying capacity. As in previous cases, the uplands and riparian area calculations differ only in their choice of cutoff forage yield index, and long-term carrying capacity (specific to the pasture area in question).

As in previous cases, the total AUM/acre number grazed on each of the uplands and riparian pastures is determined using the above stocking rate calculations. The total animal units grazed on each of the pastures are summed to get the animal units grazed on a rancher's own pasture. As before, this case now contains a herd size dependent on expected grazing capacity (through weather/forage calculations), and a total ranch grazing capacity dependent on upland and riparian forage yield cutoffs. It is expected that the base herd size will increase to accompany the regeneration of forage resources.

If the current season ranch grazing capacity falls below the base herd size, the difference is made up through pasture rental. That is, the herd size each season based on expected grazing capacity is always maintained. As pasture quality is improved through regeneration of forage resources, the herd size will increase. The previous season's herd size is subtracted from the current season's herd size, to obtain the permanent herd increase as pasture improves. These new animals are purchased at the bred heifer price.

The variable ranch costs in Case 4 are the same as those for Base Case 1 (see Table 6.5). The three new cross fences, totaling 47,520 feet, add an extra $30,888 to ranch costs in Season 0. The upkeep cost, at 2.5% of the total additional fencing cost, adds $772 per grazing season. The two new waterers, at $3,500 apiece, add $7,000 to ranch costs in Season 0 (Table 6.6).

6.2.9 *Case 5: Corridor Fencing from Poor Condition*

In this case, the producer implements a corridor fencing strategy, after 10 years of overgrazing by a previous owner (as in Cases 3 and 4). In the responses to the initial questionnaire, 42% of respondents ranked this as choice 1 or 2 for riparian restoration in a highly degraded pasture. The degraded riparian corridor was fenced off, in order to allow for rehabilitation. This case was used as an alternative to the overgrazing strategy of Case 3, and the rotational grazing strategy of Case 4.

The new corridor fencing divides the Base Case pasture into two grazeable upland pastures, and a lightly grazed riparian pasture. Each upland pasture consists of 2,450 acres. The riparian pasture measures 500 acres in area. By design, this new pasture system also incorporates a rotational strategy, as livestock graze one upland pasture unit at a time. In order to provide water for the animals, the waterers mentioned in the base case serve the two pastures. This pasture would resemble the one seen in Figure 4.5, except with a width of 15,840 feet, and pastures with the acreages noted above.

As in the previous case, the pasture starts in poor condition. The initial stocking rate for the uplands is two thirds that of Case 3. This is the same as that for Season 1 in

Case 4 (0.273 AUM/acre, 243 AU grazed per season) to simulate ten prior years of overgrazing. Because the riparian area is almost taken completely out of production, its initial carrying capacity is assumed to be only one third that of Case 3 (Table 6.6). That is, its initial stocking rate is 0.273 AUM/acre, or 25 AU grazed per season. The animals are rotated between the two large upland pastures, so grazing is assumed to be more uniform in each pasture they graze. Animals are allowed to minimally graze the riparian corridor, as it is regenerated.

The decision rules for upland grazing capacity and stocking rate are the same as those used in Case 4. However, since the riparian area is grazed at a lighter initial rate, it is assumed to regenerate faster. Its regeneration rates are 0%, 6%, 10%, 14%, and 18%. As in Case 4, the grazing capacity cutoffs are the same as those for Base Case 1.
The variable ranch costs in Case 5 are the same as those for Base Case 1 (see Table 6.5). The two new cross fences, totaling 29,634 feet, add an extra $19,262 to ranch costs in Season 0 (Table 6.6). The upkeep cost, at 2.5% of the total additional fencing cost, adds $481 per grazing season.

6.2.10 *Case 6: Rest-Rotational Grazing from Poor Condition*

In this case, the producer implements a rest rotation strategy, after a period of overgrazing by a previous owner (as in Case 4). In the responses to the initial questionnaire, more than a third of respondents ranked this as choice 1 or 2 for riparian restoration in a highly degraded pasture. In this case, the pasture is fenced off differently, separating riparian and upland pastures further. The riparian area's 500 acres are fenced to create 4 equal-sized pastures, using two east-west cross fences of 14,817 feet (as in Case 5), and three north-south cross fences of 1,470 feet. As in Case 5, there are now two large uplands pastures. These are divided into four identical pastures by running two cross fences of 7185 feet from the north and south, up to the cross fence on either side of the riparian area. The pasture appears in Figure 6.1.

For the first 8 years, one pasture in each of the uplands and riparian areas is completely rested (no grazing) each season, while the others are grazed. This means that each of the four pastures in each area will be rested twice in the first eight years. After eight years, a regular rotational strategy is employed. This case, like Case 4 and Case 5, was used as an alternative to the overgrazing strategy of Case 3.

For the first 8 years, one quarter of the original pasture is completely rested each season. Therefore, the grazeable area is reduced by one quarter in both the upland and riparian pastures. The new upland area is 3,675 acres. The new riparian area is 375 acres. After 8 years, the pasture returns to its full grazing area, increasing the stocking rate (Table 6.6). As in Case 4, two additional waterers are needed for this strategy, as the pasture has four grazeable areas. The pasture is the same as that for Case 4, rotational grazing.

As in the previous case, the pasture starts in poor condition. The initial stocking rates for the uplands and riparian area are the same as those for season 1 in Case 4 (overgrazing from poor) (0.273 AUM/acre and 0.469 AUM/acre, respectively) to simulate prior overgrazing (Table 6.6). The animals are rotated through the pastures, so grazing is assumed to be more uniform in each pasture they graze.

Regeneration rates for this case follow the same pattern as those for Cases 4 and 5. However, it is assumed that with the added rest of the rest rotational strategy, the pastures will regenerate at a slightly faster rate. Therefore, the regeneration percentages for the uplands in the first 8 grazing seasons are 0%, 3%, 5%, and 9%. For the riparian area, they are doubled, to 0%, 6%, 10%, and 18%. After 8 grazing seasons, the rates revert back to those for the regular rotational strategy of Case 4. As in the previous two cases, the stocking rate cutoffs are the same as those for Base Case 1 [0.500 AUM/acre (2,450 AUM) on the uplands, and 1.000 AUM/acre (500 AUM) on the riparian area].

The variable ranch costs in Case 6 are the same as those for Base Case 1 (see Table 6.5). Additional watering costs are the same as those for Case 4 ($7,000), with two new waterers providing four riparian watering sites. The two 14817-foot east-west riparian cross fences, three 1,470 foot north-south riparian area cross fences, and two 7185-foot north-south uplands cross fences add a total of $31,469 to ranch costs (Table 6.6). An upkeep cost of $787 per season is also added.

6.3 Chapter Summary

The stochastic simulation model will be used to analyze a whole-ranch operation, which includes a larger upland grazing area, in addition to the riparian area. One part of the simulation, a price model, simulates the price cycles for steers, heifers, bred heifers, and cull cows over time. Another part of the simulation is a weather model, which simulates changing weather patterns, and the effects on forage growth, stocking rate, etc. Whole ranch concerns such as overwintering of cattle, heifer and bull purchases, and cull cow sales will also be added to the 20-season simulation.

A number of grazing strategy cases for the stochastic simulation models will be used to capture dynamic aspects of the whole ranch using decision rules on grazing, prices, etc. Two scenarios are used: grazing from good pasture condition, and grazing from poor pasture condition. From good pasture condition, the stochastic simulation compares a conservative continuous grazing strategy (with no degradation of the pasture) to an overgrazing strategy (with pasture degradation). From poor pasture condition; the simulation compares a case in which a rancher continues to overgraze to three regenerative strategies, which restore riparian health over time (rotational grazing, corridor fencing, and rest-rotational grazing).

6.4 Tables for Chapter 6

Table 6.1 Precipitation and Forage Yield Indices Used in Stochastic Ranch Model

Year	Total Precipitation May-Oct (mm)	Precipitation Index	Forage Yield Index (From Model in 6.1)
1960	189.5	59.1	55.0
1961	315.0	98.2	98.4
1962	160.5	50.1	45.0
1963	380.7	118.7	121.2
1964	232.2	72.4	69.7
1965	350.5	109.3	110.7
1966	428.0	133.4	137.5
1967	214.4	66.8	63.6
1968	408.9	127.5	130.9
1969	367.5	114.6	116.6
1970	336.0	104.8	105.7
1971	330.5	103.0	103.8
1972	439.2	136.9	141.4
1973	204.2	63.7	60.1
1974	393.4	122.7	125.6
1975	320.7	100.0	100.4
1976	362.0	112.9	114.7
1977	344.2	107.3	108.5
1978	489.2	152.5	158.7
1979	208.3	64.9	61.5
1980	360.7	112.5	114.2
1981	327.4	102.1	102.7
1982	233.7	72.9	70.3
1983	149.4	46.6	41.1
1984	239.3	74.6	72.2
1985	291.6	90.9	90.3
1986	326.2	101.7	102.3
1987	230.4	71.8	69.1
1988	166.4	51.9	47.0
1989	232.9	72.6	70.0
1990	337.8	105.3	106.3
1991	288.4	89.9	89.2
1992	420.6	131.1	135.0
1993	503.1	156.9	163.5
1994	295.6	92.2	91.7
1995	318.5	99.3	99.6
1996	318.5	99.3	99.6
1997	351.2	109.5	110.9
1998	540.2	168.4	176.4
1999	309.0	96.3	96.3
2000	205.5	64.1	60.5

Table 6.2 Biannual Prices for Steers, Heifers, Bred Heifers, and Cull Cows

Year	Steer Price (per head – CPI Adjusted)	Heifer Price (per head – CPI Adjusted)	Bred Heifer Price (per head – CPI Adjusted)	Cull Cow Price (per head – CPI Adjusted)
May-76	116.87	93.80	71.37	114.19
Nov-76	107.14	80.22	42.67	103.41
May-77	102.95	81.68	65.35	95.45
Nov-77	118.25	95.80	55.35	106.36
May-78	159.63	142.71	102.78	137.61
Nov-78	197.55	158.65	98.37	171.39
May-79	256.20	221.20	127.08	206.26
Nov-79	217.33	181.60	104.14	221.93
May-80	150.23	137.50	90.44	278.63
Nov-80	177.18	155.31	93.93	215.13
May-81	137.10	126.69	87.84	199.10
Nov-81	126.32	111.19	66.11	186.76
May-82	125.47	108.36	78.42	158.71
Nov-82	127.61	107.41	54.30	169.85
May-83	122.72	111.43	75.44	157.87
Nov-83	125.96	113.71	53.37	168.40
May-84	116.03	99.86	67.45	161.39
Nov-84	119.08	107.37	54.58	163.91
May-85	105.43	94.33	68.65	157.58
Nov-85	116.95	105.64	54.45	151.52
May-86	113.11	102.24	59.33	139.68
Nov-86	134.15	119.90	59.99	151.32
May-87	138.64	129.98	68.15	167.32
Nov-87	142.64	127.75	62.71	176.24
May-88	134.36	121.75	66.08	171.53
Nov-88	129.53	117.98	61.75	173.67
May-89	120.73	102.46	61.01	151.17
Nov-89	119.48	108.93	57.60	158.32
May-90	115.09	103.93	62.33	167.59
Nov-90	115.13	108.18	56.82	146.16
May-91	113.58	106.94	58.80	156.90
Nov-91	106.75	98.64	48.57	138.44
May-92	106.83	99.23	56.88	145.45
Nov-92	111.31	104.89	51.06	136.36
May-93	123.89	112.73	63.85	160.74
Nov-93	127.29	122.61	59.94	151.81
May-94	131.63	119.43	62.60	178.25
Nov-94	112.22	108.75	46.95	169.34
May-95	105.33	95.74	50.39	165.77
Nov-95	87.18	81.01	37.12	130.87
May-96	70.29	60.34	43.34	120.18
Nov-96	78.76	72.89	37.28	117.61
May-97	99.67	91.25	51.38	118.28
Nov-97	107.52	100.48	41.27	126.73
May-98	113.69	101.18	50.32	133.94
Nov-98	109.93	104.63	43.19	138.12
May-99	113.12	103.34	51.49	139.86
Nov-99	125.87	120.93	47.01	143.97
May-00	137.15	125.15	56.74	160.19
Nov-00	135.59	129.31	51.22	160.19
Mean	127.22	114.5	159.75	62.933
Standard Deviation	20.769	17.782	15.895	9.9162
Variance	431.36	316.21	252.66	98.332

Table 6.3 SUR Parameter Estimates for Cattle Type Price Equations Used in Whole Ranch Model

	Parameter estimates (Standard errors)			
	Steer	Heifer	Bred Heifer	Cull Cow
Constant	49.447 (10.61)*	47.007 (9.884)*	56.056 (13.571)*	17.621 (4.626)*
Price lagged 1 period	0.44445 (0.090745)*	0.40496 (0.089311)*	0.79913 (0.13149)*	0.31898 (0.094098)*
Price lagged 2 periods	0.55442 (0.090901)*	0.56827 (0.085905)*	0.28832 (0.17356)	0.7188 (0.067248)*
Price lagged 3 periods	-0.3839 (0.087245)*	-0.37885 (0.086637)*	-0.43556 (0.12803)*	-0.3167 (0.09228)*
Goodness of Fit				
System R^2	0.9441			

* Signifies statistical significance at the 5% level or beyond

Table 6.4 Covariances and Correlation Coefficients Estimated by SUR*

	Covariance	Correlation Coefficient
$\rho 1$ 2	360.33	0.97565
$\rho 1$ 3	-19.361	-0.05865
$\rho 1$ 4	179	0.86913
$\rho 2$ 3	-6.2672	-0.01982
$\rho 2$ 4	151.82	0.86098
$\rho 3$ 4	-0.94737	-0.00601

*Numbers 1 to 4 indicate equations for steer, heifer, bred heifer, and cull cow price, respectively

Table 6.5 Variable Costs Used In All Ranch Model Simulation Cases

Variable Name	Cost Per AUM ($)
Private Pasture Rental Rate	16.81
	Cost Per Cow Wintered ($)
Winter Feed	136.54
Bedding	2.24
Veterinary and Medicine	13.25
Trucking and Marketing Charges	15.96
Fuel	11.53
Repairs - Machine	18.21
Repairs - Corrals and Buildings	7.68
Utilities and Miscellaneous Expenses	16.39
Custom Work / Specialized Labour	6.16
Paid Labour and Benefits	6.14
Salaries	72.53
Taxes, Water Rates, License, and Insurance	8.42

Table 6.6 Comparison of Grazing Scenarios Imposed on the Model Ranch

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6*
Strategy	Sustainable Grazing	Overgrazing	Overgrazing	Rotational Grazing	Corridor Fencing	Rest-rotational Grazing
Initial pasture condition	Good	Good	Poor	Poor	Poor	Poor
Season 1 AU Upland/Riparian	445/91	579/118	312/64	243/43	243/25	182/32
Capital Costs beyond base (i.e. fencing)	No	None	None	$37,888	$19,262	$38,469
Increased Annual Maintenance Costs	No	No	No	Yes	Yes	Yes
Range Index Decision Points Upland/Riparian**	90/70	90/70	90/70	90/70	90/70	90/70
Rates % per season of Range Regeneration (Degradation) upland***	0	(0, 2, 4, 6, 8)	(0, 2, 4, 6, 8)	0, 2, 4, 6, 8	0, 2, 4, 6, 8	0,3,5,7,9/ 0,2,4,6,8
Rates % per season of Range Regeneration (Degradation) riparian***	0	(0, 1, 2, 3, 4)	(0, 1, 2, 3, 4)	0, 4, 8, 12, 16	0, 6, 10, 14, 18	0, 6, 10, 14, 18 /0,4,8,12,16

*For first eight seasons one-quarter of the range is rested each season. Starting in Season 9 all the range is used. Regeneration rates decrease after Season 8.
**Below weather index 90 upland or 70 riparian need to rent additional pasture. Amount rented depends on index this season and last season.
***Rate (%) used in any one season depends on range index that season.

6.5 Figures for Chapter 6

Figure 6.1 Hypothetical Pasture with Rest-Rotational Strategy (not to scale)

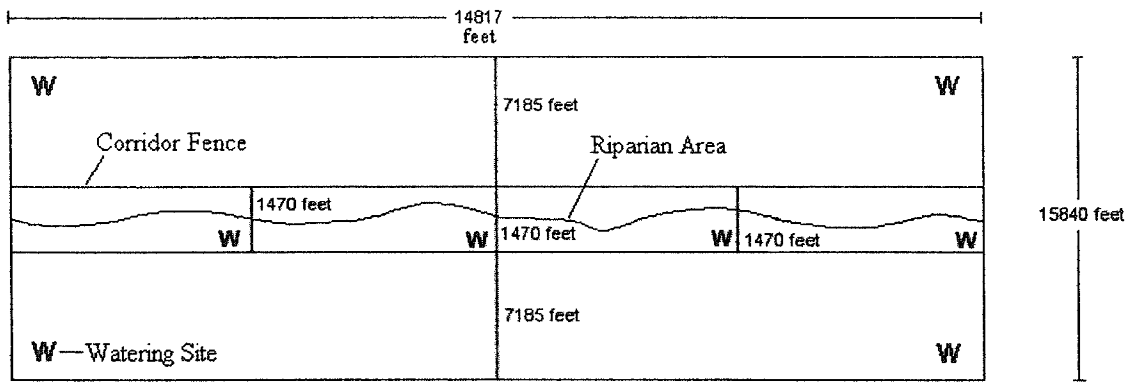


Figure 6.2 Base Case 1 with No Weather Risk

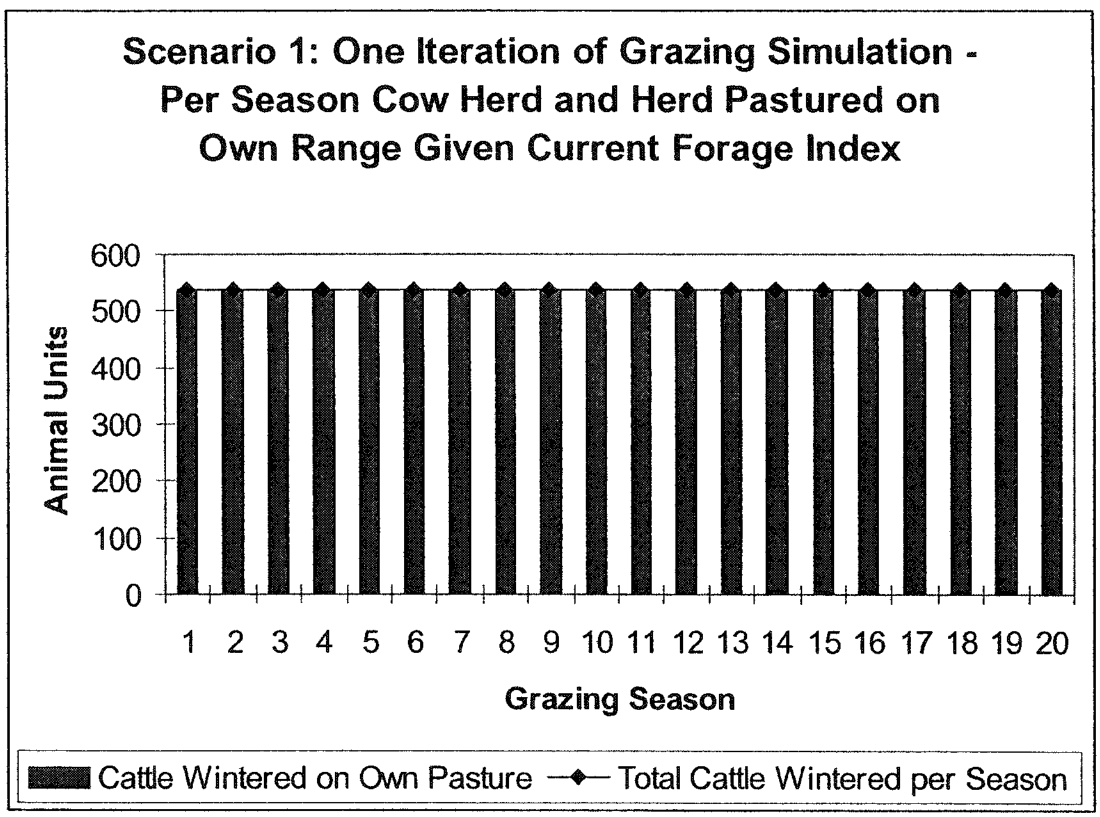


Figure 6.3 Base Case 1 with Weather Risk

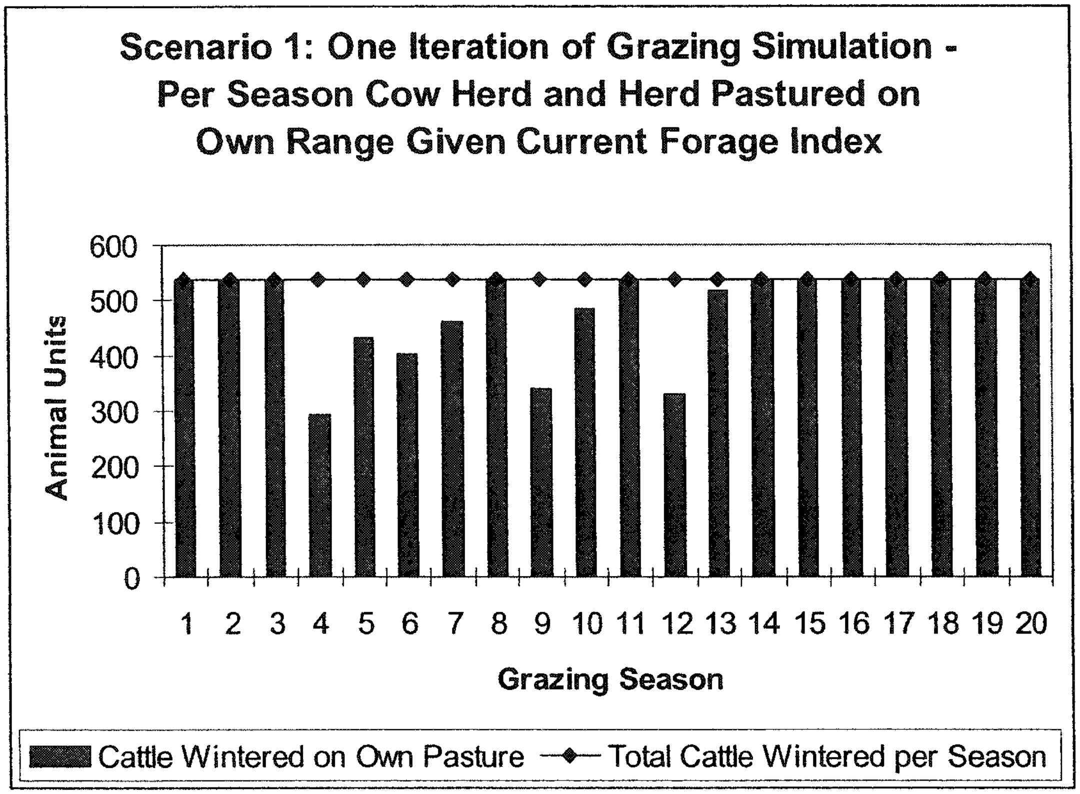


Figure 6.4 Case 2 with No Weather Risk

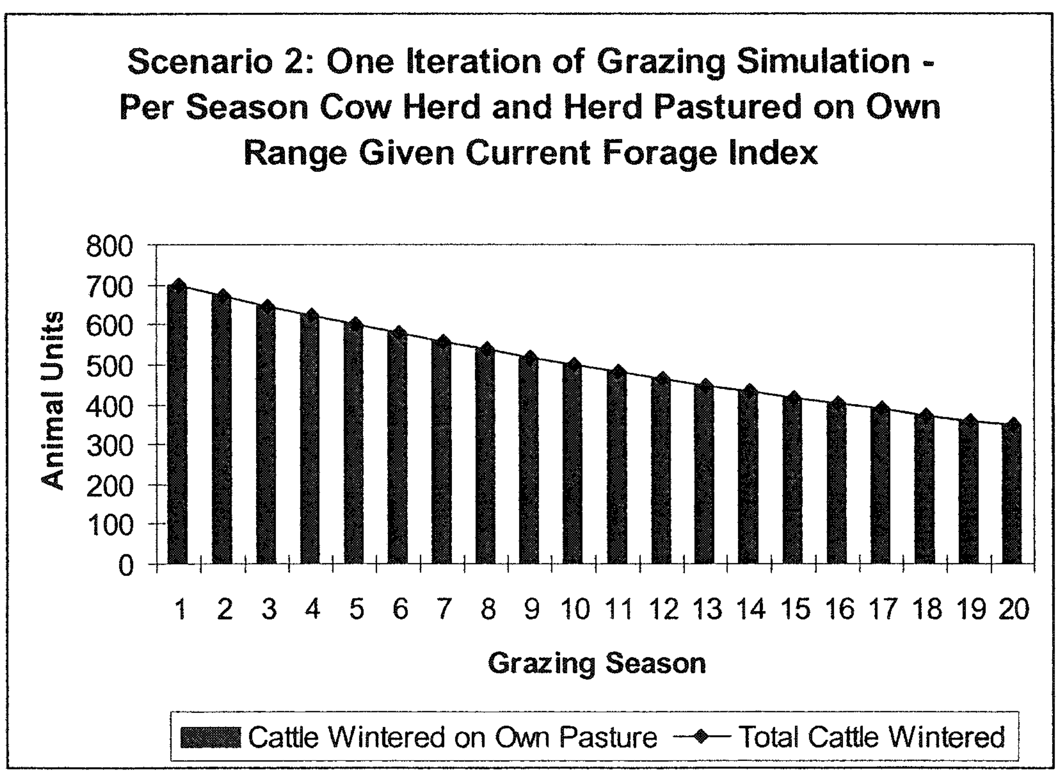
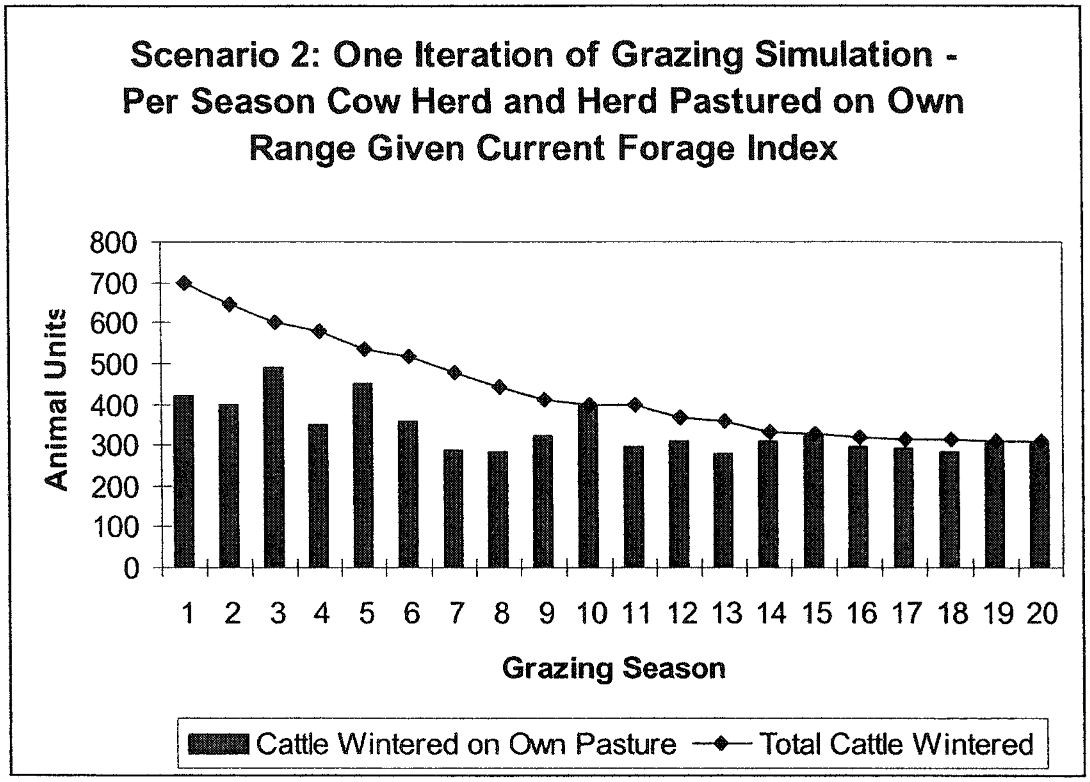


Figure 6.5 Case 2 with Weather Risk



Chapter 7

Stochastic Model Results

The following chapter presents results from the stochastic ranch model simulation, which was outlined in Chapter 6. It is arranged to present results from the comparison of Case 1 and Case 2 first, followed by a comparison of Case 3 vs. Cases 4, 5, and 6. Each comparison is broken down into mean results, and results over time. The comparisons are followed by a chapter summary.

NPV incorporates a measure of risk through the discount rate. In a Monte Carlo simulation, risk is explicitly added to the model. It is not clear how to interpret NPV in this situation. Therefore, reporting only the NPV value may not be appropriate. Instead of using NPV as the main indicator of financial well being, the results take into account the change of cash flows and stocking rates through time, as alternative means of evaluating the project.

7.1 Base Case 1 (Conservative Continuous Grazing from Good Condition) vs. Case 2 (Unsustainable Continuous Grazing from Good Condition)

7.1.1 *Mean and MIN/MAX Values*

Table 7.1 highlights some of the mean results of the stochastic analysis. The table compares all six cases, but this section will focus on Cases 1 and 2. These results provide a snapshot of the behaviour of certain variables in the initial and final grazing seasons being tracked by the stochastic simulation. For example, the uplands stocking rate in Season 1 had a mean value of 0.440 AUM/acre in Base Case 1. For Case 2 (overgrazing), which began at a stocking rate 30% higher than the sustainable rate, the mean was 0.568 AUM/acre. Season 20 upland stocking rates were 0.426 AUM/acre for Base Case 1, and 0.277 AUM/acre for Case 2. There are similar numbers reported for the riparian area.

According to the assumptions used, the pasture conditions of the conservative strategy remained relatively stable over time. Using the same assumptions (as well as price and weather values), pasture conditions in Case 2 would be degraded after 20 seasons of overgrazing. The values for number of cattle wintered showed similar trends (Table 7.1). For Base Case 1, cattle numbers remained constant, while those in Case 2 fell, as pasture conditions were degraded.

Table 7.1 also shows the differences in Net Cash between Season 1 and Season 20. For Base Case 1, the mean Season 1 Net Cash value was $159,743. For Case 2, it was $208,487. As noted above for stocking rates, the assumptions chosen led to a stable Net Cash value for Base Case 1, which had a mean Season 20 Net Cash value of $160,193. For Case 2, the assumed pasture quality degradation led to a mean Season 20 Net Cash value of $105,473. It is important to note that the Provisional NPV numbers reported in Table 7.1 are not directly comparable across the six cases. To make a comparison, the initial cow number for the cases being compared would have to be equal. This is discussed in a later section.

Though Table 7.1 focuses on mean results only, more detailed results for Cases 1 and 2 can be found in Tables 7.2 and 7.3. These tables include minimum and maximum values for each of the variables, as well as each variable's standard deviation from the mean. For example Case 1's maximum Season 1 Net Cash was $356,636, compared to $465,464 for Case 2's maximum. However, Case 2 had lower minimum Net Cash values than the Base Case. Minimum and maximum values showed similar trends in stocking rate variables.

Another variable tracked in Tables 7.1, 7.2, and 7.3 was a simple perpetuity on the net cash variable in Season 20 used to capture the value of cash flows beyond year 20. For the Base Case, in which pasture condition was assumed to remain relatively stable, the perpetuity calculation was based on all 20 grazing seasons on each iteration of the simulation. In Case 2, which assumed a pasture condition which diminished over time, the calculation of the perpetuity was based on the last 5 years of grazing of each iteration, to give a better representation of future net cash value arising from decreased grazing capacity.

In Table 7.1, Base Case 1's mean perpetuity was $1,607,229. Based on the last 5 years of grazing, Case 2 reported a mean perpetuity value of $1,149,980. With the assumption of diminished grazing capacity over 20 years, it was expected that the perpetuity for Case 2 would be lower, as it tracked the last 5 years of grazing. The perpetuity represents the value of the ranch cash flows beyond year 20. The Base Case 1 cash flows are much more valuable at this point in time.

7.1.2 *Comparisons of Case 1 and Case 2 Through Time*

Though mean, minimum, and maximum values of Tables 7.1, 7.2, and 7.3 are simple methods for analyzing differences between Case 1 and Case 2, the stochastic simulation model allowed a chance to see the differences between the two cases over time. The simulation model compared 5,000 iterations of the whole ranch. For Case 1 and Case 2, differences between the Net Cash, Upland Stocking Rates, and Riparian Stocking Rates were tracked. That is, the simulations computed a value for Case 1 Net Cash – Case 2 Net Cash, and so on, for each of 5,000 iterations. The difference represents the "better" grazing strategy (no pasture degradation) minus the "lesser" grazing strategy (pasture degradation over time).

Figures 7.1 and 7.2 graphically portray the differences in net cash over the 20 grazing seasons, for Base Case 1 minus Case 2. Figure 7.1 shows the percentage of times that Case 1 net cash equaled or exceeded Case 2 net cash. Case 1 net cash did not exceed that for Case 2 for the first six seasons. From grazing season 7 onward, Case 1 equaled or exceeded Case 2 at least some of the time. After Grazing season 15, Case 1 net cash equaled or exceeded Case 2 net cash at least 90% of the time through to Grazing season 20. The more favorable financial results of Case 1 in the later time seasons were expected, as pasture quality is assumed to degrade over time in Case 2.

Figure 7.2 tracks the mean net cash difference through time between Case 1 and Case 2. The mean difference for each season is given, as well as the 90% confidence interval from the Monte Carlo simulation. This figure shows the steady increase in the difference between net cash values. The slight decrease in net cash difference between Season 1 and Season 2 was attributed to the permanent herd reduction in Seasons 1 and 2. In Season 1, there is no permanent herd reduction, as this is the first season of grazing (though the ranch existed previously, a reduction in the number of animals grazed based on the season before was not modeled).

Total Cash Inflow for Season 1 is based on steer calves, heifer calves, and cull cows sold. In Season 2, there is a Case 2 herd reduction due to pasture degradation. The "reduced" cattle are sold as cull cows, increasing the Total Cash Inflow for the season. Hence, the decrease in net cash difference between Case 1 and 2. After Season 2, with the exception of years with very good forage growth (forage yield index > 130), there is always some permanent herd reduction.

The line graph tracking net cash difference over time between Case 1 and Case 2 shows the mean, bounded by a 90% confidence interval. The Monte Carlo simulation in @RISK gives values at the 5% confidence level and 95% confidence level. The differences between these values and the mean give upper and lower bounds for the 90% confidence interval (absolute value of difference is used). We can be 90% confident that the next difference value chosen by the Monte Carlo simulation will fall within these bounds.

7.1.2.1 Comparison of Case 1 Stocking Rate to Case 2 Stocking Rate

As in the case of the net cash comparisons, results from stocking rate differences over twenty years of grazing were also compared. Figures 7.3 and 7.4 show the uplands stocking rate (in AUM/acre) of Case 1 compared to that for Case 2. Figure 7.3 shows the percentage of times Case 1 uplands stocking rate equaled or exceeded Case 2 uplands stocking rate over 5000 ranch iterations. For the first two seasons, Case 1 did not exceed Case 2. From Season 3 onward, a percentage of Case 1 upland stocking rates equaled or exceeded Case 2 upland stocking rates. From Season 8 through to Season 20, at least 85 percent of Case 1's upland stocking rates were above those of Case 2.

Figure 7.4 shows the mean differences in upland stocking rates over time [as well as the 90% confidence interval above and below the mean for each season]. Gradually, Case 1's stocking rate equals or exceeds that of Case 2. As in the net cash comparison, the assumed degradation of Case 2 leads to lower values, as fewer animal units can be grazed on degraded pasture. At the same time, the assumed conservative grazing of Base Case 1 meant that the pasture could be grazed at a relatively stable rate throughout the 20 grazing seasons. From Season 10 onward, the lower bound of the 90% confidence interval is zero. This is due to the minimum stocking rate (0.273 AUM/acre) chosen for upland and riparian pasture. When the lower bound is zero, both cases have hit this minimum stocking rate.

This riparian stocking rate comparison was conducted in the same manner as the previous one, except focusing on riparian area stocking rates. Figure 7.5 shows the percentage of times that Case 1 riparian area stocking rate equaled or exceeded Case 2 riparian area stocking rate over 5,000 ranch iterations. The Base Case 1 stocking rate did not equal or exceed Case 2's rate as quickly as in the uplands case. This was attributed to the slower degeneration rate of the riparian area, and higher initial Case 2 stocking rate. Figure 7.6 shows an almost linear increase in the mean stocking rate difference between Case 1 and Case 2.

7.1.3 *Comparison of New NPV Difference Values (adjusted for equal initial cow number)*

As mentioned previously, provisional NPV values were not comparable across all six cases. Each case began with a different number of cattle in Season 1. The stochastic simulation included a variable that tracked the difference in provisional NPV between relevant cases. An adjustment to equate the initial cattle number of the cases being compared was applied. In this manner, a difference value was created that showed how much the NPVs of the cases would differ, had they started with the same initial cow number.

Assume that the ranchers in Case 1 and Case 2 both have a Season 1 herd size equivalent to the Season 1 herd size in Case 2 (Table 6.6). However, the rancher in Case 1 makes the decision to reduce the grazing pressure on the ranch and run a long-run sustainable grazing program. Thus the Case 1 rancher sells part of the herd in Season 1 to reach a sustainable level. The rancher in Case 2 continues to graze at a higher intensity. Through time, he or she is gradually forced to reduce the herd size as the ranch grazing capacity decreases.

The initial sale of the cows in Case 1, sold as cull cows at the price generated in Season 1, is used to generate the New NPV Difference. In the comparison of Base Case 1 and Case 2, the mean New NPV difference (Case 1 – Case 2) was $37,652. The positive value means that Case 1 New NPV exceeded that for Case 2. When tracked over time, it was found that Base Case 1's New NPV was equal to or greater than that for Case 2 at least 65% of the time.

7.2 Case 3 vs. Cases 4, 5, and 6

7.2.1 *Mean and MIN / MAX Values*

Case 3, continuous unsustainable grazing from poor condition was compared to the "regenerative" strategies in Case 4 (rotational grazing from poor condition), Case 5 (corridor fencing from poor condition), and Case 6 (rest-rotational grazing from poor condition). It was assumed that Case 3 pasture condition would degrade over the 20 grazing seasons. For Cases 4, 5, and 6, it was assumed that their grazing strategies would promote regeneration of forage resources (Table 6.6).

Mean values for all six cases can be found in Table 7.1. Stocking rates can be used as an example of differences between the strategies. The mean stocking rate for Case 3 in Season 1 was 0.325 AUM/acre. For Cases 4, 5, and 6, the mean stocking rates were all 0.273 AUM/acre. After 20 grazing seasons, the mean stocking rate for Case 3 was 0.273 AUM/acre. For Cases 4, 5, and 6, the mean stocking rates at Season 20 were 0.368 AUM/acre, 0.368 AUM/acre, and 0.381 AUM/acre, respectively. Trends for other mean variables were quite similar, with regenerative strategies posting higher Season 20 values.

Detailed results for Cases 3, 4, 5, and 6 can be found in Tables 7.4, 7.5, 7.6, and 7.7. These results include maximum and minimum values, as well as standard deviation for each variable. Maximum values for the regenerative cases tend to be higher than those for Case 3. Case 3 minimum values can sometimes exceed the minimum values for regenerative cases. As in the comparison of Case 1 and Case 2, there are combinations of certain price and weather conditions that make an overgrazing scenario appear attractive to a rancher.

Perpetuity values for Cases 3 to 6 can be found in the last row of Table 7.1. Perpetuities for all cases from 3 to 6 were based on the last five years of grazing. The three regenerative strategies all recorded higher perpetuity values than Case 3. This was expected, given the assumption that Case 3's pasture conditions would degrade over a twenty-year season. That is, the regenerative cases are more valuable after 20 years of managed grazing, while the overgrazing case is less valuable at this point in time.

7.2.2 *Comparison of Case 3 to Cases 4, 5, and 6 Through Time*

7.2.2.1 Case 3 vs. Case 4

As in section 7.1.2, the stochastic simulation model compared the differences between different cases over time. Figure 7.7 shows the percentage of times that Case 4 Net Cash equaled or exceeded Case 3 Net Cash over 5,000 iterations of the ranch. Figure 7.8 shows a similar trend in the mean difference values over time. The drop between Season 1 and Season 2 was explained in the previous comparison (section 7.1.2)

Figure 7.9 shows the percentage of times Case 4 uplands stocking rate equaled or exceeded that of Case 3 over 5,000 iterations of the ranch. Case 4's uplands stocking rate equaled or exceeded the stocking rate of Case 3 at least some of the time in each grazing season. Since the model would not allow grazing to fall below 0.273 AUM/acre, it could be assumed that in the early seasons, the stocking rates were equal at this level of grazing. Figure 7.10 shows the gradual increase in the mean uplands stocking rate difference between these two cases. Similar results for the riparian area are shown in Figures 7.11 and 7.12. Based on regeneration assumptions, the riparian area of Case 4 recovered faster than the uplands pasture of the same case.

7.2.2.2 Case 3 vs. Case 5

Figure 7.13 shows the percentage of times that Case 5 net cash equals or exceeds Case 3 net cash. This net cash comparison showed almost the same results as the previous comparison. For the first 7 seasons, the regenerative strategy's net cash did not equal or exceed Case 3's. After this point, it rises to exceed it at least 95% of the time by Season 20. Figure 7.14 shows the mean net cash difference increase to be almost the same as that for Case 3 vs. Case 4. The uplands of Case 5 regenerate at approximately the same rate as those in Case 4, gradually equaling or exceeding Case 3's upland stocking rates (Figures 7.15 and 7.16).

It takes about ten grazing seasons before there is a noticeable difference between Case 3 and Case 5 riparian stocking rates (Figure 7.17). The graph in 7.18 shows the difference remaining in the negative (i.e., Case 3 stocking rate exceeds Case 5) for a longer season than that for Case 4. This result was due to the much lower initial carrying capacity, and light grazing of the riparian area in earlier seasons.

7.2.2.3 Case 3 vs. Case 6

Figures 7.19 and 7.20 compare the differences between Case 3 and Case 6 net cash. The results are similar to the comparisons between Case 4 and Case 3 except for the sharp drop in Season 9's net cash difference (Figure 7.20). This drop was attributed to the fact that this was the season in which rest-rotational grazing was replaced by regular rotational grazing. An additional one quarter of total grazing area of the ranch was made available, resulting in the purchase of at least 25% more bred heifers to the herd in one season. This greatly reduced the net cash value for Case 6 in this grazing season. The net cash value "caught up" to the new herd size in the next season, when the calves of the newly added bred heifers were sold. The uplands regenerated at a rate similar to that of Case 4 (Figures 7.21 and 7.22). The riparian area regenerated at a faster rate than that of Case 4 (Figures 7.23 and 7.24).

7.2.3 *Comparison of New NPV Difference Values (adjusted for equal initial cow number)*

It was assumed that the ranchers in Cases 3, 4, 5, and 6 have Season 1 herd sizes equivalent to the Season 1 herd size in Case 3 (Table 6.6). The upland and riparian pastures in each case are in poor condition, due to previous overgrazing. The ranchers in these cases must make decisions concerning the grazing methods they will use. The rancher in Case 3 continues to graze at an unsustainable intensity. Through time, he or she is gradually forced to reduce the herd size as the ranch grazing capacity decreases.

The rancher in Case 4 makes the decision to use a simple rotational grazing program, in order to restore lost grazing capacity. The rancher in Case 5 fences off the riparian corridor, and lightly grazes it, until it has regenerated enough to support more cattle. The rancher rotates cattle between the upland pastures. The rancher in Case 6 takes the Case 4 strategy one step further, resting one quarter of the pasture (no grazing) each year, for eight years. He or she then returns to regular rotational grazing (as in Case 4). Cases 4 through 6 sell down the herd in Season 1 to reach a sustainable level.

For Case 3 vs. Case 4, it was found that mean New NPV difference would be -$9,800 (Table 7.8). That is, at means, Case 3's New NPV (adjusted for equal initial cow number) would slightly exceed that for Case 4. It was found that Case 4's New NPV would equal or exceed that of Case 3 at least 40% of the time (over 5,000 ranch iterations). For Case 3 vs. Case 5, the mean New NPV difference was found to be $10,163 (Case 5 exceeds Case 3 at means). Case 5's New NPV was found to equal or exceed Case 3's at least 55% of the time. For Case 3 vs. Case 6, the mean New NPV difference was found to be -$96,402 (Case 3 exceeds Case 6 at means). Case 6's New NPV was not found to equal or exceed Case 3's. The large difference in New NPVs in this case could be attributed to the restriction of grazing to 75% of the available pasture in the first eight seasons of Case 6.

7.2.4 *Alternative Scenarios*

7.2.4.1 Sensitivity to Price Expectations

The stochastic simulation model allowed for the exploration of alternative economic and ecological scenarios. Prices in the initial grazing season may be high or low relative to the long-run mean price. The impact of a rancher's short-term price expectation was evaluated using the simulation model. Prices for steers and heifers were increased by $30/cwt (price up) or decreased by $30/cwt (price down) in Season 0. The price model, with no further "shocks" will revert to the expected price. Thus the impact of these time 0 prices decreases in future seasons. Results of the New NPV Difference (including an adjustment for starting cow herd numbers) for initial prices up and initial prices down are reported in Tables 7.9 and 7.10, respectively. The net difference illustrates the impact of higher initial price expectations.

The mean New NPV Difference between Scenario 1 less Scenario 2 is $28,936 when initial prices are high. When initial prices are low, the adjusted NPV price difference is $44,070. Similar results are reported for the other strategies. Figures 7.25 to 7.32 graphically portray the Net Cash Differences between the cases when initial prices are high. These can be contrasted with Figures 7.33 to 7.40, which portray Net Cash Differences between the cases when initial prices are low. The mean initial net cash difference (Season 1) is lower when the initial calf prices are high, and higher when initial prices are lower.

As with New NPV Differences, the initial price up cases favour overgrazing strategies, while the initial price down cases favour conservative and regenerative strategies. Lower initial prices reduce the opportunity costs of adopting conservative grazing strategies. However, one caveat is that while the opportunity costs may be lower with lower prices, a rancher may still consider minimum cash flow requirements for debt payments or family living before adopting these strategies.

7.2.4.2 Economic Contribution of Riparian Areas

Expert opinion claimed that one of the benefits of having riparian areas in a cattle operation is the ability to buffer ranch grazing when dry weather reduces forage production on upland range. The forage indices used in the simulation determined when to reduce the stocking rate based upon the current season forage index. A lower cutoff implies a greater buffering capacity. The Base Case 1 conservative grazing strategy can be used to provide a value of the drought buffering capacity of riparian areas. The riparian forage index cutoff was varied from 90 to 50 and the resulting NPV compared to Base Case 1 with the riparian forage index always set to the uplands cutoff index of 90.

The results are found in Table 7.11. A 500-acre riparian area able to withstand forage indices up to one-half of the average index for the upland area has a net present value of $8,083. This value includes only the buffering capacity and specifically excludes the extra value a riparian area adds to a ranch due to its higher stocking rate (i.e. about double the AUM/acre based on uplands). The value of the riparian area buffering declines as the buffering ability declines (i.e. the riparian cut-off index increases).

7.2.4.3 Sensitivity to Degeneration/Regeneration Rates

Sensitivity analysis was also performed to test the effects of changes in degeneration and regeneration rates. Degeneration rates were increased (faster degeneration) by 2% and 4% in Case 2, and compared to the original Base Case 1. In Cases 4, 5, and 6, regeneration rates were decreased by 2% and 4% (slower regeneration), and compared to the original Case 3.

When degeneration rates were increased in Case 2, the mean 20-season degeneration rates increased (Table 7.12). Stocking rate differences between Base Case 1 and Case 2 for Season 20 increased as degeneration rates increased (lower Case 2 stocking rates for Season 20). As well, the New (adjusted) NPV difference increased as degeneration rates increased (Case 2 NPV lower relative to Base Case 1).

When regeneration rates were decreased in Cases 4, 5, and 6, 20-season mean regeneration rates also decreased (except on Case 6's riparian area, where the rate remained the same) (Table 7.13). The number of AU grazed on a rancher's own pasture fell as regeneration rates were decreased. Stocking rate differences in Season 20 between regenerative cases (4, 5, and 6) and Case 3 decreased as regeneration rates decreased (fewer AUM/acre in Cases 4, 5, and 6 by Season 20). The New NPV difference followed the same trend, decreasing as regeneration rates decreased. The above results show that the stochastic simulation model is sensitive to changes in degeneration and regeneration rates. These rates are important factors driving the results from this model.

7.3 Chapter Summary - Overall Stochastic Model Results

Case 1 and Case 2 were compared as a single simulation. The Base Case, with an assumed conservative grazing strategy, and little pasture degradation had higher mean net cash and stocking rate values. However, the results suggested that certain combinations of favorable weather and price conditions could make overgrazing more attractive to ranchers. Though the higher stocking rates (and hence, cow number) of Case 2 pushed net cash values higher at first, the assumed degradation of the pasture meant that the value fell over time. The conservative strategy of Case 1 maintained a relatively constant cow number through 20 grazing seasons, and hence, a relatively constant cash inflow. It would be up to the producer whether or not he or she wants high returns in the early seasons, or a steady and consistent return over the life of the ranch. The rancher's personal minimum cash flow requirements could play a role in making this decision.

Case 3, overgrazing from poor condition, was compared to three strategies that assumed a regeneration of range health over time. When Net Cash differences for Case 3, 4, 5, and 6 were compared, it was found that regenerative strategies of Cases 4, 5, and 6 eventually had higher values than Case 3. Case 5, Corridor Fencing, recorded the slowest riparian regeneration times. This was due to its seriously degraded Season 1 pasture condition, and light grazing in the early seasons. The assumed regeneration times for Case 6 resulted in the quickest riparian regeneration strategy.

On average, the overgrazing strategy is preferred in terms of financial return when the range is already in poor condition. In the overgrazing case, range condition is assumed to deteriorate, reducing grazing capacity as it falls. If a rancher wants long-term sustainability (healthy range after 20 grazing seasons), the assumed regeneration of forage resources in the regenerative strategies may be preferred. However, the regenerative strategies sell down the herd in the initial seasons, seriously reducing financial return. A rancher may need more financial incentive to adopt a regenerative grazing strategy.

Analysis of changes in initial price levels shows that overgrazing strategies are favoured when prices are initially high. Conservative or regenerative strategies are favoured when prices are low. An analysis of riparian area buffering capability showed that the value of the riparian area increases as the buffering ability increases (i.e. the riparian cut-off index decreases relative to the upland cut-off index). Sensitivity analysis showed that the stochastic simulation model is sensitive to changes in degeneration and regeneration rates.

7.4 Tables for Chapter 7

Table 7.1 Comparison of Mean Results Across All Scenarios

	Base Case 1: Sustainable Continuous Grazing (from good condition)	Case 2: Unsust. Continuous Grazing (from Good Condition)	Case 3: Unsust. Continuous Grazing (from Poor Condition)	Case 4: Rotational Grazing (from Poor Condition)	Case 5: Corridor Fencing (from Poor Condition)	Case 6: Rest Rotation Grazing (from Poor Condition)
	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
Provisional NPV	$1,606,108	$1,690,397	$1,018,002	$940,847	$947,188	$800,513
Season 1 AUM/Acre Uplands	0.440	0.568	0.325	0.273	0.273	0.273
Season 20 AUM/Acre Uplands	0.426	0.277	0.273	0.368	0.368	0.381
20-Season Average AUM/Acre Uplands	0.426	0.378	0.280	0.306	0.306	0.313
Season 1 AUM/Acre Riparian Area	0.896	1.165	0.628	0.426	0.273	0.426
Season 20 AUM/Acre Riparian Area	0.864	0.710	0.389	0.861	0.758	0.862
20-Season Average AUM/Acre Riparian Area	0.866	0.905	0.490	0.687	0.457	0.710
Season 1 Cattle (AU) Wintered	536	697	375	286	268	215
Season 20 Cattle (AU) Wintered	536	324	283	469	458	484
20-Season Average Cattle (AU) Wintered	536	476	305	364	339	346
Season 1 Total Cash Inflow	$367,844	$479,477	$257,741	$196,507	$184,413	$147,437
Season 20 Total Cash Inflow	$369,820	$228,726	$196,608	$324,158	$315,094	$334,423
20-Season Average Total Cash Inflow	$370,271	$343,189	$214,405	$252,041	$233,807	$239,502
Season 1 Total Cash Outflow	$208,101	$270,991	$144,215	$109,123	$101,675	$82,317
Season 20 Total Cash Outflow	$209,627	$123,253	$107,368	$196,365	$177,154	$201,338
20-Season Average Total Cash Outflow	$209,548	$183,824	$115,873	$151,856	$134,374	$150,394
Season 1 Net Cash	$159,743	$208,487	$113,526	$87,384	$82,738	$65,120
Season 20 Net Cash	$160,193	$105,473	$89,240	$127,793	$137,940	$133,085
Perpetuity	$1,607,229	$1,140,980	$899,146	$1,209,520	$1,269,656	$1,259,999

Table 7.2 Results for Base Case 1 Conservative Grazing

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$548,981	$2,729,322	$1,606,108	272,911
Season 1 AUM/Acre Uplands	0.273	0.500	0.440	0.088
Season 20 AUM/Acre Uplands	0.273	0.500	0.426	0.084
20-Season Average AUM/Acre Uplands	0.341	0.500	0.426	0.023
Season 1 AUM/Acre Riparian Area	0.411	1.000	0.896	0.188
Season 20 AUM/Acre Riparian Area	0.411	1.000	0.864	0.188
20-Season Average AUM/Acre Riparian Area	0.677	1.000	0.866	0.052
Season 1 Cattle (AU) Wintered	536	536	536	0
Season 20 Cattle (AU) Wintered	536	536	536	0
20-Season Average Cattle (AU) Wintered	536	536	536	0
Season 1 Total Cash Inflow	$162,727	$572,395	$367,844	56,978
Season 20 Total Cash Inflow	$92,354	$608,401	$369,820	71,673
20-Season Average Total Cash Inflow	$271,461	$480,723	$370,271	25,379
Season 1 Total Cash Outflow	$195,935	$230,947	$208,101	8,857
Season 20 Total Cash Outflow	$195,109	$232,753	$209,627	8,765
20-Season Average Total Cash Outflow	$201,452	$218,655	$209,548	2,387
Season 1 Net Cash	-$41,127	$356,636	$159,743	57,585
Season 20 Net Cash	-$109,908	$401,020	$160,193	72,209
Perpetuity (20 Years of Grazing)	$578,532	$2,681,203	$1,607,229	255,091

Table 7.3 Results for Case 2 Overgrazing from Good Condition

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$677,466	$2,693,344	$1,690,397	278,185
Season 1 AUM/Acre Uplands	0.273	0.650	0.568	0.124
Season 20 AUM/Acre Uplands	0.273	0.414	0.277	0.013
20-Season Average AUM/Acre Uplands	0.290	0.521	0.378	0.034
Season 1 AUM/Acre Riparian Area	0.534	1.300	1.165	0.245
Season 20 AUM/Acre Riparian Area	0.299	1.040	0.710	0.163
20-Season Average AUM/Acre Riparian Area	0.619	1.145	0.905	0.077
Season 1 Cattle (AU) Wintered	697	697	697	0
Season 20 Cattle (AU) Wintered	302	463	324	18
20-Season Average Cattle (AU) Wintered	414	582	476	25
Season 1 Total Cash Inflow	$212,087	$746,029	$479,477	74,288
Season 20 Total Cash Inflow	$62,688	$435,200	$228,726	46,616
20-Season Average Total Cash Inflow	$232,171	$471,335	$343,189	28,832
Season 1 Total Cash Outflow	$254,789	$305,522	$270,991	12,328
Season 20 Total Cash Outflow	$112,147	$181,553	$123,253	7556
20-Season Average Total Cash Outflow	$163,783	$221,655	$183,824	8,833
Season 1 Net Cash	-$53,000	$465,464	$208,487	75,180
Season 20 Net Cash	-$57,118	$285,698	$105,473	44,924
Perpetuity (Last 5 Years of Grazing)	$83,570	$2,446,997	$1,140,980	323,365

Table 7.4 Results for Case 3 Overgrazing from Poor Condition

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$530,467	$1,560,382	$1,018,002	138,492
Season 1 AUM/Acre Uplands	0.273	0.350	0.325	0.035
Season 20 AUM/Acre Uplands	0.273	0.273	0.273	0.000
20-Season Average AUM/Acre Uplands	0.273	0.301	0.280	0.005
Season 1 AUM/Acre Riparian Area	0.288	0.700	0.628	0.132
Season 20 AUM/Acre Riparian Area	0.273	0.584	0.389	0.075
20- Season Average AUM/Acre Riparian Area	0.351	0.630	0.490	0.040
Season 1 Cattle (AU) Wintered	375	375	375	0
Season 20 Cattle (AU) Wintered	276	296	283	3
20-Season Average Cattle (AU) Wintered	296	328	305	4
Season 1 Total Cash Inflow	$108,584	$398,107	$257,741	39,718
Season 20 Total Cash Inflow	$191,025	$206,689	$196,608	1,911
20-Season Average Total Cash Inflow	$176,454	$264,532	$214,405	11,700
Season 1 Total Cash Outflow	$137,196	$154,308	$144,215	4,055
Season 20 Total Cash Outflow	$104,101	$112,044	$107,368	1,165
20-Season Average Total Cash Outflow	$112,665	$124,177	$115,873	1,516
Season 1 Net Cash	-$39,646	$257,131	$113,526	40,034
Season 20 Net Cash	$85,592	$95,036	$89,240	1,194
Perpetuity (Last 5 Years of Grazing)	$854,578	$949,739	$899,146	12,655

Table 7.5 Results for Case 4 Rotational Grazing from Poor Condition

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$505,351	$1,474,127	$940,847	133,984
Season 1 AUM/Acre Uplands	0.273	0.273	0.273	0.000
Season 20 AUM/Acre Uplands	0.273	0.500	0.368	0.074
20-Season Average AUM/Acre Uplands	0.273	0.392	0.306	0.019
Season 1 AUM/Acre Riparian Area	0.273	0.469	0.426	0.077
Season 20 AUM/Acre Riparian Area	0.353	1.000	0.861	0.192
20-Season Average AUM/Acre Riparian Area	0.428	0.877	0.687	0.074
Season 1 Cattle (AU) Wintered	286	286	286	0
Season 20 Cattle (AU) Wintered	317	536	469	42
20-Season Average Cattle (AU) Wintered	299	441	364	24
Season 1 Total Cash Inflow	$82,787	$303,518	$196,507	30,279
Season 20 Total Cash Inflow	$218,395	$372,710	$324,158	28,806
20-Season Average Total Cash Inflow	$178,058	$326,340	$252,041	20,256
Season 1 Total Cash Outflow	$105,407	$112,967	$109,123	1173
Season 20 Total Cash Outflow	$120,473	$264,362	$196,365	22,261
20-Season Average Total Cash Outflow	$116,996	$187,275	$151,856	11,561
Season 1 Net Cash	-$26,103	$195,228	$87,384	30,345
Season 20 Net Cash	$69,932	$169,480	$127,793	16,574
Perpetuity (Last 5 Years of Grazing)	$839,195	$1,694,200	$1,209,520	116,827

Table 7.6 Results for Case 5 Corridor Fencing from Poor Condition

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$514,122	$1,450,841	$947,188	130,260
Season 1 AUM/Acre Uplands	0.273	0.273	0.273	0.000
Season 20 AUM/Acre Uplands	0.273	0.500	0.368	0.074
20-Season Average AUM/Acre Uplands	0.273	0.392	0.306	0.019
Season 1 AUM/Acre Riparian Area	0.273	0.273	0.273	0.000
Season 20 AUM/Acre Riparian Area	0.273	1.000	0.758	0.212
20-Season Average AUM/Acre Riparian Area	0.283	0.703	0.457	0.077
Season 1 Cattle (AU) Wintered	268	268	268	0
Season 20 Cattle (AU) Wintered	290	536	458	53
20-Season Average Cattle (AU) Wintered	275	426	339	26
Season 1 Total Cash Inflow	$77,690	$284,855	$184,413	28,424
Season 20 Total Cash Inflow	$200,128	$372,710	$315,094	36,397
20-Season Average Total Cash Inflow	$163,214	$311,290	$233,807	21,025
Season 1 Total Cash Outflow	$98,531	$105,055	$101,675	912
Season 20 Total Cash Outflow	$107,025	$243,181	$177,154	30,478
20-Season Average Total Cash Outflow	$104,587	$172,718	$134,374	12,152
Season 1 Net Cash	-$22,978	$183,622	$82,738	28,474
Season 20 Net Cash	$64,982	$228,585	$137,940	28,983
Perpetuity (Last 5 Years of Grazing)	$767,938	$1,993,026	$1,269,656	191,691

Table 7.7 Results for Case 6 Rest-Rotational Grazing from Poor Condition

Variable Name	Minimum	Maximum	Mean	Std Deviation
Provisional NPV	$411,472	$1,242,556	$800,513	114,935
Season 1 AUM/Acre Uplands	0.273	0.273	0.273	0.000
Season 20 AUM/Acre Uplands	0.273	0.500	0.381	0.079
20-Season Average AUM/Acre Uplands	0.273	0.402	0.313	0.022
Season 1 AUM/Acre Riparian Area	0.273	0.469	0.426	0.077
Season 20 AUM/Acre Riparian Area	0.373	1.000	0.862	0.191
20- Season Average AUM/Acre Riparian Area	0.446	0.892	0.710	0.073
Season 1 Cattle (AU) Wintered	215	215	215	0
Season 20 Cattle (AU) Wintered	332	536	484	41
20- Season Average Cattle (AU) Wintered	274	417	346	25
Season 1 Total Cash Inflow	$62,117	$227,725	$147,437	22,715
Season 20 Total Cash Inflow	$228,953	$372,740	$334,423	28,211
20-Season Average Total Cash Inflow	$166,572	$306,361	$239,502	20,240
Season 1 Total Cash Outflow	$79,538	$85,149	$82,317	867
Season 20 Total Cash Outflow	$126,151	$265,340	$201,338	21,061
20-Season Average Total Cash Outflow	$110,816	$182,867	$150,394	12,023
Season 1 Net Cash	-$19,968	$146,019	$65,120	22,764
Season 20 Net Cash	$72,001	$169,465	$133,085	17,622
Perpetuity (Last 5 Years of Grazing)	$858,958	$1,694,054	$1,259,999	126,931

Table 7.8 New NPV Difference Results (Original Scenarios)

	Case 1 - 2	Case 4 - 3	Case 5 - 3	Case 6 - 3
Minimum	-$248,428	-$132,095	-$154,856	-$304,129
Maximum	$353,358	$161,710	$256,467	$176,335
Mean	$37,652	-$9,800	$10,163	-$96,402
Std Deviation	76,917	37,063	54,489	57,218
Percentage of Times Conservative or Regenerative New NPV Exceeds Degenerative New NPV	65	35	55	0

Table 7.9 New NPV Difference Results (Initial Price Up)

	Case 1 - 2	Case 4 - 3	Case 5 - 3	Case 6 - 3
Minimum	-$252,258	-$141,444	-$189,447	-$317,102
Maximum	$350,715	$112,377	$216,384	$113,447
Mean	$28,936	-$14,635	$4,774	-$105,525
Std Deviation	76,969	36,596	54,751	56,599
Percentage of Times Conservative or Regenerative New NPV Exceeds Degenerative New NPV	65	30	50	0

Table 7.10 New NPV Difference Results (Initial Price Down)

	Case 1 - 2	Case 4 - 3	Case 5 - 3	Case 6 - 3
Minimum	-$319,559	-$158,145	-$188,231	-$343,293
Maximum	$363,727	$155,329	$267,787	$151,852
Mean	$44,070	-$3,222	$17,952	-$84,771
Std Deviation	77,416	37,397	54,541	57,597
Percentage of Times Conservative or Regenerative New NPV Exceeds Degenerative New NPV	70	45	60	5

Table 7.11 Provisional NPV Differences with Varying Riparian Grazing Cut-offs*

	Case 1b (80) - Case 1a (90)	Case 1c (70) - Case 1a (90)	Case 1d (60) - Case 1a (90)	Case 1e (50) - Case 1a (90)
Minimum	-$2,046	-$1,920	-$1,519	-$1,244
Maximum	$2,068	$11,770	$22,813	$22,813
Mean	$90	$1,736	$6,852	$8,083
Std Deviation	396	1,766	3,436	3,693
% of Times Adjusted Case Equals or Exceeds Base Case	At least 85%	At least 90%	At least 95%	At least 95%

* Riparian Grazing Cut-offs represented by Forage Yield Indices in parentheses

Table 7.12 Sensitivity to Degradation Rate Increase (Case 2)

	Case 2
	MEAN
Original Deg Rate	
Mean Deg Rate (Upland)	4.78%
Mean Deg Rate (Riparian)	2.39%
Net Cash Diff (Case 1-2) Season 1	-$49,076
Net Cash Diff (Case 1-2) Season 20	$54,494
New NPV Diff (Case 1-2)*	$36,917
2% Deg Rate Increase	
Mean Deg Rate (Upland)	6.44%
Mean Deg Rate (Riparian)	4.05%
Net Cash Diff (Case 1-2) Season 1	-$49,076
Net Cash Diff (Case 1-2) Season 20	$65,422
New NPV Diff (Case 1-2)	$132,445
4% Deg Rate Increase	
Mean Deg Rate (Upland)	8.11%
Mean Deg Rate (Riparian)	5.71%
Net Cash Diff (Case 1-2) Season 1	-$49,076
Net Cash Diff (Case 1-2) Season 20	$70,072
New NPV Diff (Case 1-2)	$193,989

*$36,917 differs slightly from $37,652 in Table 7.8 since this was a separate simulation.

Table 7.13 Sensitivity to Regeneration Rate Decrease (Cases 4, 5, and 6)

	MEAN	MEAN	MEAN
Original Reg Rate	**Case 4**	**Case 5**	**Case 6**
Mean Reg Rate (Upland)	3.20%	3.19%	3.40%
Mean Reg Rate (Riparian)	4.18%	7.39%	4.21%
	Case 4 - 3	Case 5 - 3	Case 6 - 3
Net Cash Diff Season 1	-$26,102	-$30,921	-$48,487
Net Cash Diff Season 20	$38,679	$49,231	$43,768
New NPV Diff (Case 1-2)	-9,837	$10,047	-$96,344
2% Reg Rate Decrease	**Case 4**	**Case 5**	**Case 6**
Mean Reg Rate (Upland)	1.87%	1.85%	2.11%
Mean Reg Rate (Riparian)	4.04%	6.37%	4.13%
	Case 4 - 3	Case 5 - 3	Case 6 - 3
Net Cash Diff Season 1	-$26,102	-$30,921	-$48,487
Net Cash Diff Season 20	$20,207	$20,127	$24,538
New NPV Diff	-$54,047	-$63,081	-$141,755
4% Reg Rate Decrease	**Case 4**	**Case 5**	**Case 6**
Mean Reg Rate (Upland)	0.84%	0.83%	1.02%
Mean Reg Rate (Riparian)	3.49%	5.06%	3.77%
	Case 4 - 3	Case 5 - 3	Case 6 - 3
Net Cash Diff Season 1	-$26,102	-$30,921	-$48,487
Net Cash Diff Season 20	$9,078	$3,275	$11,928
New NPV Diff	-$76,832	-$98,866	-$170,844

7.5 Figures for Chapter 7

Figure 7.1 Comparison of Case 1 and Case 2 Net Cash

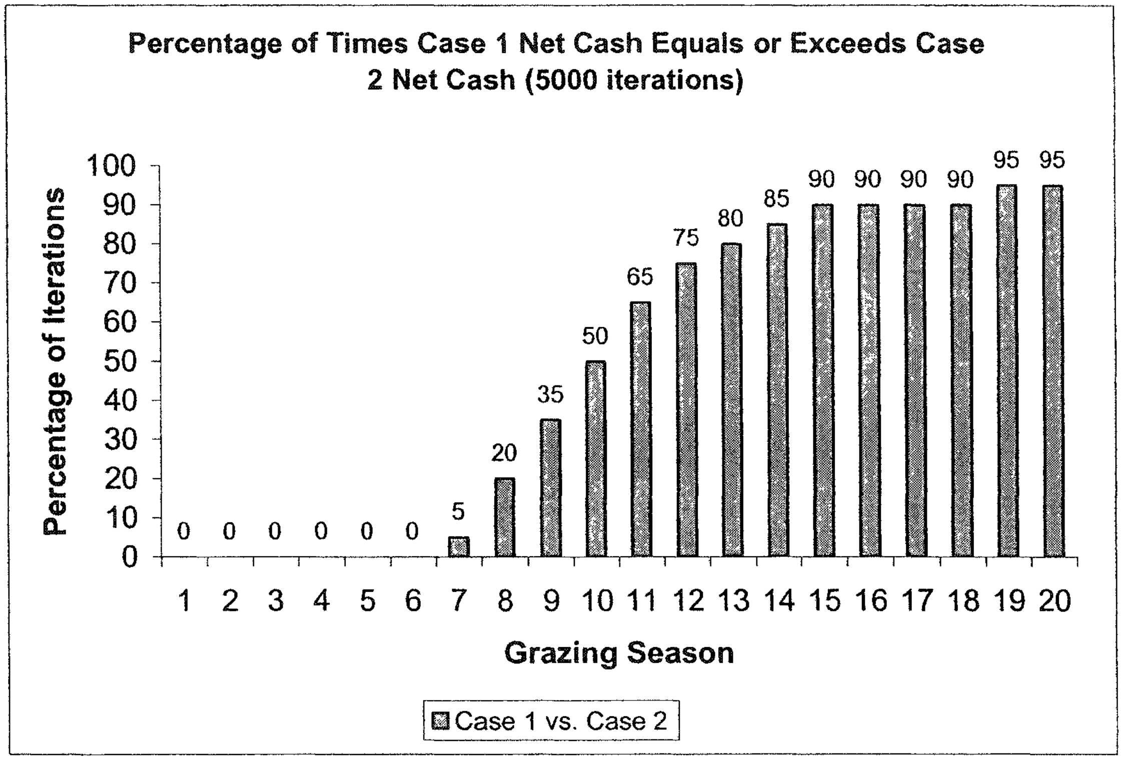


Figure 7.2 Net Cash Difference (Case 1 – Case 2) Over Time (90% CI Bound)

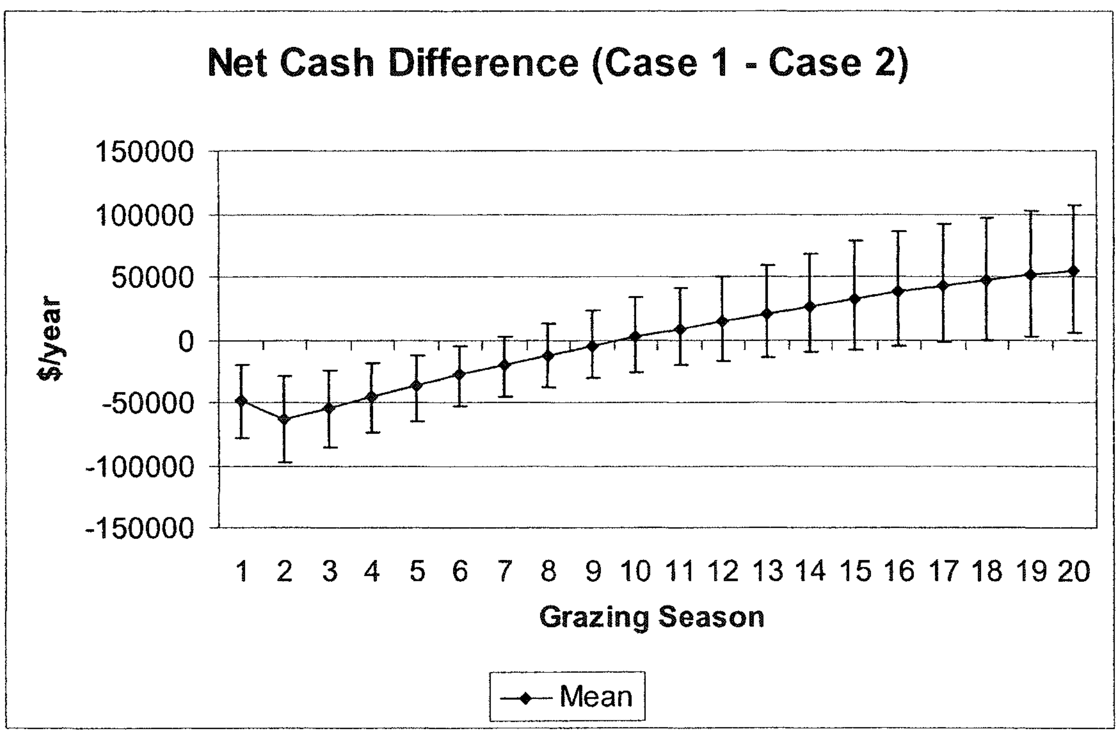


Figure 7.3 Comparison of Case 1 and Case 2 Upland Stocking Rates

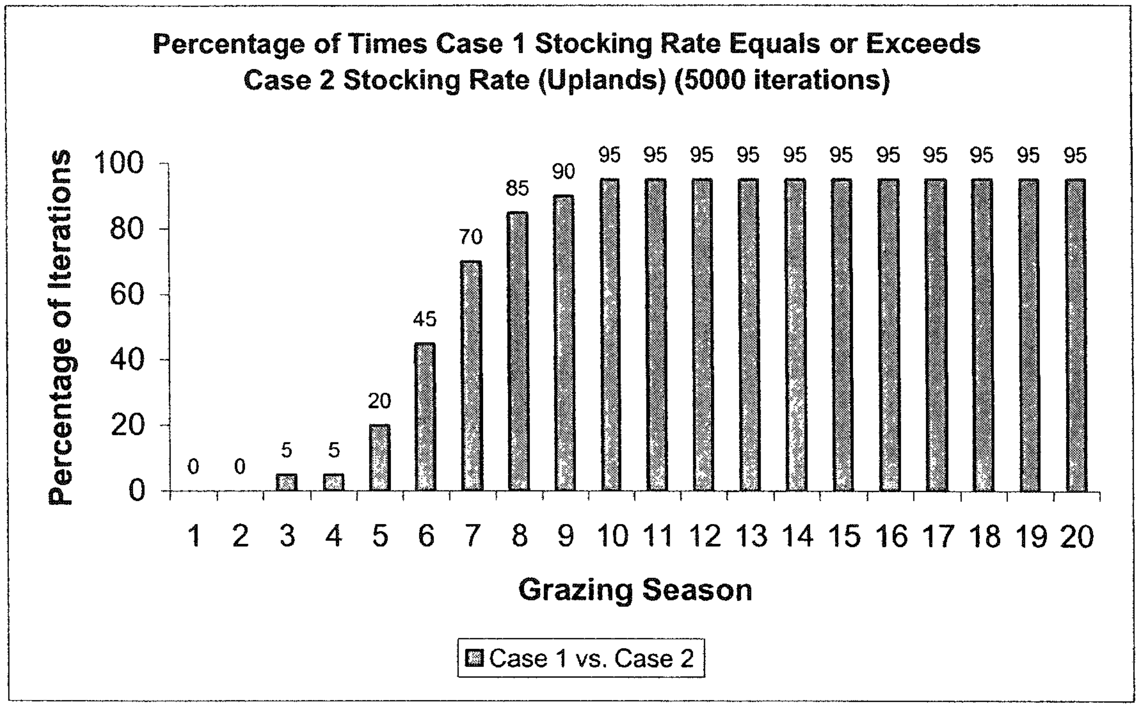


Figure 7.4 Upland Stocking Rate Difference (Case 1 – Case 2) Over Time (90% CI Bound)

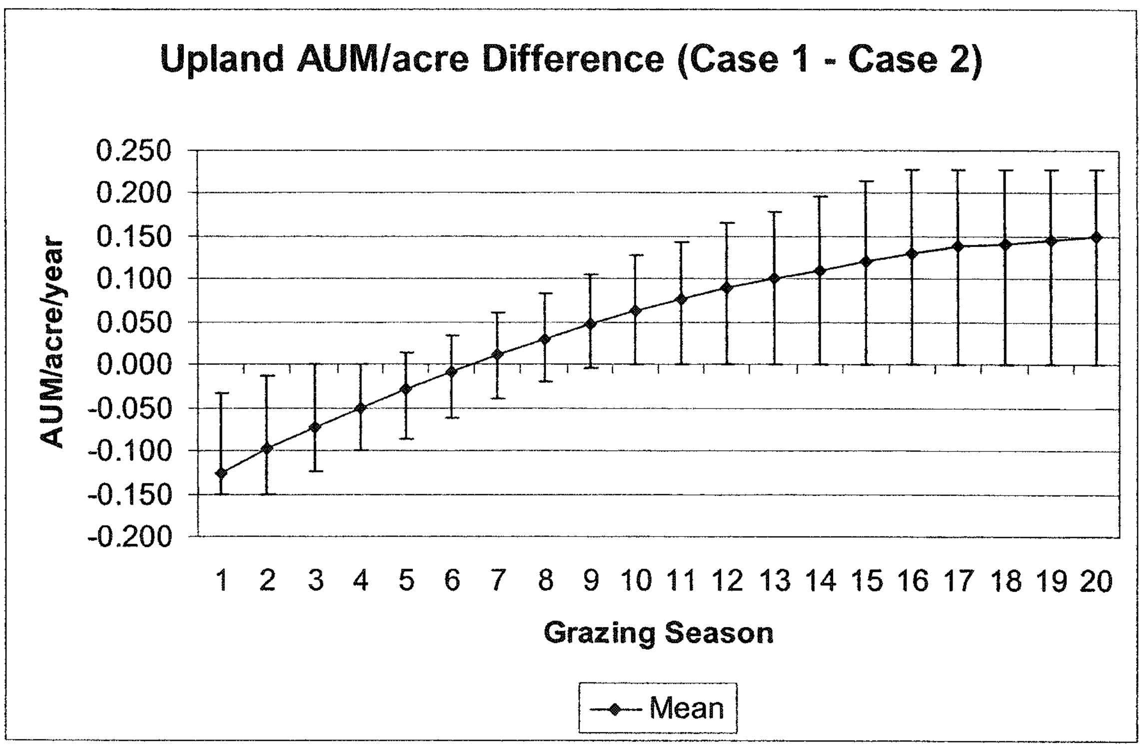


Figure 7.5 Comparison of Case 1 and Case 2 Riparian Area Stocking Rates

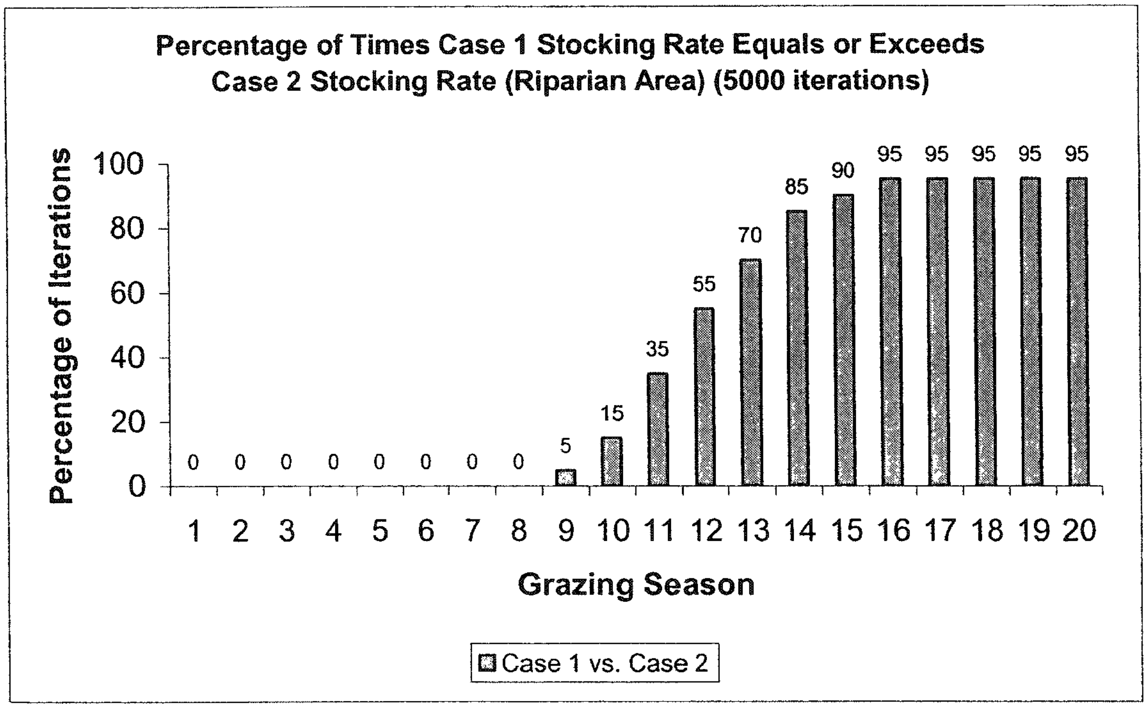


Figure 7.6 Riparian Stocking Rate Difference (Case 1 – Case 2) Over Time (90% CI Bound)

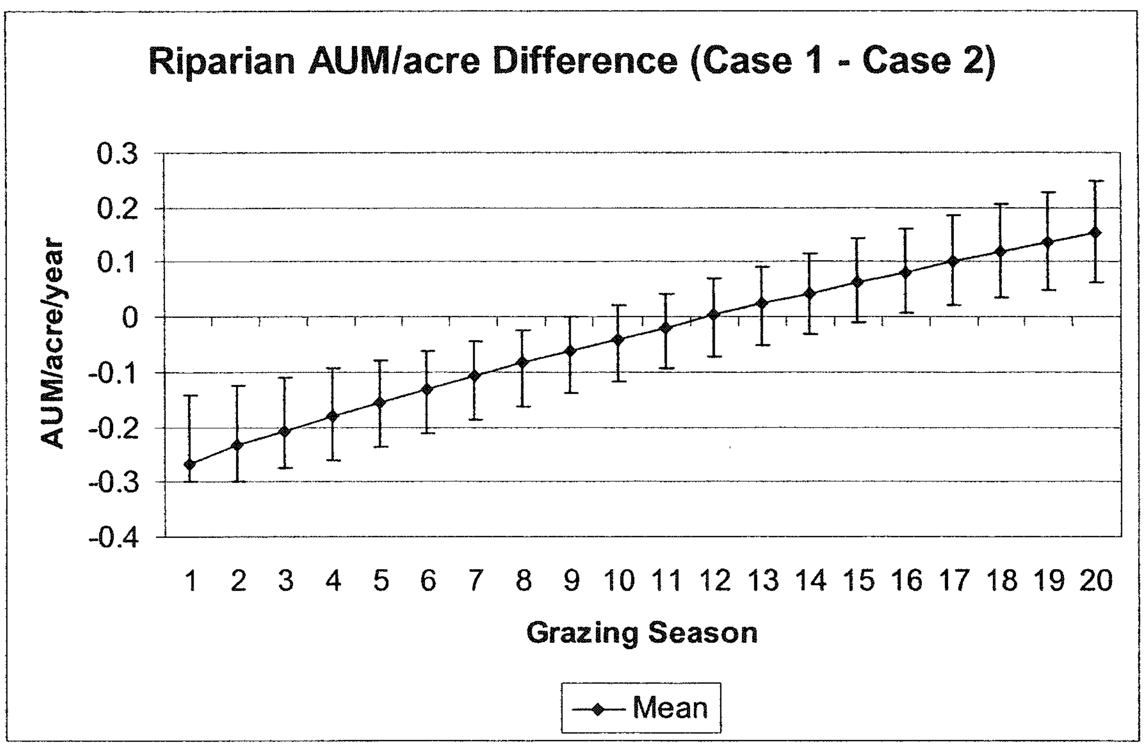


Figure 7.7 Comparison of Case 3 and Case 4 Net Cash

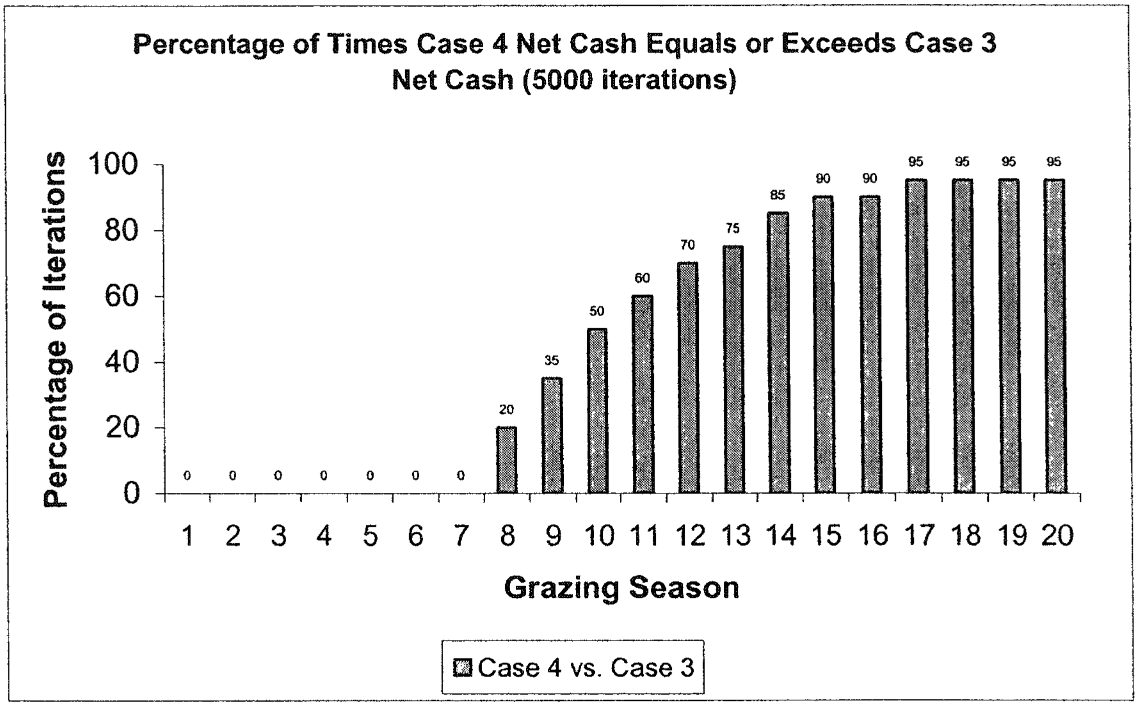


Figure 7.8 Net Cash Difference (Case 4 – Case 3) Over Time (90% CI Bound)

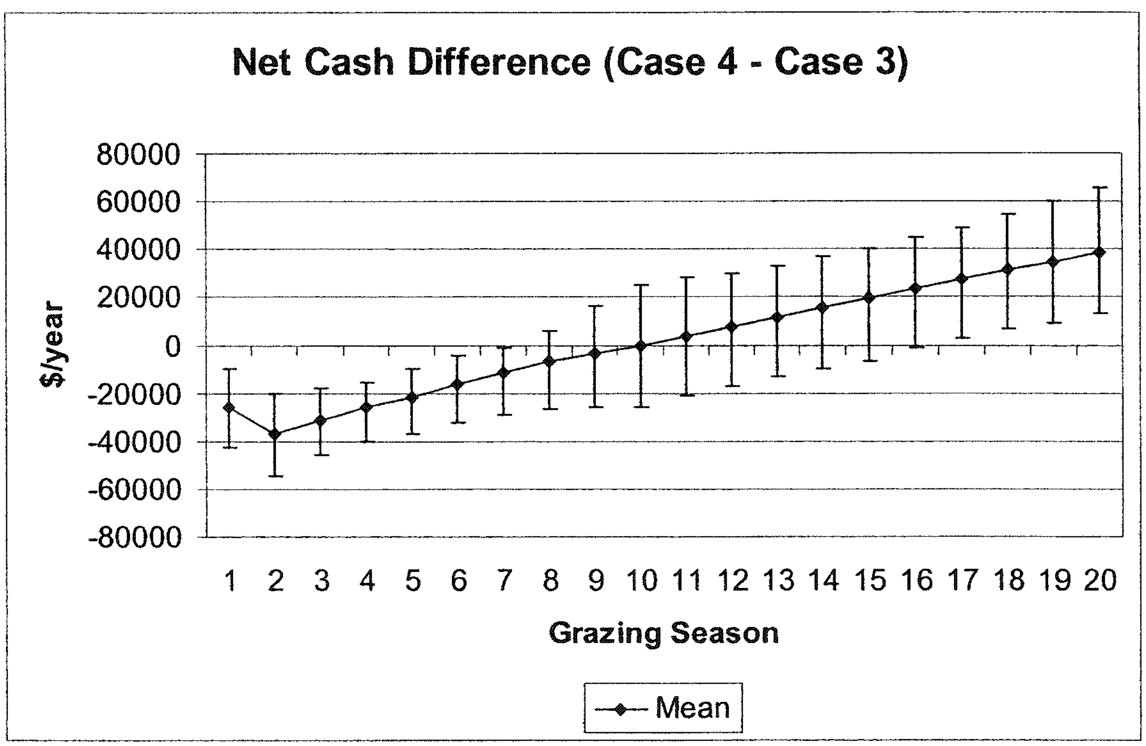


Figure 7.9 Comparison of Case 3 and Case 4 Upland Stocking Rates

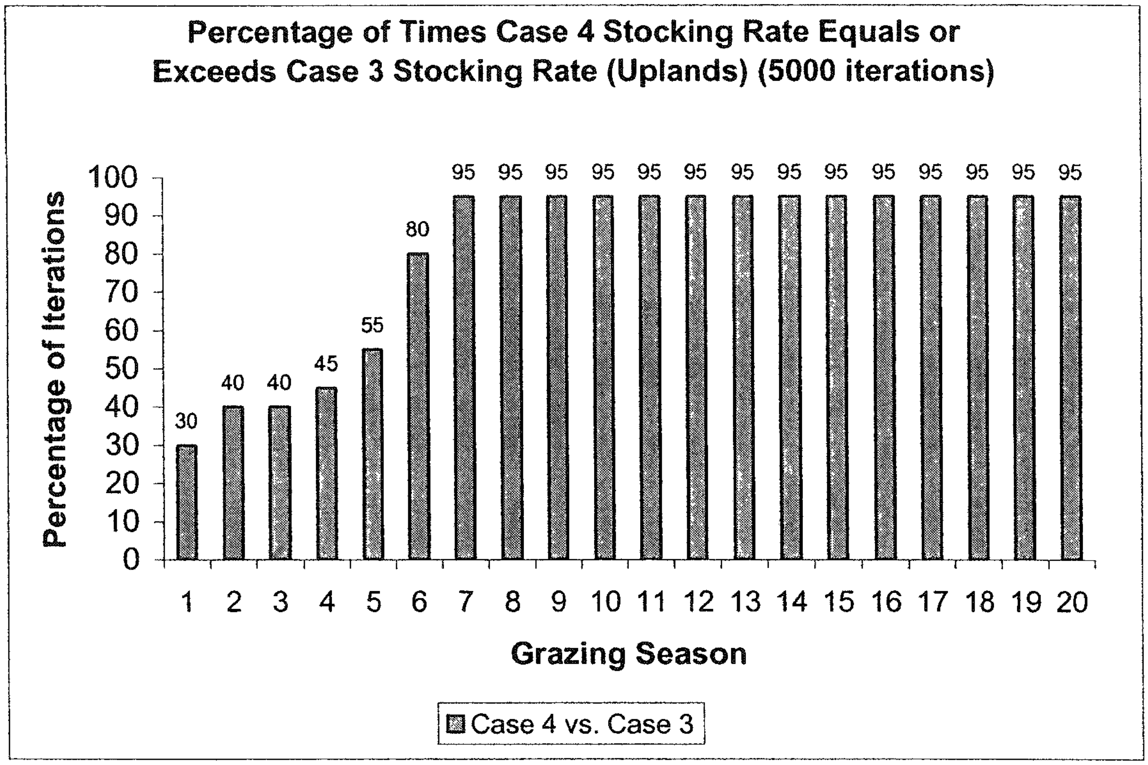


Figure 7.10 Upland Stocking Rate Difference (Case 4 – Case 3) Over Time (90% CI Bound)

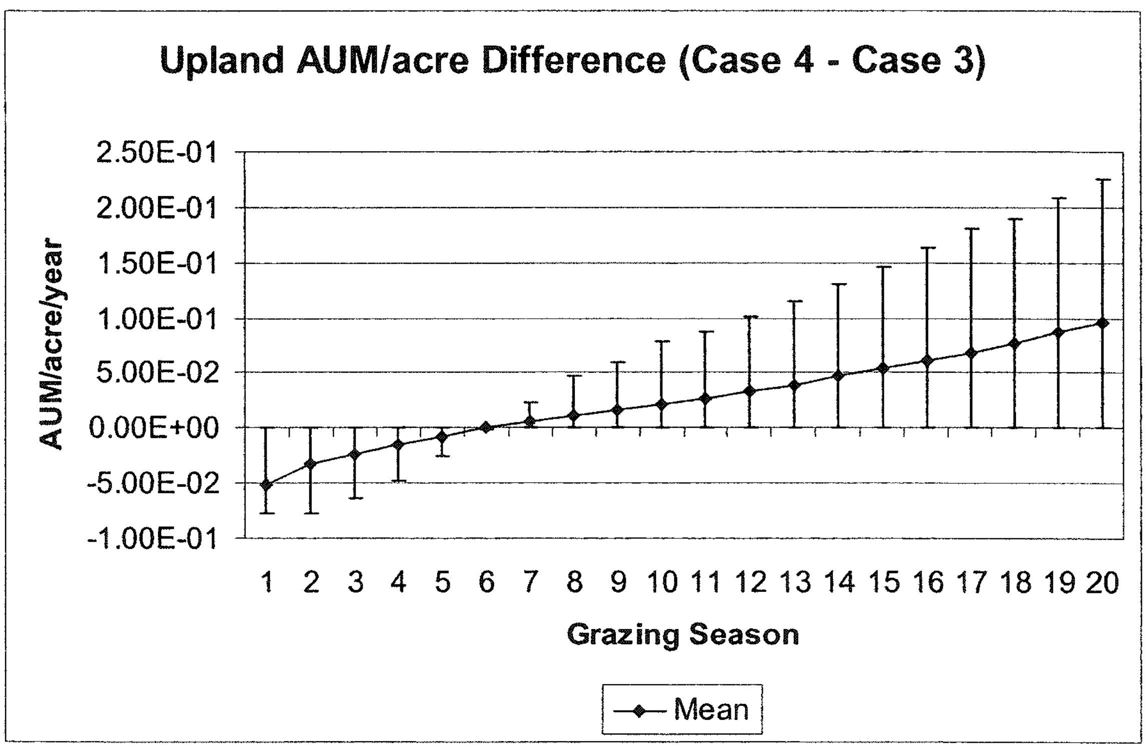


Figure 7.11 Comparison of Case 3 and Case 4 Riparian Area Stocking Rates

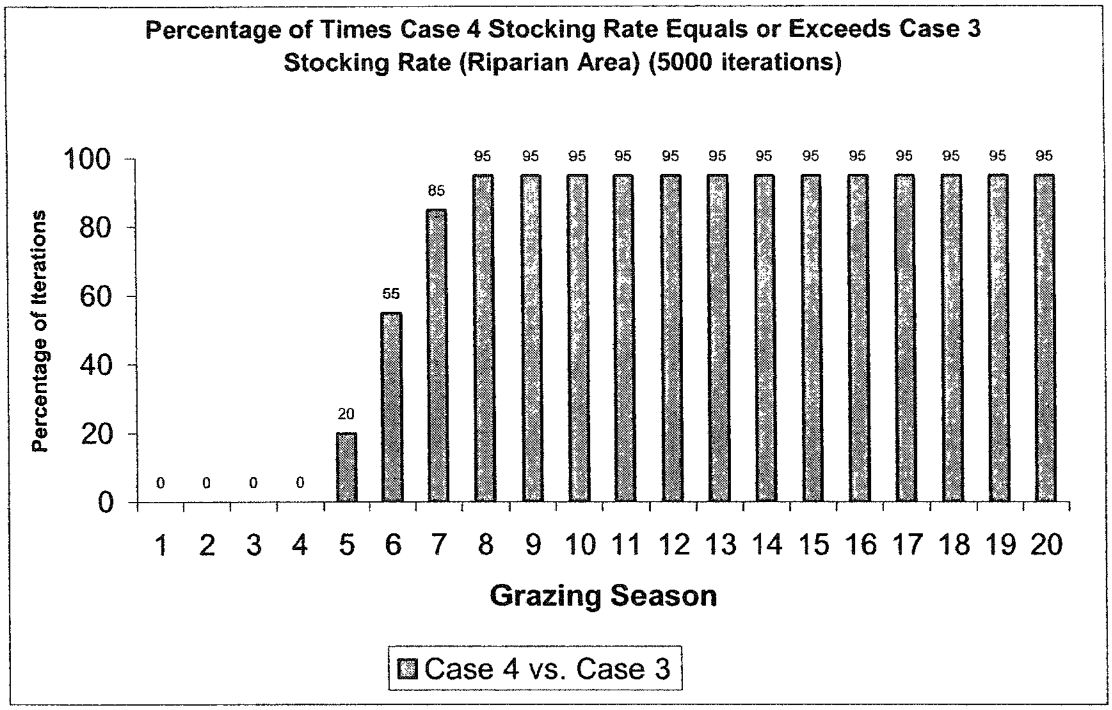


Figure 7.12 Riparian Stocking Rate Difference (Case 4 – Case 3) Over Time (90% CI Bound)

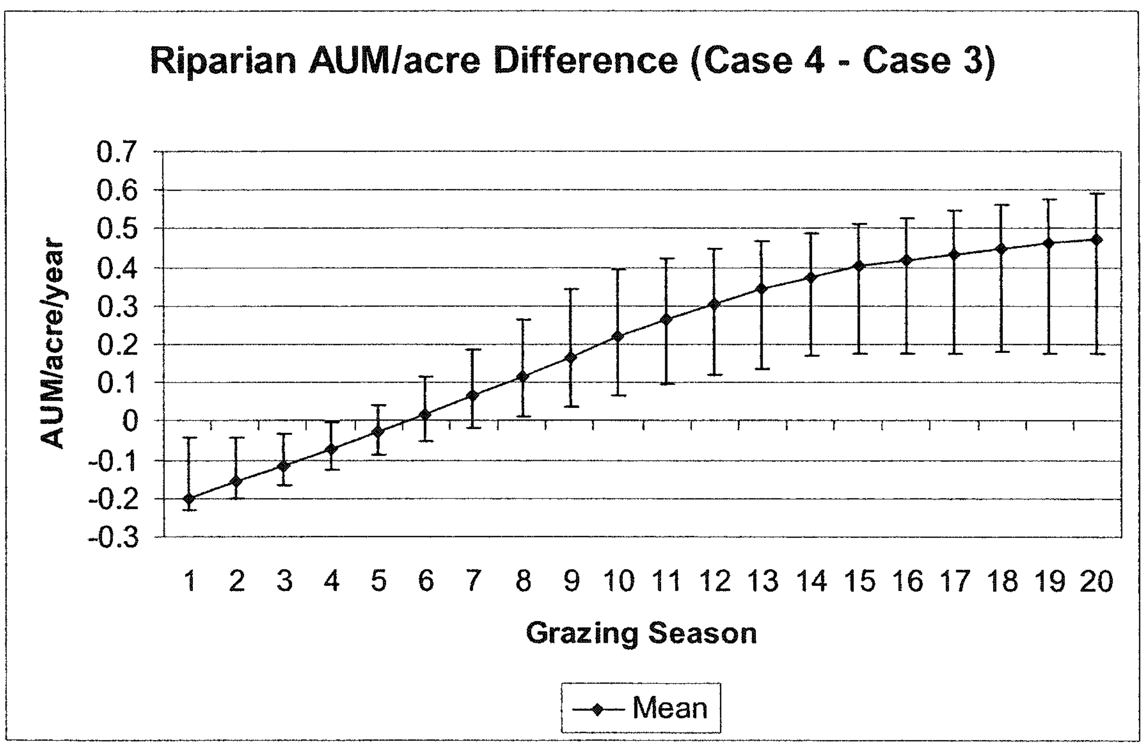


Figure 7.13 Comparison of Case 3 and Case 5 Net Cash

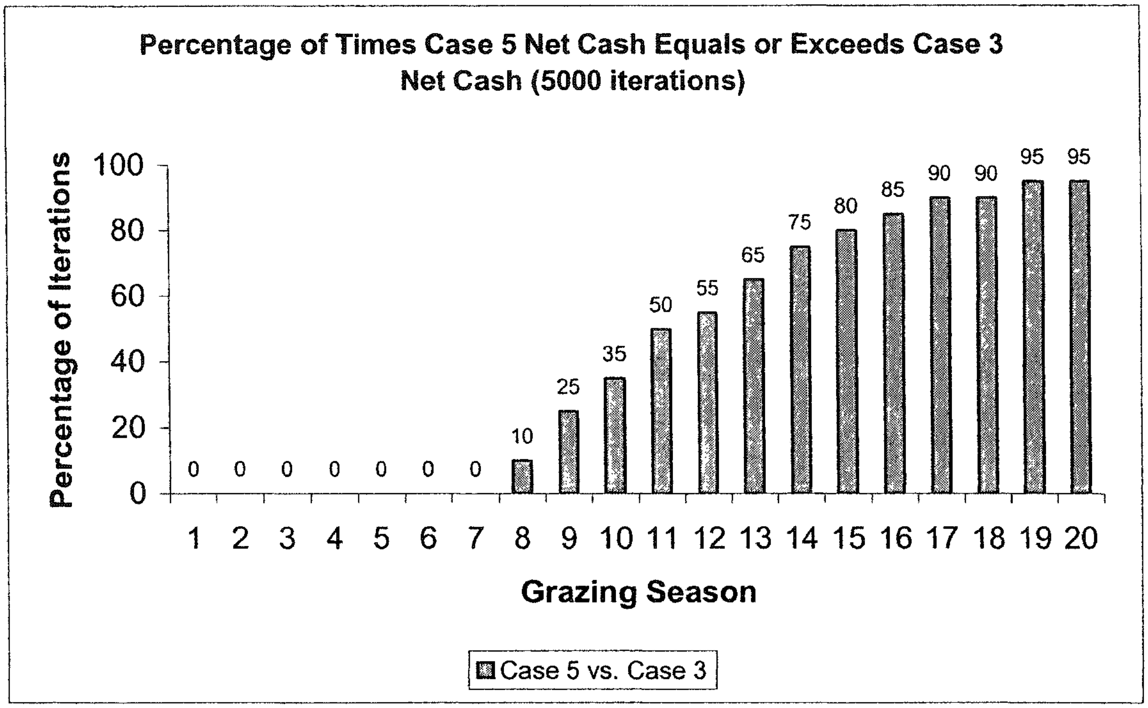


Figure 7.14 Net Cash Difference (Case 5 – Case 3) Over Time (90% CI Bound)

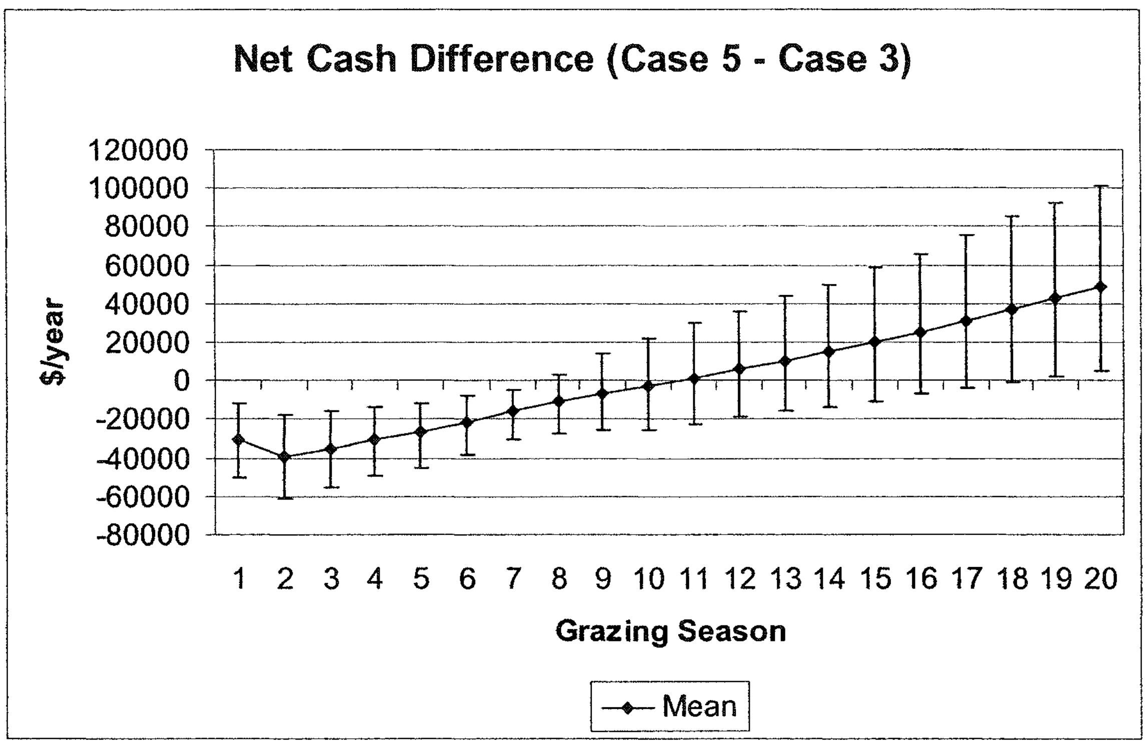


Figure 7.15 Comparison of Case 3 and Case 5 Upland Stocking Rates

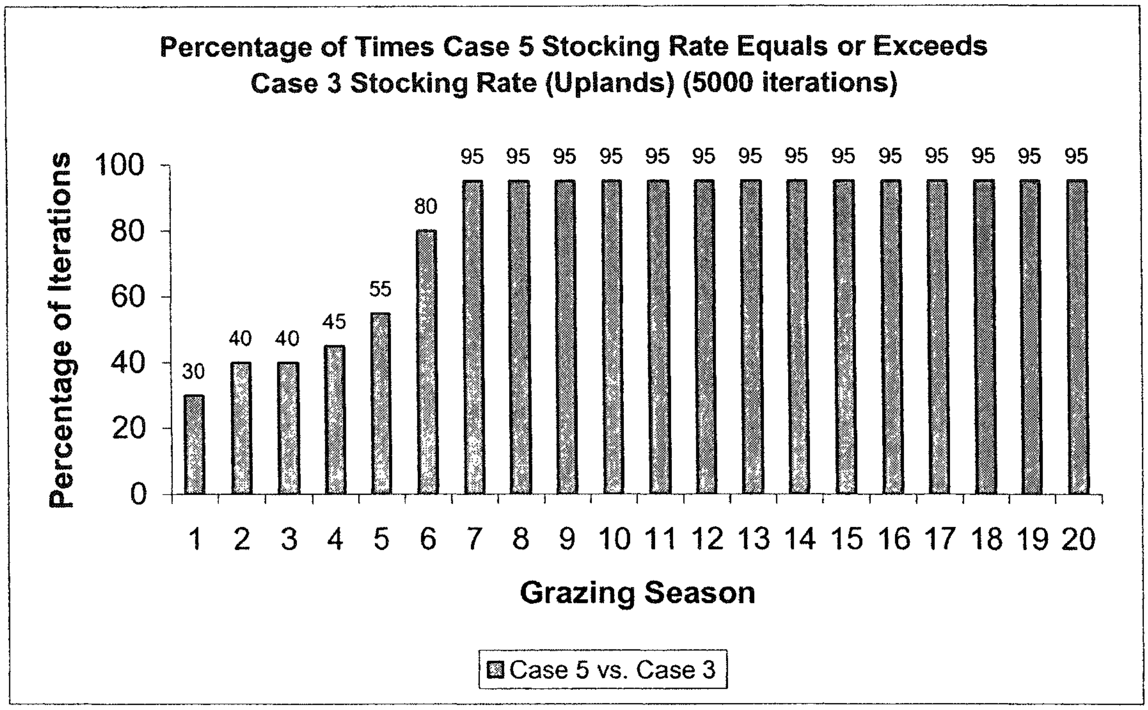


Figure 7.16 Upland Stocking Rate Difference (Case 5 – Case 3) Over Time (90% CI Bound)

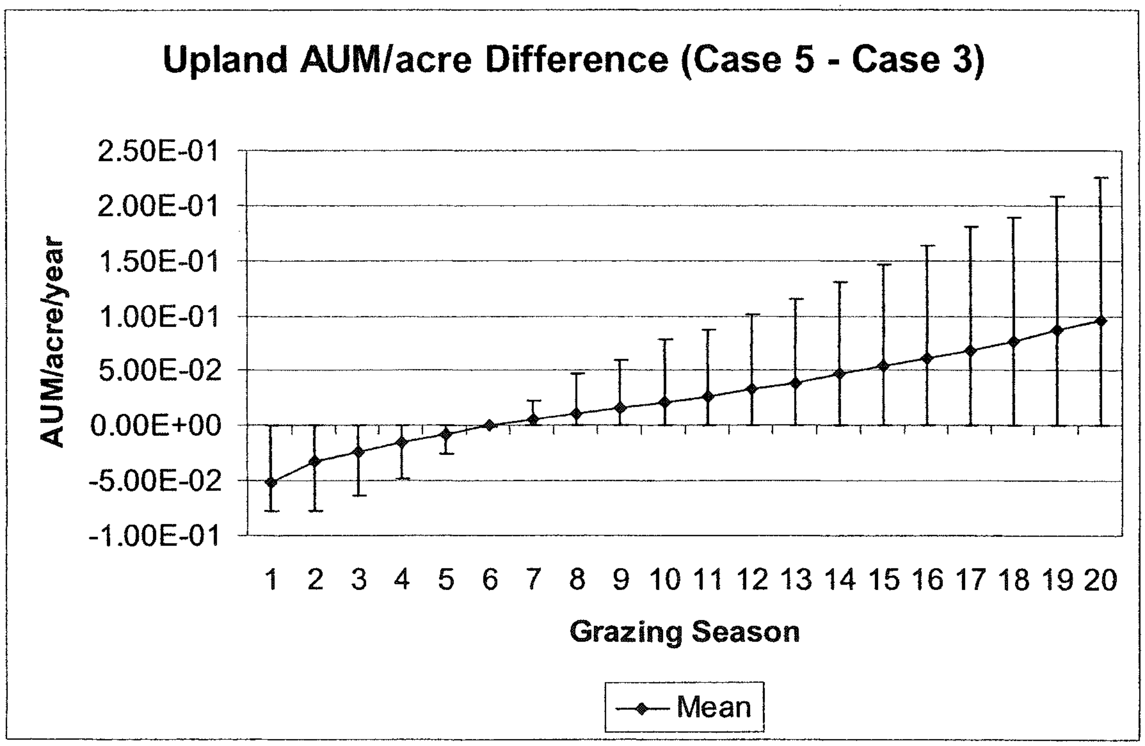


Figure 7.17 Comparison of Case 3 and Case 5 Riparian Area Stocking Rates

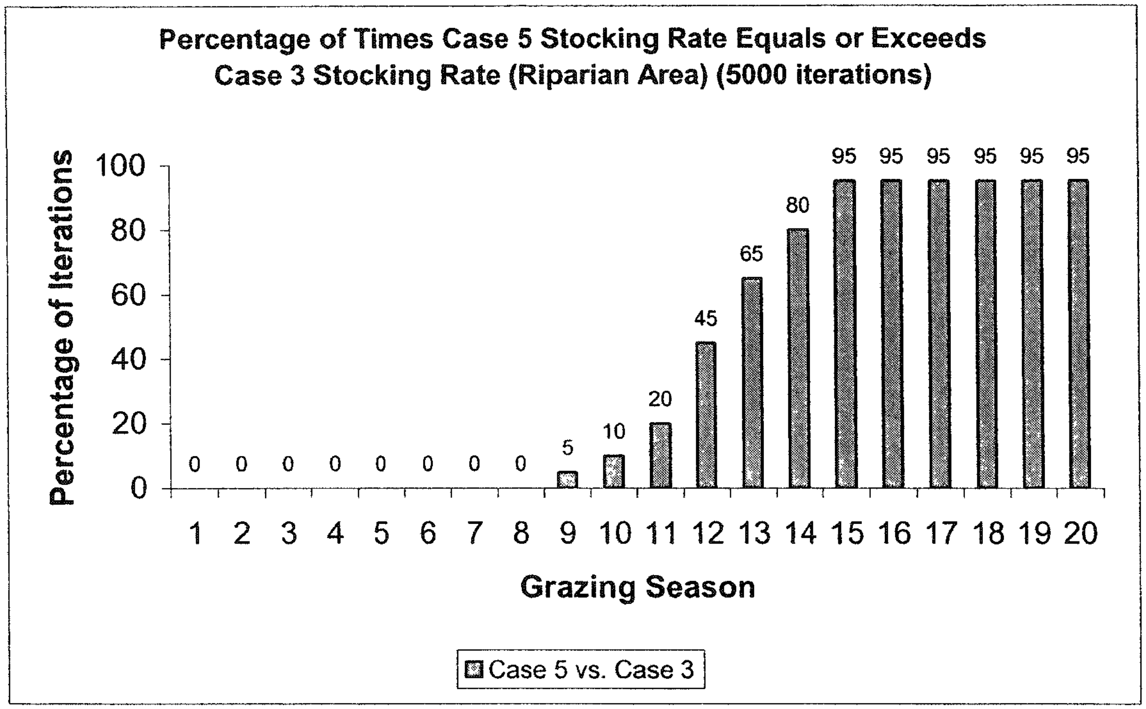


Figure 7.18 Riparian Stocking Rate Difference (Case 5 – Case 3) Over Time (90% CI Bound)

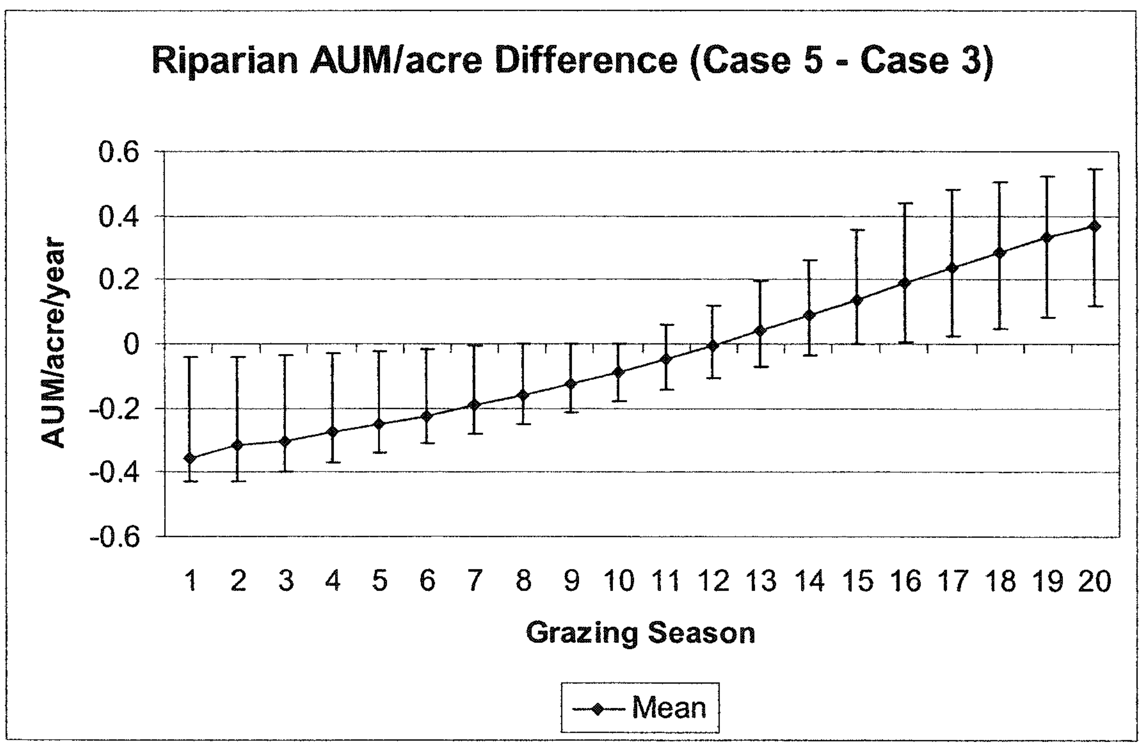


Figure 7.19 Comparison of Case 3 and Case 6 Net Cash

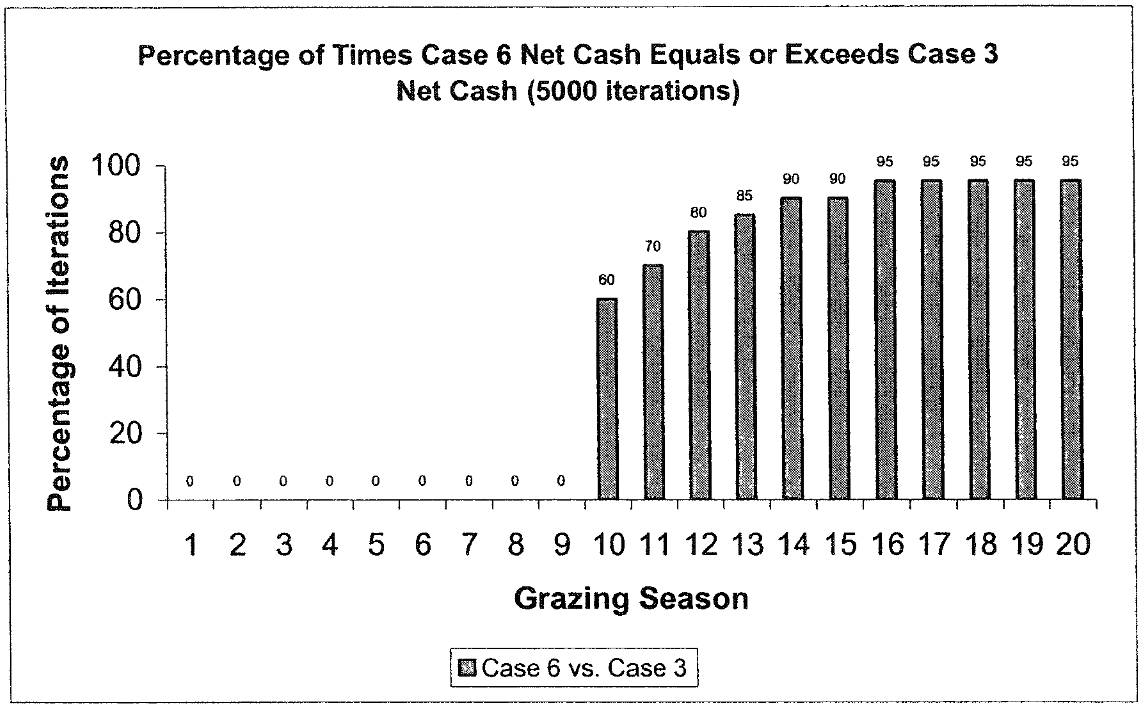


Figure 7.20 Net Cash Difference (Case 6 – Case 3) Over Time (90% CI Bound)

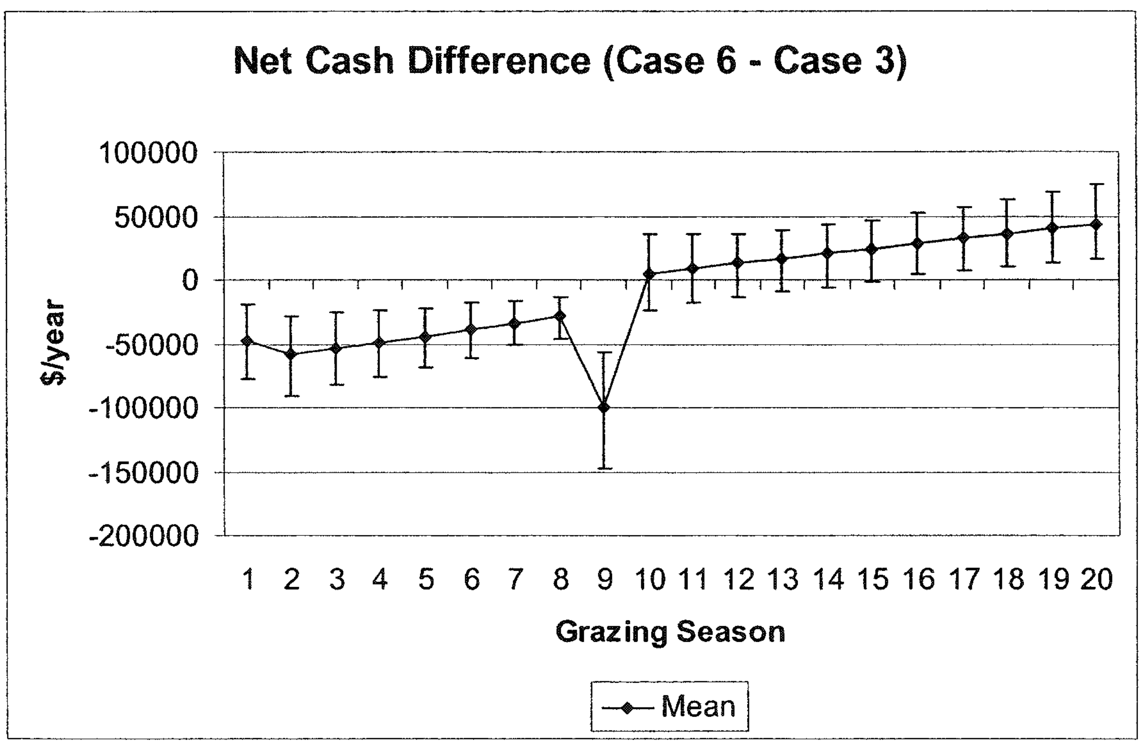


Figure 7.21 Comparison of Case 3 and Case 6 Upland Stocking Rates

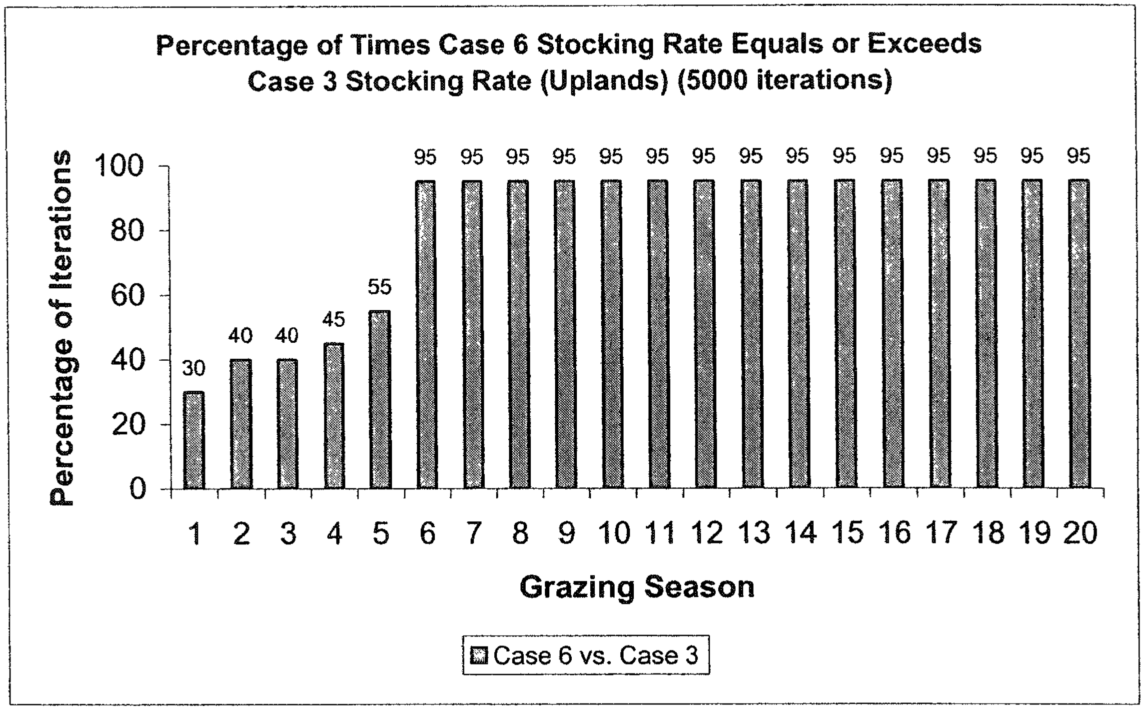


Figure 7.22 Upland Stocking Rate Difference (Case 6 – Case 3) Over Time (90% CI Bound)

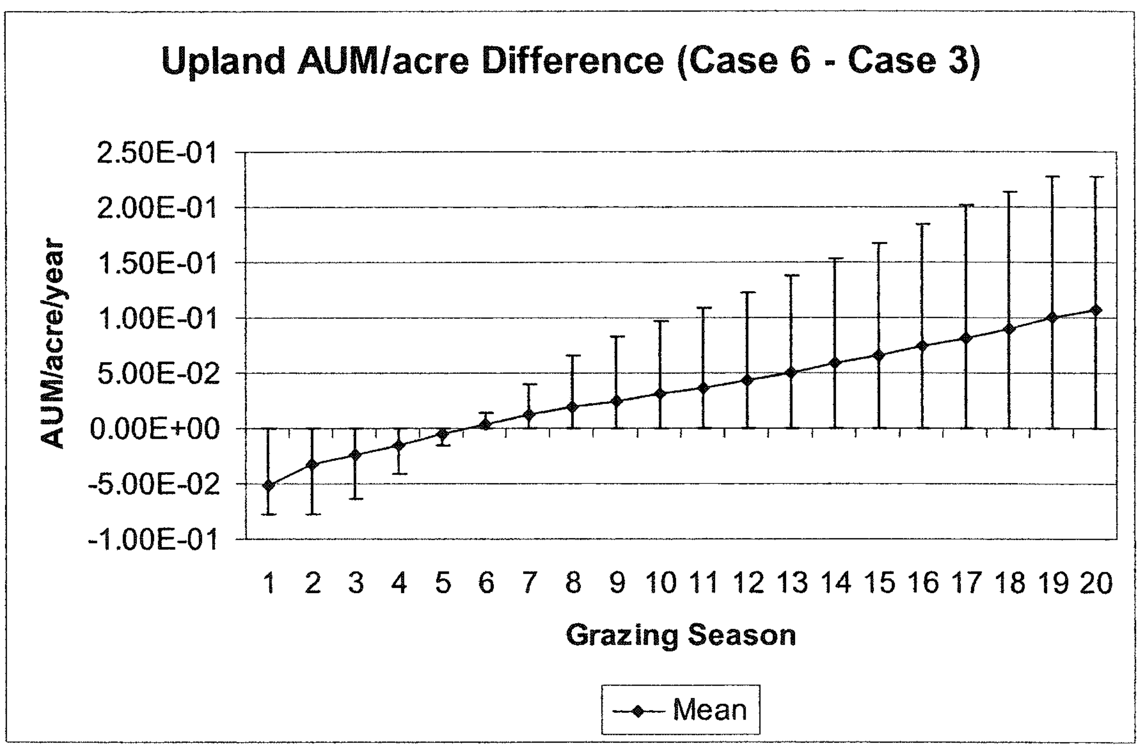


Figure 7.23 Comparison of Case 3 and Case 6 Riparian Area Stocking Rates

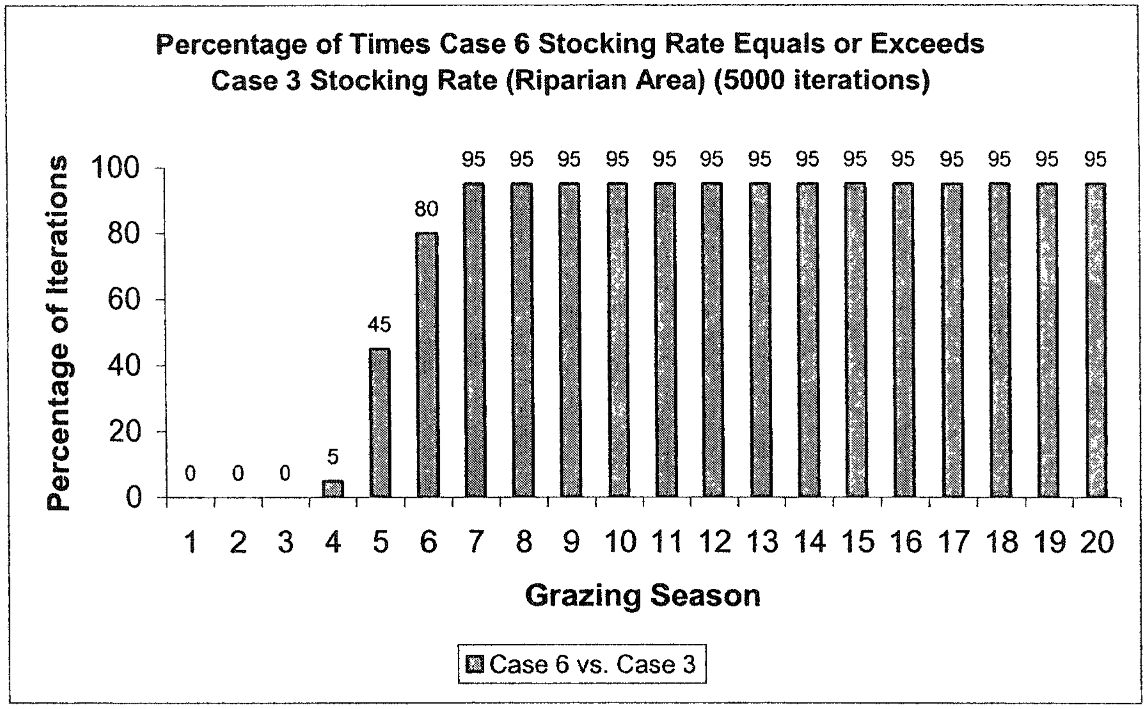


Figure 7.24 Riparian Stocking Rate Difference (Case 6 – Case 3) Over Time (90% CI Bound)

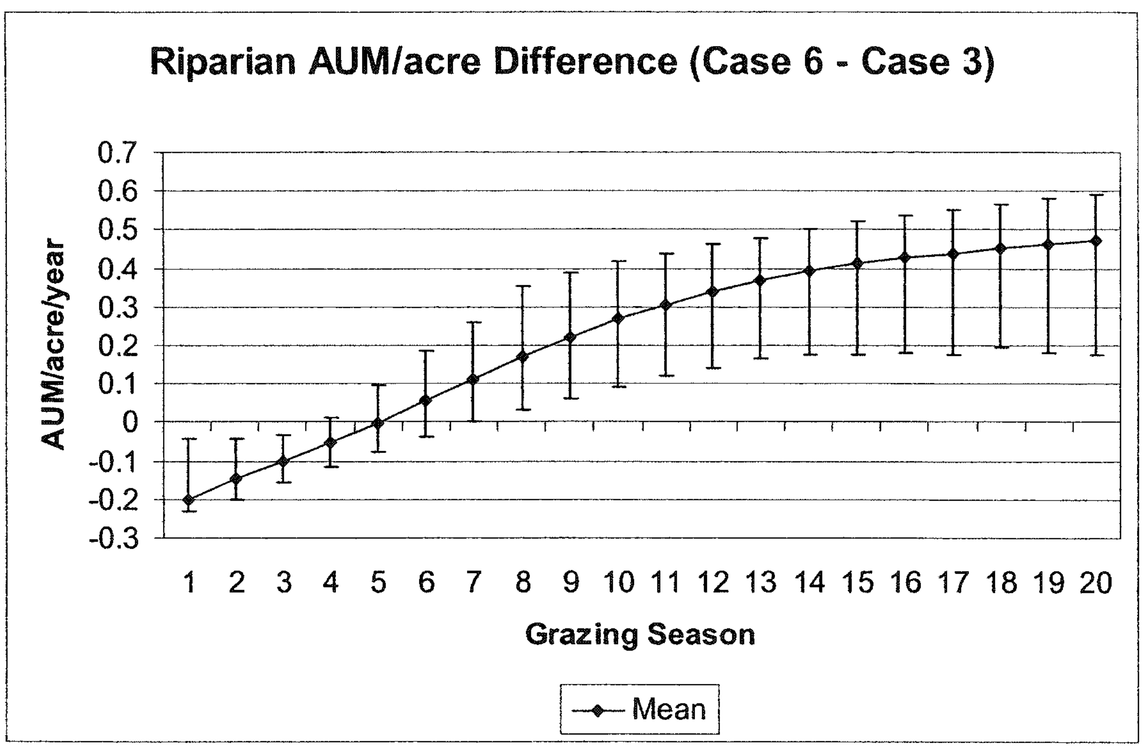


Figure 7.25 Comparison of Case 1 and Case 2 Net Cash (with 30 cent/cwt Increase in Initial Steer and Heifer Prices)

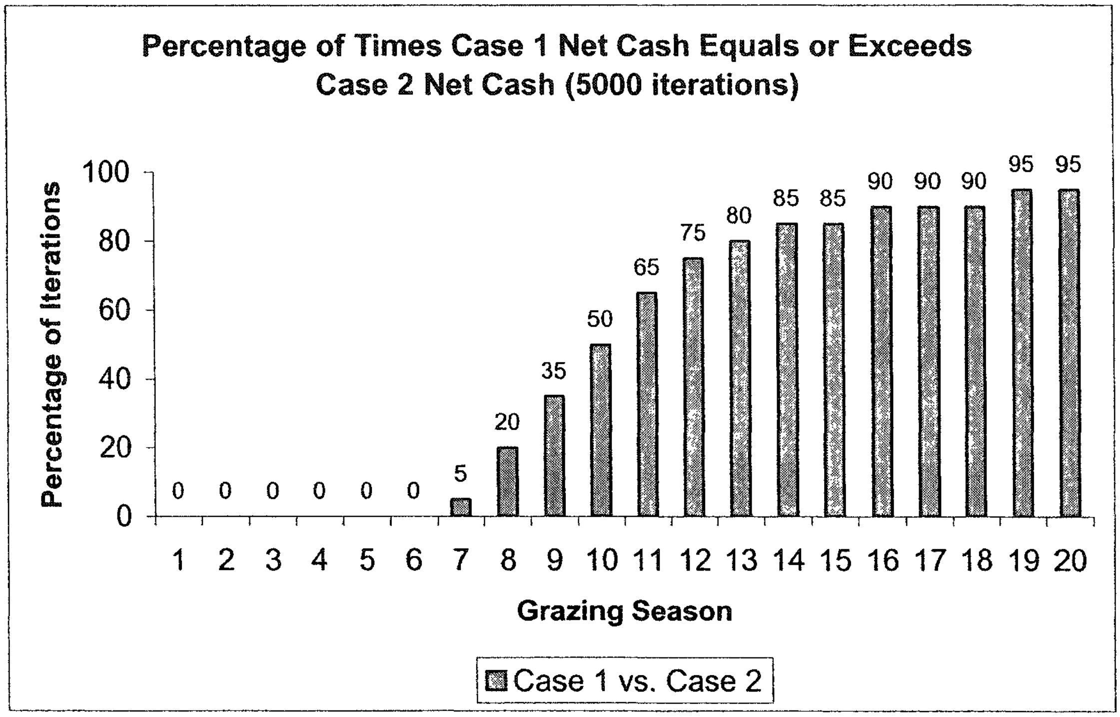


Figure 7.26 Net Cash Difference (Case 1 – Case 2) Over Time (with 30 cent/cwt Increase in Initial Steer and Heifer Prices) (90% CI Bound)

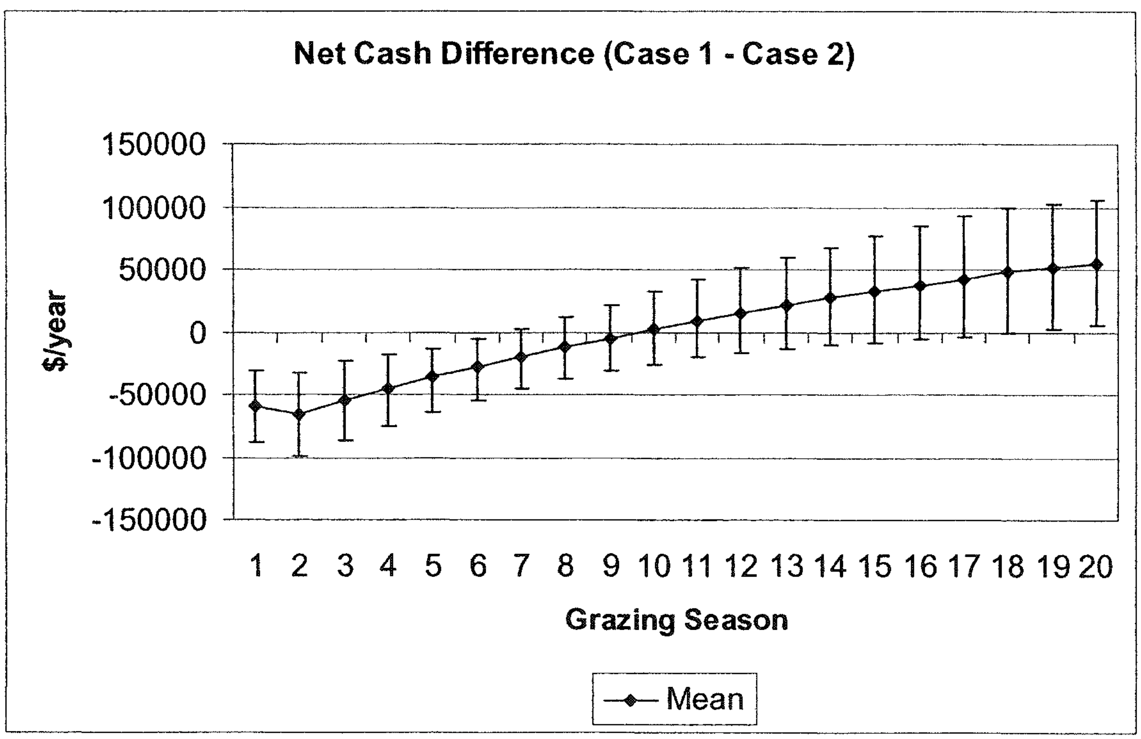


Figure 7.27 Comparison of Case 3 and Case 4 Net Cash (with 30 cent/cwt Increase in Initial Steer and Heifer Prices)

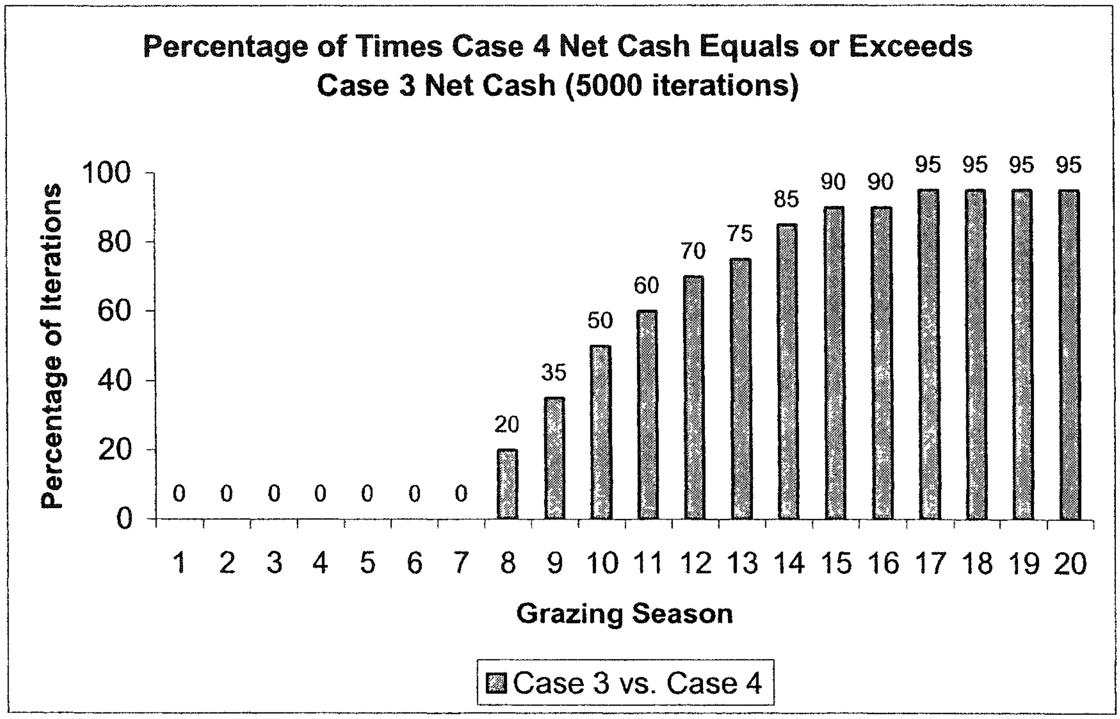


Figure 7.28 Net Cash Difference (Case 4 – Case 3) Over Time (with 30 cent/cwt Increase in Initial Steer and Heifer Prices) (90% CI Bound)

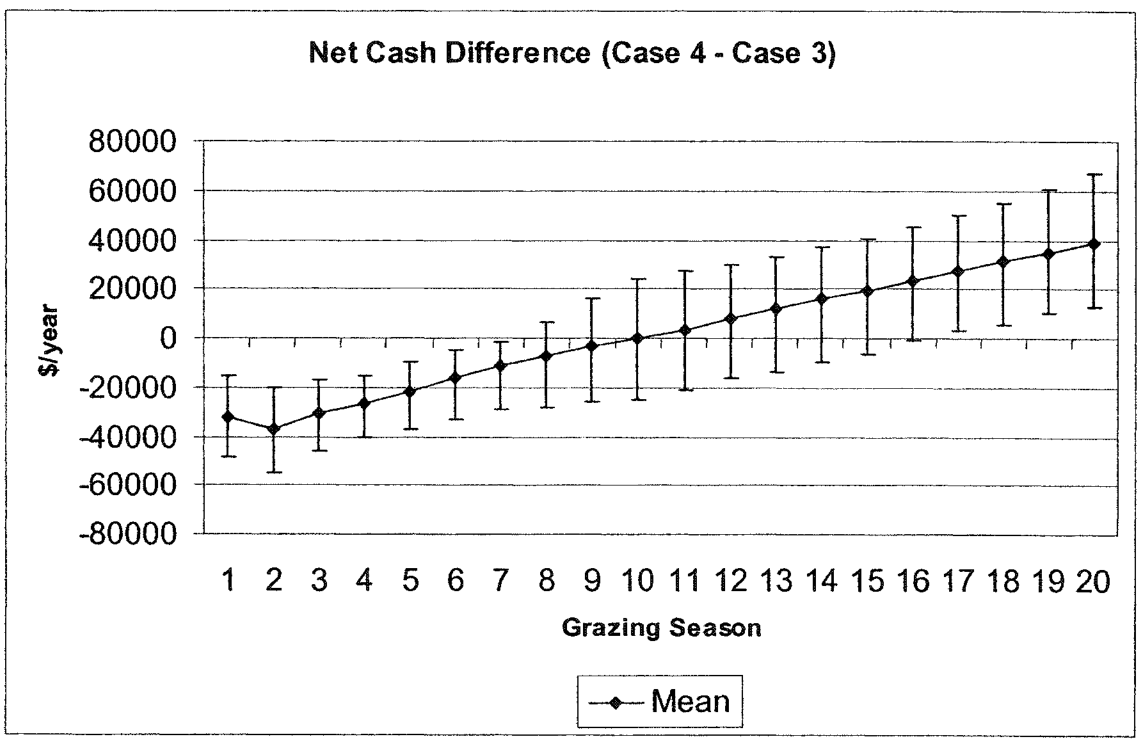


Figure 7.29 Comparison of Case 3 and Case 5 Net Cash (with 30 cent/cwt Increase in Initial Steer and Heifer Prices)

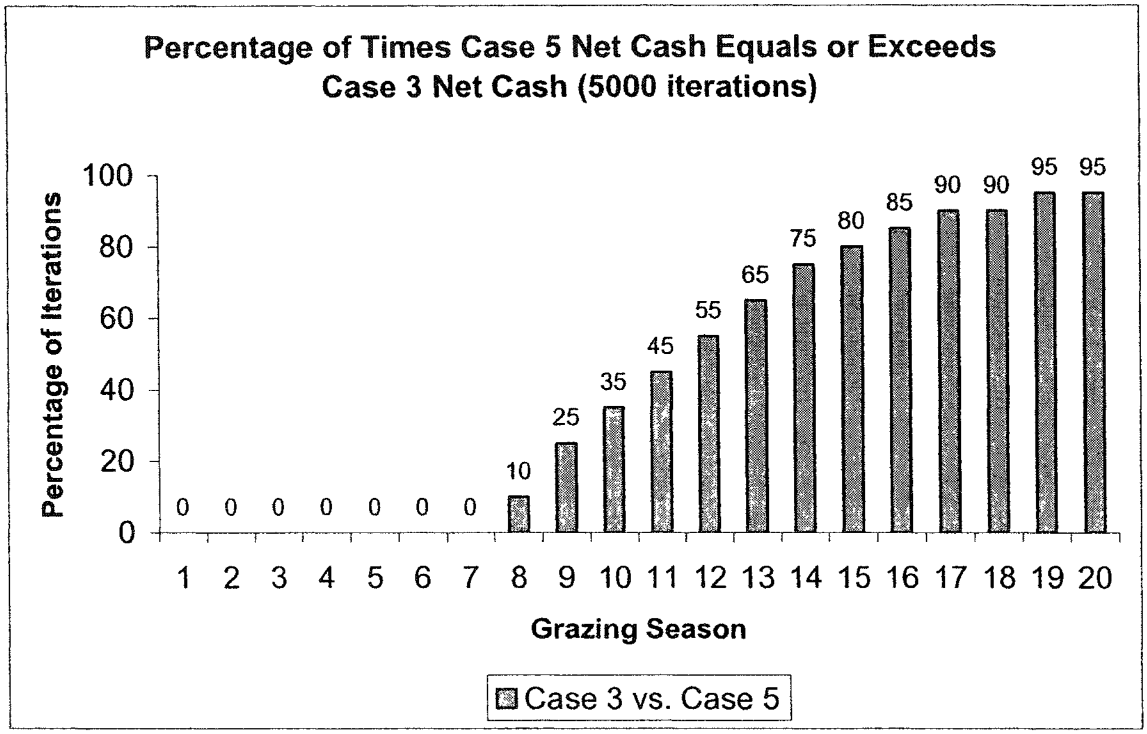


Figure 7.30 Net Cash Difference (Case 5 – Case 3) Over Time (with 30 cent/cwt Increase in Initial Steer and Heifer Prices) (90% CI Bound)

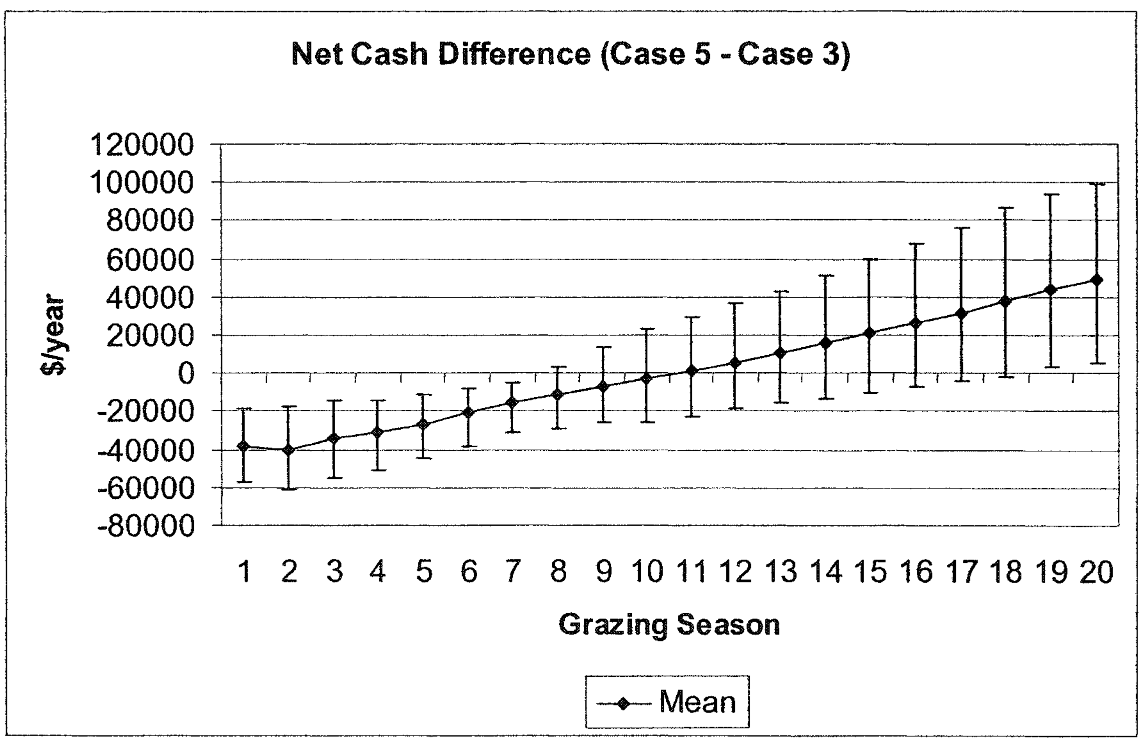


Figure 7.31 Comparison of Case 3 and Case 6 Net Cash (with 30 cent/cwt Increase in Initial Steer and Heifer Prices)

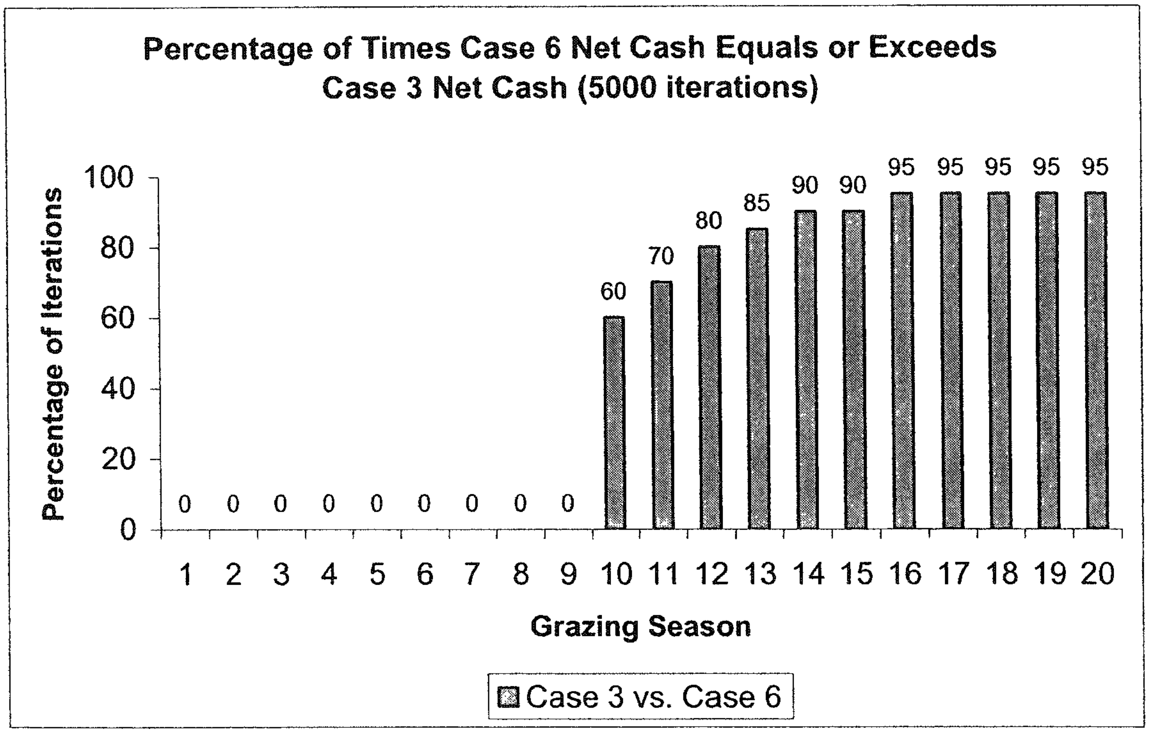


Figure 7.32 Net Cash Difference (Case 6 – Case 3) Over Time (with 30 cent/cwt Increase in Initial Steer and Heifer Prices) (90% CI Bound)

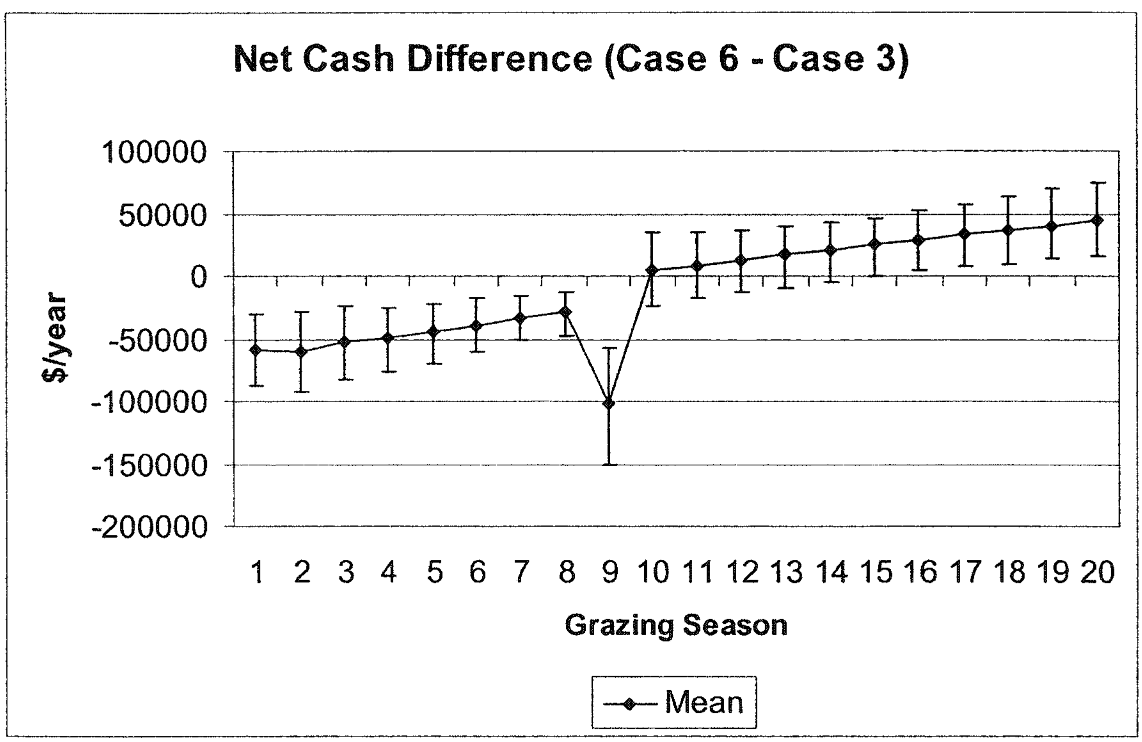


Figure 7.33 Comparison of Case 1 and Case 2 Net Cash (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices)

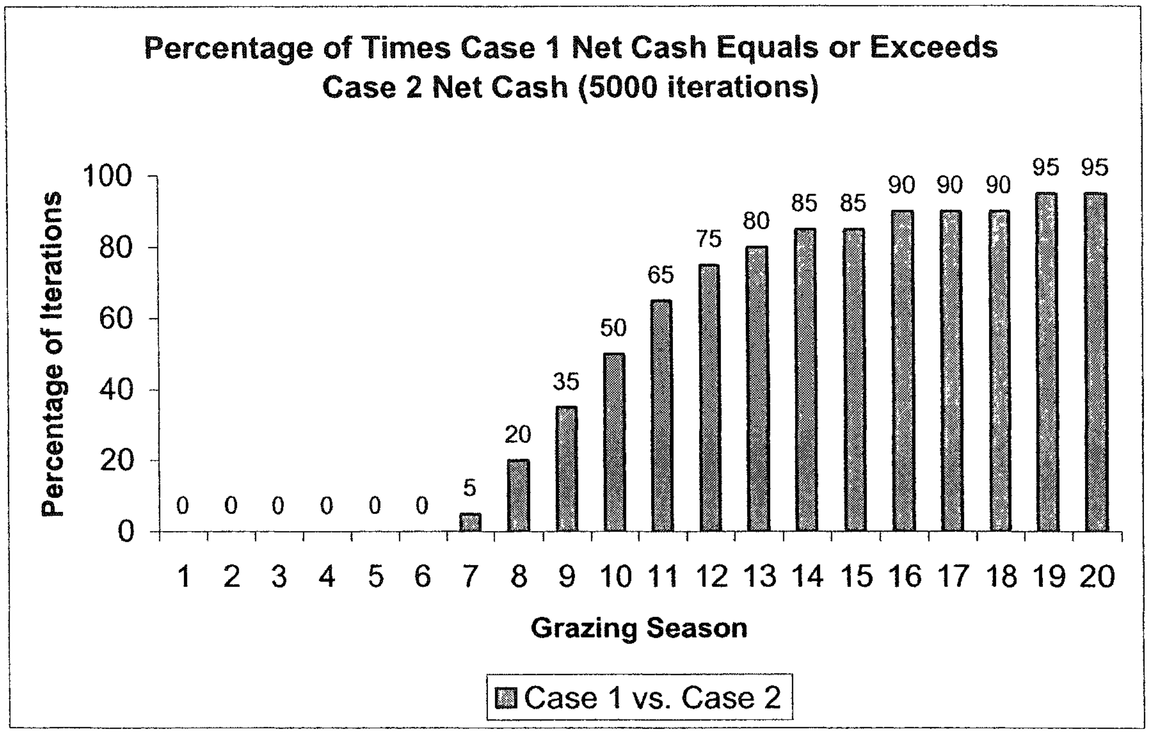


Figure 7.34 Net Cash Difference (Case 1 – Case 2) Over Time (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices) (90% CI Bound)

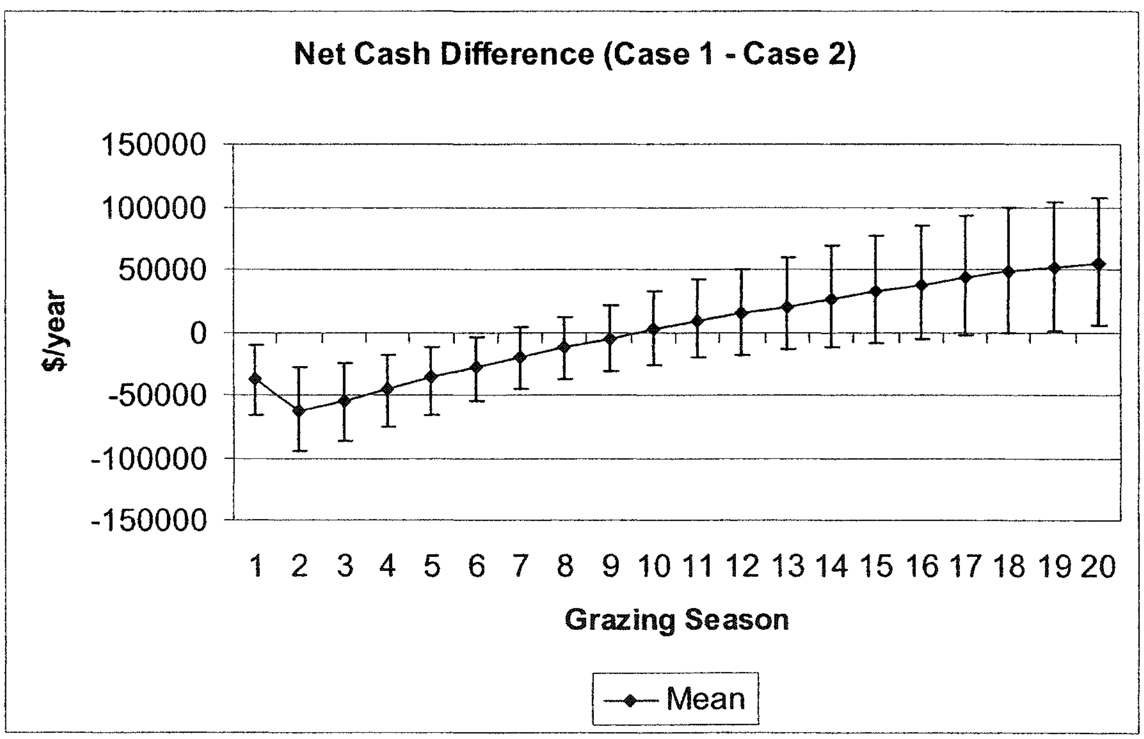


Figure 7.35 Comparison of Case 3 and Case 4 Net Cash (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices)

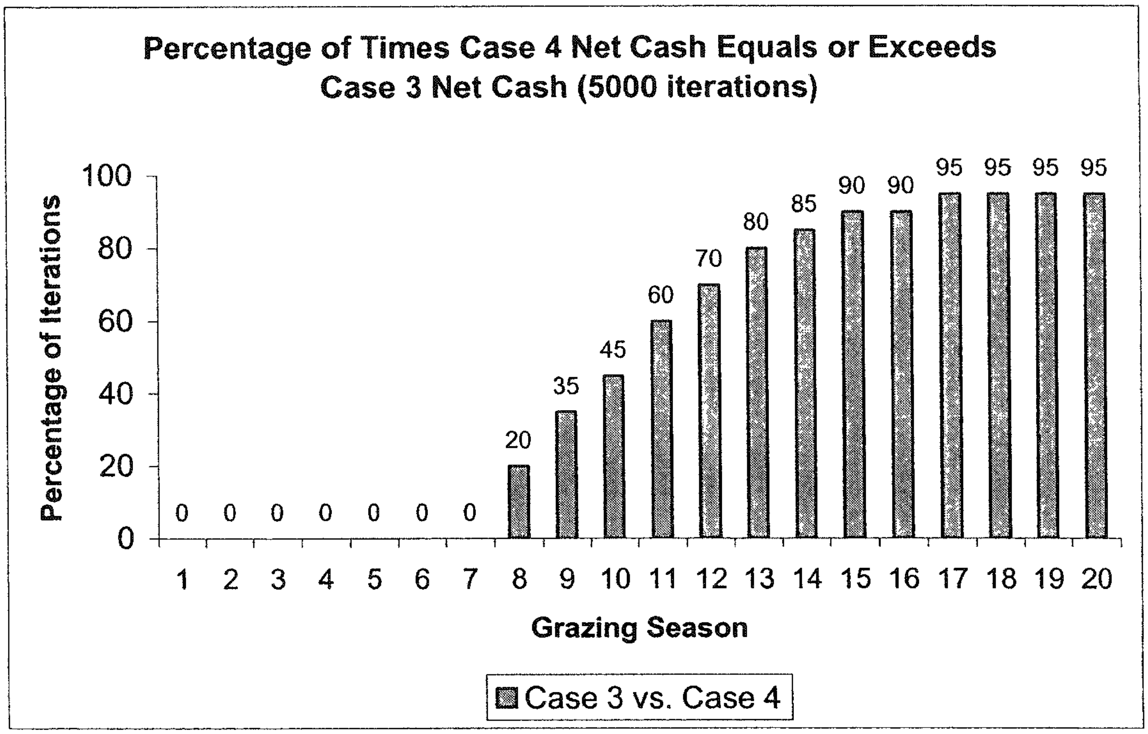


Figure 7.36 Net Cash Difference (Case 4 – Case 3) Over Time (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices) (90% CI Bound)

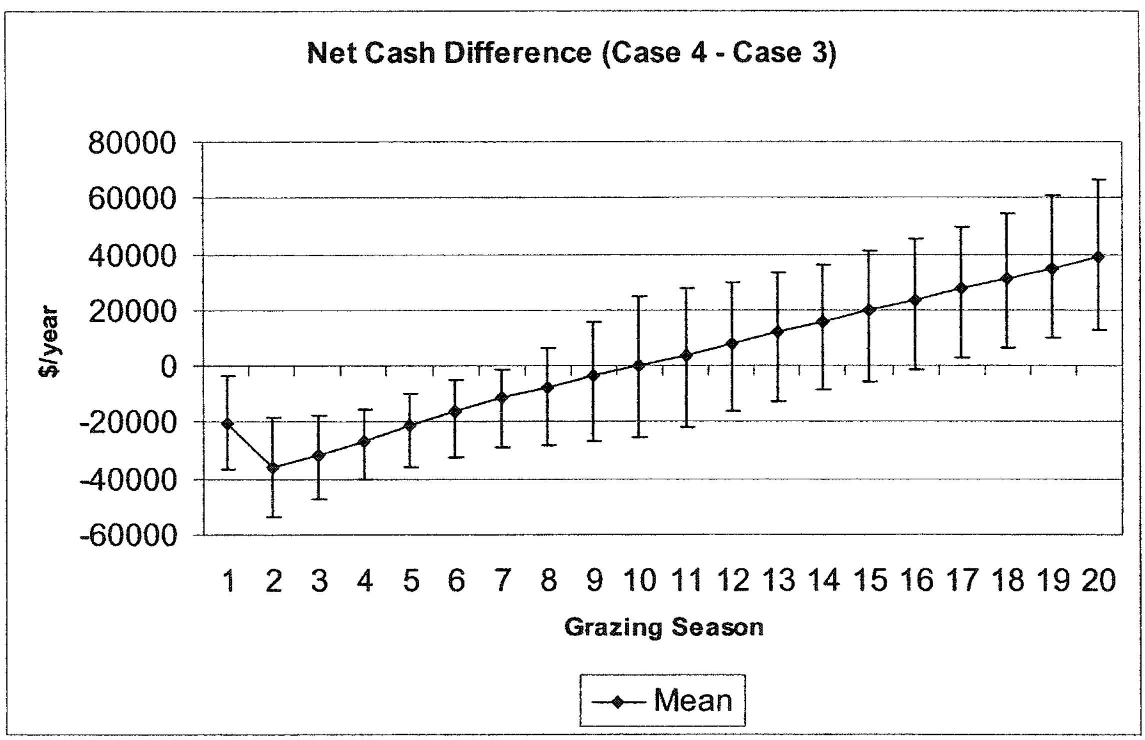


Figure 7.37 Comparison of Case 3 and Case 5 Net Cash (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices)

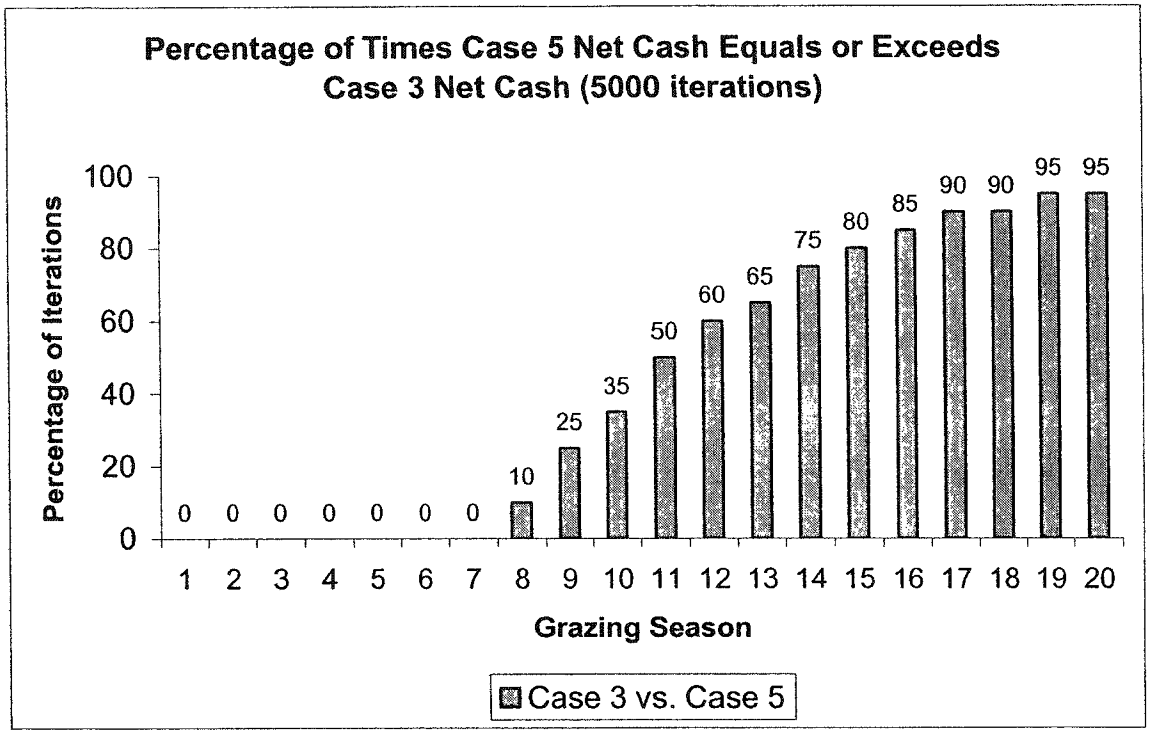


Figure 7.38 Net Cash Difference (Case 5 – Case 3) Over Time (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices) (90% CI Bound)

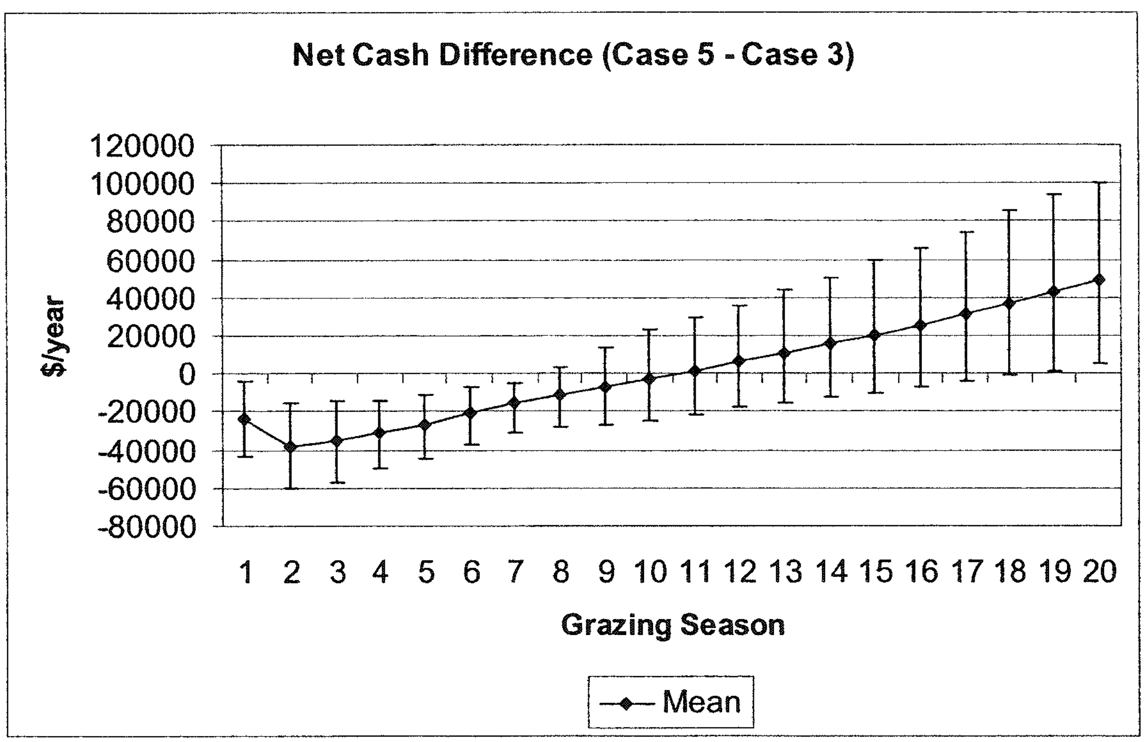


Figure 7.39 Comparison of Case 3 and Case 6 Net Cash (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices)

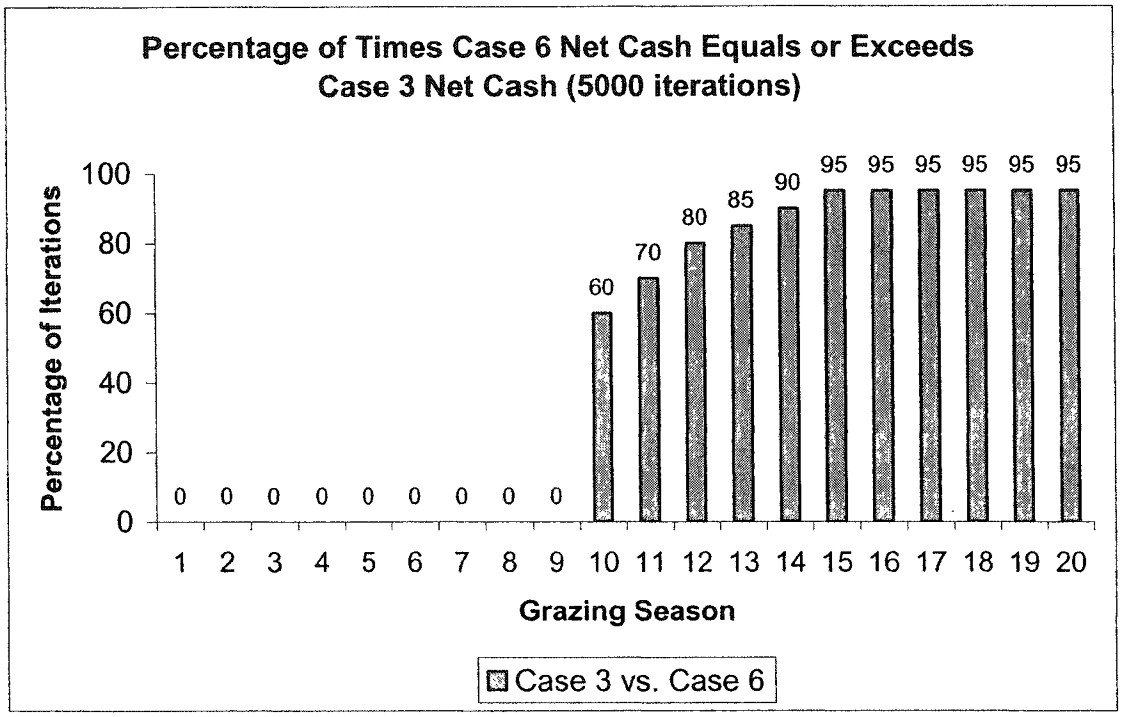
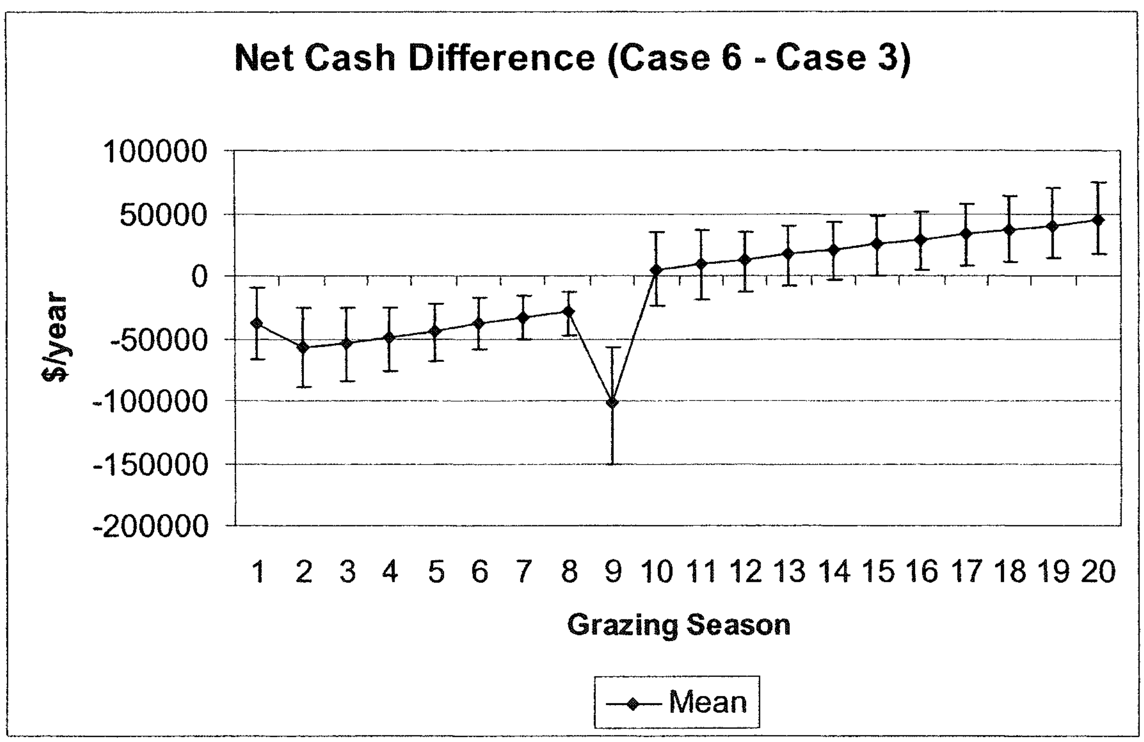


Figure 7.40 Net Cash Difference (Case 6 – Case 3) Over Time (with 30 cent/cwt Decrease in Initial Steer and Heifer Prices) (90% CI Bound)



Chapter 8

8.1 Conclusions

8.1.1 *Questionnaire Conclusions*

According to the questionnaire, selected producers have good knowledge concerning riparian management. Results of the survey suggested that costs of riparian management strategies would play a role in the management decisions of producers. However, the producers considered the future of ranch operations when making their choices. Grazing systems with higher initial costs would be considered if they were needed to restore pasture health. The producers were also open to suggestions from groups concerned with riparian health, such as Cows and Fish.

8.1.2 *Static Model Conclusions*

Incremental NPV results suggest that overgrazing is generally not a feasible long-term grazing strategy. Grazing strategies that improve range health in the long run put producers in a better long-run financial position. Cases 2 and 3 (overgrazing from good condition and overgrazing from poor condition, respectively) were examples of overgrazing strategies. Initial values of calves attributed to the pasture are higher in early time periods, but these values decrease as pasture condition degrades. Though the initial costs are higher, the rotational strategy (Case 4) results in improved incremental NPV over time, as does the corridor fencing system (Case 5) and the rest rotational system (Case 6) versus overgrazing. These results are highly sensitive to assumptions concerning pasture degeneration and regeneration rates.

The results appear to be relatively insensitive to additional costs (Cases 4, 5, and 6) or to calf prices (which were held constant over the 20-year timeline being modeled). If initial calf prices are high, and future prices are expected to be lower, there may be more incentive to overgraze a pasture. By overgrazing in the first few years of grazing, a rancher could capitalize on higher prices, while possibly disregarding future range health. Lower degradation rates (and faster regeneration rates) will tend to favour short run overgrazing strategies.

Cases 4, 5, and 6 had stocking rates in their early stages that were much lower than the early stocking rates for the first three cases. The results are very sensitive to the lower initial stocking rates. Though range health improves over time (often improving stocking rates to levels close to the initial stocking rates of the Base Case), the initially diminished numbers of animals on the range (and accompanying loss of cash inflow) keeps the final NPVs lower than those for the Base Case and Case 2. If a ranch manager could forecast long-range calf prices, it is possible that a producer would be better off financially by overgrazing in the short term when calf prices are high, then implementing a management strategy that improves range health. This would pre-suppose low degradation rates and high regeneration rates (which riparian area pastures were noted for previously).

Using the same assumptions, indifference point results indicate the grazing intensities which will encourage producers to opt for grazing strategies that promote forage regeneration. In order to be financially indifferent, a pasture must have the capability to support very high initial stocking rates. However, it should be noted that time preferences for cash flows vary among ranch operators. If initial calf prices are high, and future prices are expected to be lower, this might increase the incentive to overgraze. At higher discount rates, the producer will favour short-term returns, such as those provided by an overgrazing system (e.g., Case 2). A producer in this case may be considering short-term cash flow needs (debts, family considerations, etc.). At lower discount rates, producers favour systems that give them higher returns in the long run, such as the rotational system in Case 4. A producer in this case might be considering long-term financial stability for both the farm business and farm family.

A different model financial structure may give different results. For example, taxes could have been included in the model calculations. However, in the static model, whole farm considerations (such as taxes) were left out. Model results showed that long-run NPV was very sensitive to pasture degeneration and regeneration rates. The model would be improved if more information on these range regeneration/degeneration rates were known and included. Comprehensive studies on this subject have yet to be performed in the plant science/range science community. Rates used in the current model were chosen based on examples of previous riparian management strategy implementations (Adams, 2000).

8.1.3 *Stochastic Model Conclusions*

When the strategies for good condition pasture were compared in the stochastic model simulation, the continuous conservative grazing of Base Case 1 assumes that pasture conditions will remain relatively stable over the course of twenty grazing seasons. As well, the model is set up to maintain a herd at the maximum initial sustainable level (even if this means renting pasture). Case 2's continuous unsustainable grazing assumes that overgrazing pasture units will reduce their health and ability to support grazing. This leads to the Base Case exceeding Case 2, in terms of net cash and stocking rate, as the pasture quality in Case 2 begins to deteriorate.

It was noted however, that in times of good weather and cattle prices, Case 2's overgrazing strategy could exceed the Base Case in areas such as net cash and stocking rate. However, in times of poor (dry) weather and price conditions, the Base Case would come out ahead. Comparing NPVs with equal initial cow numbers, Case 1's New NPV will equal or exceed that of Case 2 at least 65% of the time.

The simulation results provide economic support for the rancher to adopt conservative grazing strategies versus adopting an unsustainable overgrazing strategy. The difference in financial return between the two strategies may be minimal. Using the Norton et al. (1994) theoretical model to explore the trade-off between environmental quality and rancher wealth, little or no financial incentive needs to be provided to encourage ranchers in this situation to adopt conservative grazing strategies.

Cash flow analysis of the simulations of the two strategies (i.e. conservative versus long-run overgrazing) indicates that it takes at least 10 years before there is a 50% chance the conservative strategy generates higher annual net cash flows. Therefore, annual cash flow constraints, such as rancher debt or personal living expenses, may limit the adoption of conservative strategies. A rancher might adopt conservative grazing strategies if he or she could borrow to make up the cash short fall in the first ten seasons, and then pay back the loans in later years. While not specifically examined in the model, the simulation indicates there are some outcomes where overgrazing strategies will provide higher wealth (with probabilities greater than zero). One policy outcome may be to explore rancher access to long-term capital (i.e. borrowing) to implement the conservative grazing strategy.

For grazing on poor condition pasture, the regenerative strategies (Case 4 – Rotational Grazing, Case 5 – Corridor Fencing, and Case 6 – Rest-Rotational Grazing) post lower initial results than the overgrazing of Case 3. By the end of the simulation's 20 grazing seasons, the assumed degradation of Case 3's overgrazing scenario leaves it behind the regenerative strategies, in terms of stocking rate and net cash. Final Net Cash values for each of the regenerative strategies exceeded those for Case 3 (Continuous Unsustainable Grazing). Corridor Fencing saw the slowest regeneration time on the riparian area. Case 6 (Rest-Rotational Grazing), assumed to have fast regeneration under rest-rotation, proved to have the fastest regeneration time for riparian pasture in poor initial condition.

Though it has a faster assumed regeneration time, Case 6's low initial grazing capacity (reduced by one quarter for the first eight seasons) left its NPV behind that of Case 3, when equal initial cow numbers were used. Case 6's New NPV did not equal or exceed that of Case 3. The New NPVs of Cases 4 and 5 equal or exceed that of Case 3 40% and 50% of the time, respectively.

When range conditions are initially poor, the simulation results suggest the continued use of overgrazing strategies rather than adopting regeneration strategies. The costs of additional fencing and the reduced number of animals grazed make the implementation of a regeneration strategy, on average, a path to lower financial return. Though there are non-zero probabilities that the regeneration strategies sometimes lead to higher financial return, the expected outcome of adopting these strategies is lower financial return. Based on the Norton et al. (1994) model, compensation may be required to induce ranchers in these situations to adopt regenerative strategies.

The amount of funds required to promote adoption may be substantial based on the ranch situation, and the regeneration strategy chosen. The simulation results provide some guidelines to the upper bound of financial support required for the ranch modeled in this paper. As suggested by Norton et al. (1994), it must be recognized that the environmental preferences for on-ranch environmental benefits held by individual producers may reduce the dollar amount of this direct support. Similarly, the early season cash flow constraints in the three regeneration strategies examined may require additional access to long-term capital.

Compensation to adopt regenerative strategies could also come in the form of a government (Provincial, Federal, or Shared Jurisdiction) program. If long-term range and riparian health is the goal, a government program might offer start-up funding for specific on-farm programs to promote range or riparian health. Such a program might involve a matching component, whereby government matches a farmer's financial contribution up to a certain amount, for programs or strategies leading to improved range and riparian health. Government programs of a smaller scale might focus specifically on the riparian areas of ranches.

A program promoting the use of off-stream watering sites would be a low-cost way of enhancing riparian health. As strategies become more complex, ranchers would require more compensation for fencing and management costs. As the stochastic simulation noted, regenerative strategies often require selling down the herd in early seasons. Thus, ranchers would also need some compensation for lost cash flow. A program such as the Conservation Reserve Enhancement Program, reviewed by Kingsbury and Boggess (1999), may be too extreme (for producers) and expensive (for government), as it involves taking the riparian area out of production for up to 15 years, and compensating producers for the full grazing opportunity foregone.

8.1.4 *Stochastic vs. Static Results*

The stochastic model was a way of checking the results of the static model against a situation that was closer to a real-world ranch. Different results for the two models were expected, as differences between the static and stochastic models were numerous. The ranch in the stochastic model was larger (with the riparian area making up about 10% of ranch area), and modeled using variable costs not included in the static model. Weather and price conditions remained at a fixed level in the static model, but were chosen at random in the stochastic model. Cattle were not bought and sold in the static model, as they were in the stochastic one.

Some of the initial pasture conditions were set at different levels for the two model types. For instance, the total numbers of animals grazed in Season 1 of Cases 5 and 6 in the static model are almost equal. However, the regeneration of Case 5's uplands is always 2%, while that for Case 6 is 3% for the first eight seasons. For Case 4 in the static model, its regeneration rates are equal to (uplands) or lower than (riparian) those for Case 5. Case 4 also begins with approximately 30 more animals on the riparian pasture. These differences give Case 6 an advantage over the other regenerative strategies in the static model, with Case 4 the second best strategy.

When Case 6 numbers are compared for both models, even fewer animals are grazed on the riparian area in the stochastic model (starting in a more degraded pasture condition in the stochastic model) than were grazed on the initial riparian pasture of the static model. In the stochastic model, Case 5 starts at a stocking rate of 0.273 AUM/acre on both the uplands and riparian pasture. The cattle number in this case cannot fall any lower. However, the cattle number can fall for both Case 4 and Case 6 (from their initial values). The stochastic model Case 3 starts with more animals than the other cases, by a larger margin than in the static model.

An important difference to note is, in the static model, Case 3 was degraded in every case, without the chance to maintain the current level of grazing in a season (as in the stochastic model). This was because weather was assumed to remain at a specific level throughout the life of the ranch, and overgrazing was assumed to degenerate pasture in every season. The opposite was also true. In the static model regenerative cases, there is no chance of the animal unit number remaining constant over the 20 seasons of grazing, as it can in the stochastic model. Lighter grazing was assumed to regenerate pasture each season. These differences biased the results of the static model toward specific regenerative strategies, and away from degenerative ones.

The lack of weather risk in the static model also caused differences between the two model types. For example, Base Case 1 in the static model had upland and riparian grazing remain at their upper limits (0.5 AUM/acre and 1.0 AUM/acre, respectively) for all twenty grazing seasons. In the stochastic model, weather fluctuations (risk) led to long-term average upland and riparian AUM/acre values of 0.426 AUM/acre and 0.866 AUM/acre, respectively. Poor weather years meant producers in the stochastic simulation would rent pasture, in order to make up for lost grazing capacity. This suggests that the stocking rate used in the static model may have overstated the true grazing capacity of the range. Relying only on assumed degeneration/regeneration rates for changes in stocking rates, average static stocking rates would differ from average stochastic stocking rates in all cases.

Even with these differences, the static results did point out that overgrazing did provide financial incentives over conservative and regenerative strategies in some situations. The stochastic model provided insight into how often this occurred. It also highlighted the initial loss of financial return caused by the regenerative strategies' lower initial cow numbers, suggesting that real-life financial concerns such as debt and family income could have a greater impact on rancher decision-making.

The static model might be improved by using some of the long-run average results of the stochastic model. That is, an improved static model would be based on the current stochastic model, using expected value calculations. The new static model could use long-run average steer and heifer prices, long-run average grazing capacities, etc. Weather effects on the static model would use long-run average forage yields found in the stochastic model. Though the effects of weather and prices would be a "snapshot" of an average 20-year period, these changes might add more realism to the static model used in this study.

8.2 Model Limitations and Further Research

8.2.1 *Grazing Strategies and Costs*

The grazing strategies used to regenerate pasture conditions in both the static and stochastic model were based on real-world examples. However, the models assume very simplistic ranch shapes, sizes, etc. In the real world, a rancher would probably not find a riparian area flowing straight through his or her ranch, within an easily fenced corridor. That said, the diagrams used to represent the whole ranch and riparian area were used only to convey the ideas surrounding grazing and riparian area management, and were not meant as examples of actual southern Alberta ranches.

The fencing strategies used to separate animals into specific parts of a ranch were also created for simplicity. If one were intent on keeping animals out of riparian areas, then fencing across a stream to divide a ranch into grazing paddocks (Case 4) would not be the wisest decision, as animals would still have access to the area being protected.

In addition to the fence placement, the model assumed that the rancher had management time available to implement the different grazing strategies. The model did not account for the opportunity cost associated with the regenerative strategies. A rancher would forego a number of opportunities (chance to earn off-farm income, leisure time, etc.) by having to spend time fencing and moving animals through pastures. The extra work for a rancher could be factored into the model as a labour cost. The rancher would have to carefully weigh the costs and benefits associated with the different strategies.

The variable costs used in the model were obtained from AAFRD. However, they used the same cost per cow wintered for every season. In the real world, this would not be the case. For example, in a time of drought, many producers might have trouble grazing their animals on their own pasture. If rental pasture was in high demand (and supply scarce), rental prices would rise as well. Many costs, such as pasture rental cost and feed barley prices would vary with weather and market conditions. Another variation on the stochastic model might include making variable costs dynamic.

8.2.2 *Assumptions Used*

The static and stochastic models assumed that riparian areas could support twice the stocking rate of the uplands. This was a guideline provided by (Adams and Ambrose, 2001), and was not empirical. The ratio would likely vary depending on region, climate, etc. Upland and riparian recovery was assumed to be relatively linear. It is possible that a pasture would degrade very quickly under grazing, then slowly regenerate over time.

The stochastic simulation also assumed that a rancher would choose a strategy, and continue to use it for 20 seasons. Another simulation might involve allowing the rancher to change strategies at any point in the 20-year period, based on price, weather, and pasture conditions (dynamic optimization). Another simulation might involve allowing a rancher to vary stocking rate according to conditions, instead of changing the entire grazing system.

The stochastic simulation assumed that many ranch variables would not vary. However, grazing time, market weight of calves, and death loss would all vary with climatic conditions on a ranch. Allowing some change in these variables would add to model realism. Variables such as the bull turnover rate could also be made more realistic (rate used was very high). Loitering of animals in riparian areas may also be an important issue, which was not taken into consideration in this simulation. Loitering would be affected by number and placement of watering sites. The number of sites used in the static and stochastic models was likely too low to prevent loitering.

8.2.3 *Data Collection*

As noted in previous chapters, many assumptions were made considering the use of pasture on uplands and in the riparian area. While data such as fencing and maintenance costs were easily obtained, the biological data were not. For example, the rate of pasture degradation due to overgrazing was an assumption, based on losses seen in earlier riparian management studies (Adams, 2000) and conversations with range specialists (Adams and Ambrose, 2001).

The equation for forage yield was obtained from Sneva and Hyder (1962). Their work was specific to the Intermountain Region in the western United States. The weather model combined the Sneva and Hyder (1962) forage yield calculation with precipitation data from Stavely, Alberta. A forage yield equation specific to the Porcupine Hills region (Foothills Grassland range type, 18-22 inch precipitation zone) would likely have resulted in more accurate forage yield numbers.

Another option may have been to use an equation from Smoliak (1986). The author obtained range forage yields over a fifty-year period in Manyberries, in southeastern Alberta. Equations for forage yield used by Smoliak (1986) incorporated several climatic factors, including precipitation, temperature, hours of sunlight, and wind velocity. Though the grassland type was different than that assumed in this model, data and equations for Southeastern Alberta may have been more representative.

Different forage yield equation types might also be possible. Bork et al. (2001) studied grassland herbage production in the Boreal region of Central Alberta. Herbage response based on growing season precipitation was compared to response based on dormant and growing season precipitation. Though upland response was estimated using a linear regression, riparian herbage response (based on previous May to August) was measured using a linear regression incorporating quadratic terms. Further study of different forage yield models may be helpful in choosing the best one for Southern Alberta Foothills Grassland ranches.

Cohen (2001) stated that there was no single mathematical function to describe the relationship between climate and forage growth. However, researchers at the University of Saskatchewan in 2001 were working to complete a software package called GrassGro (Cohen, 2001). Software such as GrassGro would take into consideration grazing location(s), the soil textures and the management (including stocking rates, dates on and off pasture, grazing system, etc.), as well as data such as amount of rain on specific days, amount of snow pack in spring, etc. and calculate regeneration times for forages (Cohen, 2001). Adding a package such as this one to the existing stochastic model might produce more realistic results, until such time as other long-term field data were available for different grazing strategies in Alberta.

It would also be beneficial to have empirical data on degeneration and regeneration of range over time. Sensitivity analysis showed the stochastic simulation model to be sensitive to the assumed rates. Empirical rates could be used to more accurately model systems designed to rest pastures, such as rotational systems, and compare them to overgrazing scenarios. This is an area of where current range management studies are deficient.

Future research would also benefit from data collection from multiple pastures, showing rates of pasture degradation at different stocking rates, under different management strategies. This research might lead to strategies specific to particular areas. That is, a comparison of grazing strategies could be developed for specific Alberta ranches, in various range and precipitation zones. It would take into account cost, difficulty or ease of fencing, and management time involved with each strategy for the area in question.

The findings of this study are key elements in designing effective economic instruments to foster the adoption of sustainable grazing management systems. However, more research must be conducted on understanding the environmental preferences of the cattle producers. As well, the preferences of public (downstream) beneficiaries of environmental services flowing from upland and riparian rangelands must also be determined before these policies can be effectively developed.

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Appendix 1

Initial Questionnaire

What are the Costs and Benefits of Riparian Grazing Management?

We would like to evaluate the benefits and costs of riparian grazing management strategies. To do this, we need to communicate with you, the producers making changes on the ground. This is the first step in the design of a survey and evaluation. Your help at this stage will allow us to better understand the economic components of riparian grazing management. It will also help us to get this information back to you, the livestock producers making decisions.

Accordingly, we are requesting that you please fill in this brief questionnaire. The questions are about managing riparian grazing areas, and will take fifteen to twenty minutes to complete. Your participation is **voluntary** and all individual answers are confidential. The information gathered from you is confidential. Nothing that identifies the participant by name will be shared with any other participants in the project or with other agencies. The results of the study may be published, but individual responses will remain confidential.

The survey has three parts. After reading through some suggested management practices on the next page, Part I presents two scenarios concerning two unhealthy riparian areas, and requests you rank different practices for managing these areas. Part II requests that you indicate which methods of reporting benefits and costs of different riparian management practices are most useful to you. Part III requests information on whether you have cattle, and manage riparian areas.

This project is funded by the Cows and Fish Program. The evaluation is conducted by researchers from the University of Alberta. Participation in the survey is voluntary.

Contact information for Jamie Miller, Dr. Peter Boxall, and Dr. Jim Unterschultz was presented here.

Part I

1. Distribution Practices

The most basic option is to place cattle attractants in the uplands, away from riparian areas. Things like salt, minerals, upland or off-stream watering sites, oilers or rubbing posts will help draw animals away from riparian areas. With the exception of watering sites, these tend to be low-cost treatments.

2. Rotational Grazing

This strategy allows part of the range to be grazed, while other parts are rested. This normally requires subdividing a ranch into smaller pasture units. It is possible, however, to practice rotational grazing with existing pasture units, or through herding practices. This often means little infrastructure change and capital cost.

3. Deferred Rotational Grazing

Deferral means to delay grazing until a critical growth stage of the plant is passed. Along with moderate stocking rates, deferral promotes the full growth potential of range vegetation. Deferred rotation involves altering the deferral period between pastures. With more pastures, the early graze is alternated or cycled among other pastures from year to year and the harmful effects of early use are reduced.

4. Time-Controlled Grazing

Time-controlled systems minimize regrazing of the regrowth that plants require for rebuilding roots and energy supplies. This strategy involves shortening the period of grazing use on riparian pastures. High stocking rates for short periods can be harmful to woody plant restoration. This may mean moving animals if the strategy is slowing riparian recovery. More management time may be needed than in 1 or 2.

5. Rest-Rotation Grazing

Deferred rotation may not be enough to help restore woody plant growth to a badly damaged riparian area. In this case, more rest may be required. Rest-rotation grazing can involve completely resting a pasture for an entire growing season, or even a number of years. This usually allows woody plants to re-establish and become more resistant to grazing. Taking a pasture out of use for a number of years can be costly.

6. Riparian Pastures

This strategy involves defining fields to reduce variation within fields. This could mean fencing uplands separately from lowland pasture in the floodplain. Though more fencing is required for this strategy, riparian pastures can help to restore woody vegetation.

7. Holding Pastures

Holding pastures are fields where animals are held for long periods of time (winter feeding or calving). Supplemental feeding is usually required. In a riparian area, high stocking rates can be harmful. Off-stream watering sites and careful placement of supplemental feed away from riparian areas may be required. This strategy is difficult to manage and has higher infrastructure costs than other methods.

8. Corridor Fencing

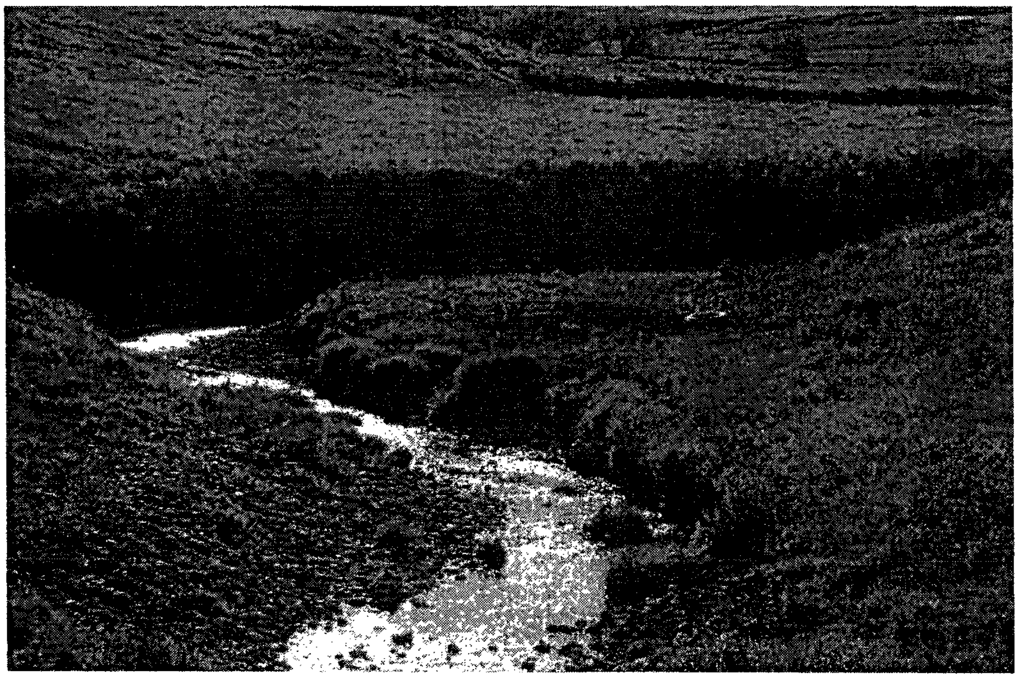
This strategy involves eliminating livestock grazing on a narrow corridor along the riparian area through fencing. This is normally a last resort measure, and can be very expensive.

Please proceed to the scenarios on the following page.

Scenario A

This quarter section-sized pasture (Figure A) has been grazed season-long for 50 years. The lowlands and riparian area are in poor condition. Grazing use is light in the uplands, where there is at least one reliable spring present. Use in the riparian area is heavy. Forage production has declined, and woody species along the stream are absent.

Figure A



If a riparian area on your ranch looked like this, which riparian management strategy would you choose to correct it? Please rank each from first choice to last choice (1-8).

_____ Distributional Practices
_____ Rotational Grazing
_____ Deferred Rotational Grazing
_____ Time-Controlled Grazing
_____ Rest-Rotation Grazing
_____ Riparian Pastures
_____ Holding Pastures
_____ Corridor Fencing

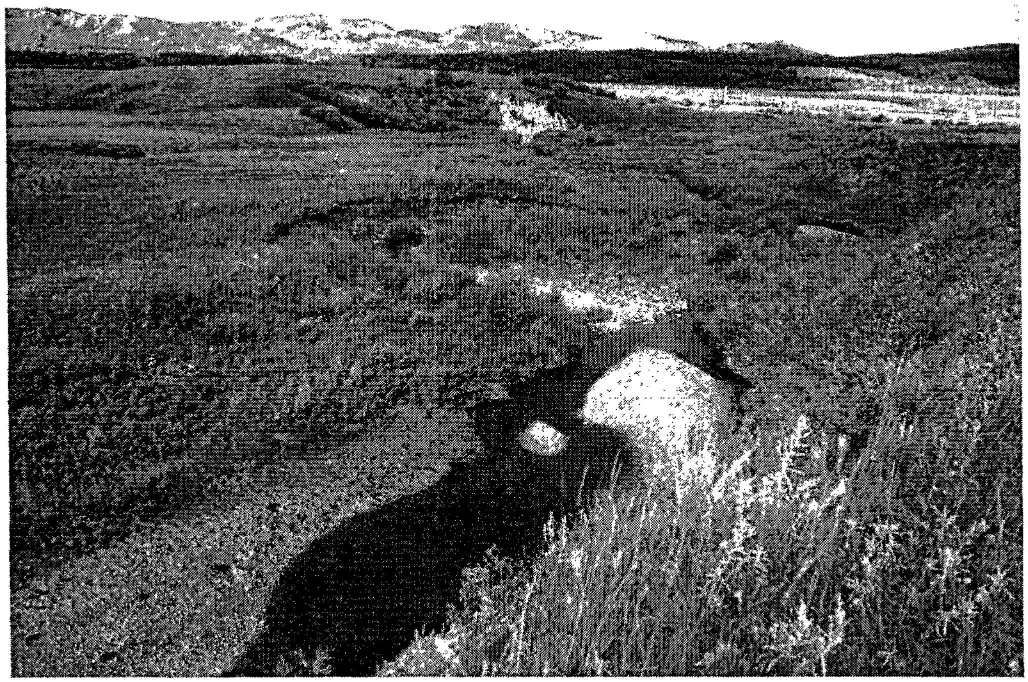
_____ Other (Specify) ___________________________

Comments?

Scenario B

This pasture is showing signs of recovery with a rotational grazing program. Forage production is improving, and young, woody plants are visible. Cattle tend to water at hardened crossings. You would like to make some additional changes to further the regeneration of woody species.

Figure B



Which riparian management strategy would you choose to manage this area? Please rank each from first choice to last choice (1-8).

Comments?

_____ Distributional Practices
_____ Rotational Grazing
_____ Deferred Rotational Grazing
_____Time-Controlled Grazing
_____ Rest-Rotation Grazing
_____ Riparian Pastures
_____ Holding Pasture
_____ Corridor Fencing

_____ Other (specify) ______________________________

How much did each of the following factors affect your management choices about Figures A and B?

Please rate them from High Influence (1) to Low Influence (7).

For example, if you chose 1 for letter a), that means that "fencing and other capital costs" highly influenced your decision.

	High Influence					Low Influence
a) Fencing and other capital costs	1	2	3	4	5	6	7
b) Management time required	1	2	3	4	5	6	7
c) Water quality for livestock	1	2	3	4	5	6	7
d) Water quality for downstream users	1	2	3	4	5	6	7
e) Effect on public perception	1	2	3	4	5	6	7
f) Changes in forage production	1	2	3	4	5	6	7
g) Changes in forage quality	1	2	3	4	5	6	7
h) Effect on fish and wildlife	1	2	3	4	5	6	7
i) Impact on short-term grazing capacity	1	2	3	4	5	6	7
j) Impact on long-term grazing capacity	1	2	3	4	5	6	7
k) Cows and Fish Recommendations	1	2	3	4	5	6	7
l) Effect on long-term ranch cash flow	1	2	3	4	5	6	7
m) Other (Examples: fish shelter, stable banks, etc.) ____________________	1	2	3	4	5	6	7

Please proceed to Part II on the next page.

Part II

When reporting the Costs/Benefits of different grazing management strategies, which one of the following measurements/units would you want to see used? Feel free to check more than one.

1. _____ Tonnes of Forage per Acre

2. _____ Animal Unit Months* of Grazing

3. _____ Net Dollars of Benefit per Acre

4. _____ Pounds of Beef per Animal Grazed

5. _____Cost ($) per Acre

6. _____ Revenue ($) per Acre

7. _____ Profit ($) per Acre

8. _____ Other (specify)

***Animal Unit Month (AUM): Amount of forage required (usually 1000 lbs of dry matter) by one AU (1000 lb cow with calf) for a month.**

Part III – Please circle, check or enter your response

1. Do you farm or ranch? Yes No

If no, this survey is complete. If yes, go to 2.

2. Do you have grazing livestock such as cattle? Yes No

If no, this survey is complete. If yes, go to 3.

3. Check the type below which describes your operation:

_____ Cow/Calf	**Number of Animals (1999)**		
_____ Backgrounder	Less than 50	_______	(cows)
_____ Finishing Cattle	50 - 199	_______	(cows)
_____ Other (specify) ___________________	More than 200	_______	(cows)

4. Do you have a riparian area (streamside green zone, or floodplain) on your ranch?

Yes No

5. Do you support the objectives of this survey?

Yes No

6. Do you think that this is a good way to get information from ranchers?

Yes No

Comments

Please feel free to add any additional comments you may have about this survey.

Thank you for your time.

Appendix 2

Responses to Initial Questionnaire

Part I

Table 1: Responses to Figure A (Scenario 1)

	Distributional Practices		Rotational Grazing		Deferred Rotational Grazing		Time Controlled Grazing	
Rank	#	%	#	%	#	%	#	%
1	9	22	3	12	4	10	2	5
2	12	30	5	15	3	8	6	15
3	4	10	6	20	11	27	8	20
4	5	12	8	22	10	24	4	10
5	3	7	9	12	5	13	4	10
6	3	7	5	7	5	13	10	23
7	2	5	3	5	2	5	7	17
8	3	7	2	7	0	0	0	0

Table 2: Continuation of Responses to Figure A (Scenario 1)

	Rest Rotation Grazing		Riparian Pastures		Holding Pasture		Corridor Fencing	
Rank	#	%	#	%	#	%	#	%
1	3	7	9	22	1	3	11	27
2	7	17	6	15	0	0	2	5
3	6	15	2	5	0	0	4	10
4	6	15	5	13	2	5	1	3
5	9	22	9	22	2	5	0	0
6	7	17	3	8	7	18	1	3
7	1	2	4	10	16	39	4	10
8	2	5	2	5	12	30	17	42

Table 3: Responses to Figure B (Scenario 2)

	Distributional Practices		Rotational Grazing		Deferred Rotational Grazing		Time Controlled Grazing	
Rank	#	%	#	%	#	%	#	%
1	16	39	4	10	6	15	5	12
2	6	15	11	26	7	17	4	10
3	1	2	8	20	11	27	10	23
4	4	10	6	15	11	27	8	19
5	6	15	5	12	4	10	7	17
6	5	12	4	10	1	2	8	19
7	1	2	3	7	0	0	0	0
8	2	5	0	0	1	2	0	0

Table 4: Continuation of Responses to Figure B (Scenario 2)

	Rest Rotation Grazing		Riparian Pastures		Holding Pasture		Corridor Fencing	
Rank	#	%	#	%	#	%	#	%
1	6	15	5	12	0	0	1	2
2	8	19	4	10	0	0	1	2
3	6	15	3	7	1	2	1	2
4	6	15	4	10	0	0	2	5
5	8	19	8	19	2	5	1	2
6	2	5	11	25	6	15	4	10
7	3	7	5	12	21	51	8	20
8	2	5	2	5	11	27	23	57

Table 5: Factors Affecting Management Choices

	Fencing and other capital costs		Management time required		Water quality for livestock		Water quality for downstream users	
Rank	#	%	#	%	#	%	#	%
1	9	20	6	14	11	25	10	23
2	11	25	6	14	10	23	4	9
3	11	25	14	31	11	26	13	29
4	7	16	9	20	6	14	10	23
5	3	7	3	7	3	7	5	11
6	3	7	6	14	2	5	2	5
7	0	0	0	0	0	0	0	0

Table 6: Continuation of Factors Affecting Management Choices

	Effect on public perception		Changes in forage production		Changes in forage quality		Effect on fish and wildlife	
Rank	#	%	#	%	#	%	#	%
1	8	18	13	30	14	32	12	28
2	9	20	12	27	11	25	12	27
3	6	14	18	41	13	30	12	27
4	11	25	0	0	5	11	5	11
5	3	7	1	2	1	2	1	2
6	4	9	0	0	0	0	2	5
7	3	7	0	0	0	0	0	0

Table 7: Continuation of Factors Affecting Management Choices

	Impact on short-term grazing capacity		Impact on long-term grazing capacity		Cows and Fish recommendations		Effect on long-term ranch cash flow	
Rank	#	%	#	%	#	%	#	%
1	5	11	14	32	4	10	12	27
2	5	11	18	40	12	29	11	26
3	6	14	7	16	12	29	11	26
4	8	18	2	5	13	30	5	12
5	11	26	2	5	1	2	1	2
6	8	18	1	2	0	0	2	5
7	1	2	0	0	0	0	1	2

Table 8: Mean Responses to Factors Affecting Management Choices

Factor Affecting management Choice	Mean Rating
Fencing and Other Capital Costs	3
Management Time Required	3
Water Quality for Livestock	3
Water Quality for Downstream Users	3
Effect on Public Perception	3
Changes in Forage Production	2
Changes in Forage Quality	2
Effect on Fish and Wildlife	2
Impact on Short-term Grazing Capacity	4
Impact on Long-term Grazing Capacity	2
Cows and Fish Recommendations	3
Effect on Long-term Ranch Cash Flow	3

Part II

Measurement Unit	Percentage of Responses
Tonnes of Forage per Acre	47%
Animal Unit Months of Grazing	69%
Net Dollars Benefit per Acre	29%
Pounds of Beef per Animal Grazed	27%
Cost ($) per Acre	38%
Revenue ($) per Acre	24%
Profit ($) per Acre	22%

Part III

Demographics

1. Do you farm or ranch?

Answer	# of Respondents	Percentage
Yes	42	95%
No	2	5%

2. Do you have grazing livestock such as cattle?

Answer	# of Respondents	Percentage
Yes	41	98%
No	1	2%

3. a) Choose the (farm) type below which best describes your operation:

Answer	# of Respondents	Percentage
Cow/Calf	37	88%
Backgrounder	12	29%
Finishing Cattle	3	7%
Other	7	17%

3. **b)** Choose the number of animals (1999)

Answer	# of Respondents	Percentage
Less than 50	4	10%
50-199	11	26%
More than 200	26	62%

4. Do you have a riparian area (streamside green zone, or floodplain) on your ranch?

Answer	# of Respondents	Percentage
Yes	33	81%
No	3	7%
NA	5	12%

5. Do you support the objectives of this survey?

Answer	# of Respondents	Percentage
Yes	34	83%
No	0	0
NA	7	17%

6. Do you think that this is a good way to get information from ranchers?

Answer	# of Respondents	Percentage
Yes	31	76%
No	2	5%
NA	8	19%