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

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Abstract

A simulation model of a ranch based in Southern Alberta was developed to evaluate the on-ranch economics of adopting different grazing management strategies to improve riparian health in rangeland. Under low cost scenarios, there are positive economic incentives to adopt strategies to maintain riparian zones that are already in good range condition. However, riparian zones in fair or poor range condition may require additional economic incentives to encourage ranches to adopt more costly management strategies. The economic incentives to adopt costly management strategies are highly sensitive to the riparian zone area, shape and rates of decline/improvement.

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

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). In Western Canada and the northwestern United States, streams in riparian areas often flow through rangelands that support herds of beef cattle (Adams and Fitch, 1998). These riparian areas are highly valued for livestock grazing as well as for other human uses (Clary 1999). Riparian zones provide significant public benefits, yet are highly vulnerable to the influence of human activities (Clary and Leininger 2000) such as private grazing operations. Overuse of riparian range by grazing operations has negative impacts on the forage quality and on the public benefits associated with riparian areas such as water quality. Riparian zones have been identified as areas in need of rehabilitation (Clary 1999; Platts and Wagstaff 1984; Saunderson 1975).

Analysis of riparian zone economics has not been adequately researched. Questions about the on-ranch economics of riparian area management, rehabilitation and how this impacts adoption of different riparian zone management strategies by individual ranchers in Western Canada have been asked. Literature on the economics of riparian zone management is scarce. There are papers outlining the economic feasibility of range management practices in either a general approach (Workman and Tanaka 1991, Batabyal and Godfrey 2002) or in specific circumstances (Johnson et al. 1999). Economists have provided various models and results on grazing management (Garoian, Mjelde and Conner 1990; Karp and Pope 1984; Huffaker and Cooper 1995; Passmore and Brown 1991; Pope and McBryde 1984; Torell, Lyon and Godfrey 1991), but these have not included separate analysis of riparian zones.

Tanaka, Rimbey and Stillings (1999) developed a bioeconomic multi-period non-linear programming model to evaluate the economics of managing riparian zones in northeast Oregon. They reported that a ranch with approximately 300 head cow herd could increase annual gross margin by over $7000 (US) by implementing management practices such as off-stream waterers and off-stream salt. These management practices improved the dispersion of cattle. It should be noted that there was a penalty in the model for exceeding pre-set utilization forage levels in the riparian zone situated on leased public land. Tanaka et al. did not explore the economics of riparian zone improvement specifically or alternative strategies that required more expensive management alternatives. We provide further research steps by outlining a series of on-ranch economic outcomes related to riparian zone management. These outcomes apply to the fescue grassland soils region of Western Canada.

The economist's dilemma with undertaking this analysis has been identified by Workman and Tanaka (1991) and Tanaka et al. (1999). The most important variable for economic analysis in these situations is the long-run forage response function to weather and grazing, however data on long-run response functions for rangeland are usually not available or unreliable. Researchers on riparian zone management have identified significant gaps in the research. Larsen et al. (1998) in their literature assessment of over 1500 articles related to riparian zones concluded that up to 1996 there had been little progress on key research questions regarding riparian areas. Much of the body of knowledge on common usage for riparian areas is made up of non-refereed, non-experimental or experimentally inadequate reports or findings. Recommendations for managing riparian zones continue to be based on collective experience and case studies (Clary 1999). Holechek Pieper and Herbel (2001: 279) claim there is a lack of replicated long-term studies comparing riparian recovery under controlled experimentation and Sarr (2002) discusses the difficulties of undertaking livestock impact on riparian zone research. Typical research findings do not provide enough information to estimate long-run forage response functions for different management strategies (i.e. Schultz and Leininger 1990; Richard and Cushing 1982). This research lacuna is not confined to riparian zones and has been identified as a research shortcoming in upland range (Dormaar and Willms 1998).

Action to improve riparian zones in rangeland is deemed necessary due to the provision of important public benefits associated with these areas. Projects such as the Alberta Riparian Habitat Management Program (also called Cows and Fish) have been developed to promote on-ranch management strategies to improve riparian zones in poor to fair condition or to maintain existing riparian zones in good to excellent conditions. These strategies range from simple changes in animal distribution to more labour-intensive and costly fencing strategies (Adams and Fitch 1998). Scrimgeour and Kendall (2002) in their study on livestock impacts on water quality in a southeast area of Alberta Canada, also provide a series of livestock management strategy suggestions to improve riparian areas. However questions as to the on-ranch economics (i.e. private costs and benefits to ranchers) of these different strategies are being raised. Since riparian zone programs are being developed and promoted to ranchers, it is incumbent upon the research community to also begin addressing these economic questions. As suggested by Workman and Tanaka (1991) this leaves two alternatives: 1) make educated guesses as to the response function; or 2) rely on simpler models to evaluate near-optimal solutions keeping in mind the data limitation caveats. Our research approach is to make educated guesses about long-run responses functions, apply these in a simulation model setting and evaluate an array of management scenarios.

This study addresses some of the missing economic information on the economics of grazing and in particular the economics of riparian zone grazing management in Southern Alberta, Canada. On-ranch costs and benefits of various riparian area management schemes for a hypothetical ranch in Southern Alberta are evaluated. Net Present Value (NPV) stochastic simulation models incorporating dynamic prices and weather impacts are used to model and evaluate riparian zone grazing management strategies in a whole ranch setting. The simulation model is not a decision tool for within season grazing management but a tool for evaluating long-run impacts on the economics of the ranch adopting different riparian zone management strategies. This tool is adaptable to different ranch settings and can in future be used to evaluate policy alternatives such as discussed by Weersink, Jeffrey and Pannell (2002). This general approach recognizes that vegetation responses are highly site specific and that riparian ecosystems are highly variable in space and time (Larsen et al. 1998, Sarr 2002).

Additional Background

Alberta has over 6.5 million hectares of natural rangeland for pasture, and about 1.9 million hectares of tame or seeded pasture. While much of this rangeland is publicly owned, it is managed under long term leases with private ranchers. Riparian areas may account for up to 2% of the area of this rangeland (Adams and Fitch, 1998). Kauffman and Kreuger (1984) suggest that riparian areas form a minor proportion of the overall grazing area (i.e. 1 to 2% of the summer range in the US Pacific Northwest) but that a significant portion of this rangeland is used by the cattle industry.

Detailed discussions are found elsewhere describing riparian areas (i.e. Kauffman and Kreuger 1984; Clary and Leininger 2000; Hawkins, 1994; Adams and Fitch 1998) and associated management strategies. From a rancher's viewpoint riparian areas stay greener longer and produce more forage per unit area than upland range. Thus, further claims are made that riparian areas serve as important buffer zones for a ranch. If a drought or flood occurs, these zones serve as an insurance policy for ranchers. Droughts are offset by a higher water table, while the effects of floods are lessened by deep-rooted riparian vegetation (Stillings, 1997).

Previous research has established that cattle grazing can adversely impact riparian zones. Research identifies that ranches following range management practices designed to maintain the upland carrying capacity may still lead to a decline in the ecosystem health and carrying capacity of riparian zones. Water, forage quality and shade attract cattle to the riparian zone (Marlow and Pogacnik 1986, Platts and Wagstaff 1984, Clary and Leininger 2000) resulting in heavy grazing pressure on the zone. Riparian zone grazing capacity may decline despite a conservative stocking rate designed to maintain upland carrying capacity. While a continuous grazing strategy with a moderate stocking rate may be appropriate for uplands, it may be damaging to riparian zones (Holechek et al. 2001: 248, 250 and 277).

Several on-range management strategies are proposed to improve riparian areas. These can vary from low cost changes in management practice to more expensive fencing and destocking alternatives. We view these as a continuum of practices going from the least expensive to more expensive without specifying a specific management practice. For example, at the low cost end changes in management may entail attending management training courses to learn alternative practices associated with managing riparian areas (e.g. placement of salt and mineral; McInnis and McIver 2001). The next level of costs may involve management training plus placement of additional off-stream watering sites to improve distribution practice. The higher cost levels may involve management training (MT), additional off-stream watering sites (W) and some level of additional fencing (F). Each of these strategies may also be associated with some reduction in stocking rate in the riparian zone. The least cost strategies are associated with changing the distribution practice of cattle by using off-stream waterers and salt placement, whereas the most expensive strategies are associated with various rotational grazing systems that may include corridor fencing and long-run stocking rate reductions. Due to the highly variable features of riparian zones and their associated uplands such as. area, shape, gradient, aspect, topography, elevation and plant community (Kauffman and Kreuger), cost will vary across sites. A limited series of costs and scenario alternatives are presented here.

The key costs associated with these management strategies are capital costs such as fencing or watering installation; annual maintenance costs of this equipment, and reduced carrying capacity. While the management time opportunity costs of implementing these strategies has been cited as another cost, it is not clear that this should be included since the true opportunity cost for some rancher's time may actually be close to zero.

The voluntary adoption of riparian management strategies can be thought of as improving on-ranch environmental quality. This improvement may result in reduced profit for the landowner, yet provide considerable off-farm social benefits through increased provision of public goods such as wildlife habitat. Norton, Phipps; and Fletcher (1994) provide theoretical tools to evaluate voluntary programs such as Cows and Fish for managing riparian areas. Two key issues are identified in their model. These issues are the individual rancher's preference trade-off between ranch profits and on-ranch riparian area health and the actual tradeoff between ranch profits and riparian management. This study provides steps in identifying this second tradeoff between ranch profits and riparian range management. Ribaudo and Horan (1999) in a North American context and Rhodes et al. (2002) in a New Zealand setting indicate that net returns or financial considerations are the major concern of agricultural producers when evaluating alternative management practices related to nonpoint pollution policies. However, Torrell et al. (2001) argue that rancher preferences in the United States are highly influenced by quality of life factors, and that a profit motive may not be sufficient to explain rancher investment decisions. Analysis of the on-ranch riparian economics can be an important predictor of adoption of alternative management strategies, or at the very least, provide bounds on the economic impacts on the ranch of adopting alternative riparian zone management strategies.

A Model Ranch

Overview of the Model

This study analyzes the private economic impacts of adopting various riparian management strategies. The cash flow and associated cattle business parameters for a model ranch are examined over a 20-year period. The ranch is assumed to have features similar to those of a cow/calf operation with riparian and upland range in southwestern Alberta in the fescue grassland areas similar to the location described in Willms, Smoliak and Dormaar (1985) or Dormaar and Willms (1998). Upland and riparian areas can be separated in the model. Annual prices of cattle and forage yields vary stochastically during the 20-year time period. Thus, there are elements of risk in this operation that are dependent on dynamic economic forces external to the ranch and random events such as annual precipitation levels. For each grazing strategy examined, the ranch operated for a 20-year period. This operation was simulated 5,000 times, each year of which involved a different random draw from a series of prices and forage yields. Simple perpetuity factors were added to the model to capture benefits or costs beyond the twenty-year period. Where feasible, multiple ranch scenarios were compared based on the same 5000 simulations of prices and weather.

The area of range on this ranch was fixed at 2185 hectares. While this size can be changed in the model, selected parameters are fixed to permit comparisons between different scenarios. The size of the riparian area is varied from 22 ha to 164 ha (i.e. 1% to 7% of the ranch area). Three beginning riparian zone range conditions are evaluated. Initial riparian zone range conditions are either good, fair or poor. Our definitions of good, fair and poor range conditions follow the definitions described by Holechek et al. (2001: 185). All situations assume that the upland range remains in good condition. While the model can incorporate changing upland range conditions, the focus is to evaluate the economics of riparian zones. Adding changes to the upland range condition confounds the results reported for the riparian area. An alternative justification is that we are modeling the behaviour of a rancher who conservatively manages the upland portion of the ranch through moderate continuous grazing and evaluating the economic impacts of various strategies applied to the riparian zone.

According to Willms et al. (1985), Holechek et al. (2001) and others, the most critical decision that must be made by beef producers is choice of the stocking rate on their range. Stocking rate is expressed here as Animal Unit Months (AUM) per hectare (ha). The choice of a stocking rate can be a difficult decision to make. Parsch, Popp and Loewer (1997) noted that producers must consider future weather patterns in their decisions. Weather patterns (specifically precipitation levels) can determine how much forage is available to grazing livestock. In addition to weather patterns, Parsch et al. (1997) noted that the stocking rate also has an effect on the amount of forage available. Batabyal, Biswas and Godfrey. (2001) determined theoretically that an optimally chosen stocking rate would result in lower long-run expected net unit costs than an optimally chosen grazing cycle length (i.e. length of grazing season). Therefore, the decision variables in this simulation model rely on decision rules for short-run and long-run stocking rates.

The model incorporates a long-run and a short-run planning horizon with the stocking rate decision, but unlike the dynamic optimization stocker cattle model of Torrell et al. (1991), a simulation model is used with a cow-calf operation. The long-run models the maximum carrying capacity based upon expected range conditions. The carrying capacity changes depending on decision parameters in the model and past weather. The rancher is assumed to match the herd size (i.e. AU) to the expected carrying capacity. In the short-run (i.e. a single year), conservative grazing strategies that adjust yearly stocking rates based on the expected carrying capacity for that year and the current year annual forage index are modeled. The carrying capacity for the time period determines the total AUM of grazing expected to be available and the annual forage index determines the AUM that are actually available that year under a conservative grazing strategy. Additional AUM of grazing are purchased as required in the short-run to match the cow herd and the short-run ranch carrying capacity. The ranch manager is assumed to optimally allocate the AUM within the grazing season if a management system other than continuous grazing is in place. At the start of every period the cow herd matches the expected long-run carrying capacity (i.e. cows are sold or bred heifers are purchased). A calf weight response function (i.e. weight gain as a function of total annual forage production available per AU) based directly on Willms, Smoliak and Schaalje. (1986: Figure 3) is incorporated in the model. It has little impact on the results reported here under a conservative manager who aggressively destocks in response to short-run forage availability. The grazing time available each year was assumed to be 5.5 months and was not varied.

The foothills grassland upland range type, in the 457 to 559 millimeter (annual) precipitation zone in good condition can support a carrying capacity of 1.24 AUM/ha or 0.5 AUM/acre (Adams, Ehlert and Robertson 1991). Dormaar and Willms (1998) indicate that recommended stocking rates for this area have been 1.6 AUM/ha. Their research suggests stocking at 1.6 AUM/ha resulted in a long-run decline in range condition whereas stocking at 1.2 AUM/ha over 32 years did not affect range condition. Bork, Thomas, McDougall (2001) report forage production in riparian zones double that of uplands. Platts and Wagstaff (1984) suggest productive riparian zones could have grazing at 2.5 AUM/ha. Personal communication with local range experts confirmed that riparian zones were expected to nominally support double the upland stocking rate.

Assumptions for the herd on this ranch involved parameters for a breeding program, calf growth rates, death rates, and culling rates. These assumptions were chosen from records on beef operations held by beef experts at the Alberta Department of Agriculture, Food and Rural Development. For example, the rancher's breeding program involved retention of some of the herd. This retention rate was assumed to be 10% of the heifer calves in the herd and these retained animals were not included in total calf sales from the ranch each year. The calf expected weight was 250kg (550 lbs) at time of marketing. Cows in the herd were culled at a rate of 7% annually. If the number of cows culled was greater than the number of replacement heifers available for the breeding program, then the rancher was assumed to purchase the extra bred heifers to maintain the cow herd at the expected range capacity. Decisions rules were added to the models to vary herd size and rent additional pasture/range as required based on the management strategy. The base models charged $16.81/AUM to rent additional pasture during the grazing season. Alternatively this could be viewed as the purchase of feed to maintain a cow herd when short-run forage production is low.

Stochastic Element 1: Cattle Prices

Econometric time series models in which the prices for steers, heifers, bred heifers and cull cows are correlated through time were used to forecast cattle prices in each time period. The following system of price equations was estimated using Seemingly Unrelated Regressions (SUR) procedures to capture the correlation across price equations.

$$P^S_t = \alpha^S_0 + \alpha^S_1 P^S_{t-1} + \alpha^S_2 P^S_{t-2} + \alpha^S_3 P^S_{t-3} + \varepsilon_S$$

$$P^H_t = \alpha^H_0 + \alpha^H_1 P^H_{t-1} + \alpha^H_2 P^H_{t-2} + \alpha^H_3 P^H_{t-3} + \varepsilon_H$$

$$P^B_t = \alpha^B_0 + \alpha^B_1 P^B_{t-1} + \alpha^B_2 P^B_{t-2} + \alpha^B_3 P^B_{t-3} + \varepsilon_B$$

$$P^C_t = \alpha^C_0 + \alpha^C_1 P^C_{t-1} + \alpha^C_2 P^C_{t-2} + \alpha^C_3 P^C_{t-3} + \varepsilon_{C.}$$

The superscripts *S*, *H*, *B*, and *C* index steers, heifers, bred heifers and cull cows respectively. 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 periods respectively, α_0 represents the intercept parameter, α_1 through α_3 are the parameters on the current and lagged prices, and the ε's represent the error terms associated with each price equation. This functional form identifies that each price in the present time period is dependent on the prices in the previous three periods. Since the objective was to simply develop a set of equations to model price through time, an exhaustive analysis of stationarity of the price system was not conducted. Implicitly prices are modeled as a mean-reverting series. That is, a mean and a variance exist for these prices. For a discussion of these technical issues readers are referred to the rich econometric literature on unit roots and cointegration testing (e.g. Lutkepohl 1993).

To estimate the parameters for this system, biannual cattle price data (November and May for the years 1976 to 2000) were obtained from AAFRD. Prices were adjusted for inflation using Consumer Price Index (Statistics Canada). Table 1 reports the parameter estimates and correlation coefficients between the four equations. Correlations are important for modeling the relationship between prices through time.

The price in any period is a function of the prices in past periods, as well as the error structure of the price system, thus capturing the time correlation of prices. For example the price of cull cows involves use of the three parameters in Table 1 and the appropriate prices in the previous three periods. Stochasticity enters through the error term of the cull cow equation which is a function of the equation standard deviation, correlation among the errors of the four price equations (Table 1) and a random draw from a normal distribution with mean 0 and standard deviation 1. Procedures (i.e. min and max functions) were used to ensure that each price generated was positive and within the ranges of price data provided by AAFRD. The model could simulate cattle prices through time and introduce positive or negative price shocks at the beginning of the modeling period.

Stochastic Element 2: Forage Yields

Details on the four forage index (FYI) models evaluated are discussed below. Although the growth of forage is dependent on sunlight, temperature, and other factors, precipitation was chosen as a proxy for all elements contributing to forage growth. Daily precipitation data for southern Alberta (Stavely, in the Porcupine Hills region) were obtained from W. Willms and total precipitation amounts during the grazing period (May to August) for the years 1960 through 2000 were calculated. From this precipitation record an index was determined by dividing the annual growing season precipitation amount by the median precipitation level over the 41 years, and multiplying by 100. Forty-one forage yield indices were calculated from the precipitation index using the models discussed below. Each of these indices was assumed to be independent and thus equally likely to occur in a given year. Generally, precipitation data is more readily available than direct forage yield data. This approach was chosen so that this model can be more easily adjusted to other ranches. Also, this approach matches the suggestion by Thurow and Taylor (1999) that median rainfall is the statistically more appropriate way to express normal rainfall. The stochastic method for simulating FYI preserves the skewness observed in precipitation data.

Sneva and Hyder (1962) calculated an upland forage index function for the U.S. intermountain region where the annual forage index is a linear function of the precipitation index. Western Canadian data reported in Smoliak (1986) and Bork et al. (2001) were used to estimate alternative linear upland forage index models. A riparian forage index model was also calculated from the Bork et al. riparian data that includes a quadratic index term similar to the short-run production function estimated by Bork et al. Figure 1 compares the forage index model forecasts as the precipitation index is varied. The FYI from the Bork et al. data for uplands and Smoliak data for uplands yield very similar forecasts despite the fact the Bork et al. data are from the boreal grassland region and the Smoliak data are from the mixed prairie region of Alberta. The Sneva and Hyda model (1962, Figure 1) forecasts wider variations in FYI indices given the same precipitation indices. Since the rainfall for the boreal grassland region is closer to the rainfall for the rough fescue grassland of our model, the Bork et al. upland model (Table 2) was chosen to simulate the upland FYI. While a separate FYI index for the riparian zone is preferred, the negative FYI forecasts from the riparian model (Figure 1) are not suitable for a simulation model. The upland FYI based on Bork et al. data is also used to develop the FYI (i.e. nominally 2 times the upland index) for the riparian area.

The annual FYI drawn in the simulation enters into two decision rules. It determines the per period stocking rate on own range and the expected range condition in the following year (i.e. long run response function or expected carrying capacity). The manager responds to the short run ranch stocking rate decision when the FYI drops below some predetermined FYI. For example, the simulations under good riparian condition reported here had a FYI of 70. Any annual FYI below 70 results in short-run destocking (i.e. renting of pasture) to match the AU to the ranch capacity. FYI above 70 result in the complete cow herd grazing on the ranch's own range. The model also checks the prior period FYI since, as discussed by Holechek et al. (2001: 49.), two or more consecutive years of drought have more impact on forage than one year of low precipitation.

It is in the long-run response that additional guesses have been incorporated into the model. Four different FYI cutoff levels were used to determine annual changes in long run carrying capacity. Riparian zones highly sensitive to overgrazing are modeled with higher FYI cut off levels for triggering either rates of decline or rates of improvement. Less sensitive riparian zones have lower FYI cut-off levels for triggering rates of decline or rates of improvement. Rates of decline or improvement associated with any FYI cut-off level could be varied across scenarios to achieve different expected rates (i.e. mean rates) of decline or improvement.

A series of mean rates of long-run riparian zone decline or improvement were evaluated to capture the array of possibilities alluded to by the academic and extension literature. Torell et al. (1991, equation of motion Table 2) used an expected 5.4% rate of decline at the recommend stocking rates and starting in good range condition. Clary and Leininger (2000) state that riparian zones are highly vulnerable to human activity suggesting significant rates of mean annual decline in expected carrying capacity under a continuous grazing system. Adams and Fitch (1998, p 3) state that in some circumstances, the decline in the riparian zone can be very slow and extend beyond the memory of one individual such that individuals fail to notice the decline in the riparian zone. This suggests mean rates of decline of 1% or less. The simulation models are varied to capture a variety of expected mean rates of riparian zone decline.

Similarly Adams and Fitch (1998) present a simple case study suggesting that in some circumstances riparian zone forage production can recover quickly with different management strategies (e.g. over 10%/year improvement in forage production implied in their Callum Creek example). Clary (1999) indicates that riparian zone improvements are slow in a different type of rangeland. A variety of rates of improvement are possible depending upon the current state of the riparian zone and the sensitivity of the zone to human activities. No single mean rate of decline or improvement fits the varied riparian zone eco-systems reported in the research.

Additional Non-Stochastic Elements

Costs of implementing different riparian management strategies may be highly sensitive to the size and shape of the riparian area. Capital expenditures such as off site waterers come in fixed investment increments. Fencing costs, if required, are sensitive to the size and the shape of the riparian zone under management. For simplicity, the riparian zone is assumed to be either rectangular or circular. If rectangular, the width can vary from just a few meters to several hundred meters. This variation in perimeter length has a large impact on fencing costs.[1]

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[1] Dosskey (1998) suggests that a riparian zone width of 10 to 75 meters may be required for wildlife habitat needs. However, management needs vary from one location to the next.

If the costs associated with management training, offsite waterers and fencing are assumed to be non-stochastic and fully charged to the riparian zone of the ranch, these can be analyzed separately from the simulation to explore their importance. Table 3 provides a comparison of the present value of costs per hectare under increasingly higher cost scenarios and illustrates the impact of zone shape on the costs. The present value of costs are calculated as:

$$PV = \text{Initial Capital Costs} + (0.025 \times \text{Initial Capital Costs})/r$$

where PV is present value, Initial Capital Costs are all the investment costs at time 0, 0.025 is the proportion of original capital costs used to estimate annual maintenance costs for waterers or fences, and r is the risk adjusted discount rate used in the perpetuity for the PV of maintenance costs. For simplicity it was assumed the fence or waterers, if maintained, would last for a very long time. Costs per hectare are highly sensitive to zone width and area when additional fencing is included in the management scenarios. For example under the assumptions for this ranch with 2.5% riparian area, the present value of costs may range from $18/ha in the riparian zone for some management training up to $1796/ha if the management strategy includes completely fencing a 30.5 meter (m) wide riparian zone.

The choice of the discount rate is critical in any net present value analysis. The ranch owners are assumed to be non-diversified investors in the ranch and thus an appropriate risk adjusted discount rate needs to account for this whole firm risk. Using the capital market line, estimates of public risk premiums in Canada reported in Ross et al. (1999) and standard deviation of cow-calf enterprise returns observed by Bauer (1997) or Munro (1993), the appropriate risk adjusted discount rate is in the range of 10 to 12 %. If adjusted for approximately 1 to 2 % inflation this puts the risk adjusted rate at 10% which is the base case discount rate used in the model. Issues related to the appropriateness of using a risk adjusted discount rate in models that are directly simulating risk are discussed below. Since individual ranch businesses may have widely varying capital structures, this ranch model is based on 100% equity.

Grazing Management Scenarios

Three general starting scenarios are explored along with variations on each scenario. These are:

1) Decline scenarios on riparian zone starting in good range condition (2.48 AUM/ha nominal period 1 zone carrying capacity).
2) Improvement scenarios on riparian zone starting in fair range condition (1.24 AUM/ha nominal period 1 zone carrying capacity).
3) Improvement scenarios on riparian zone in starting poor range condition ((0.74 AUM/ha nominal period 1 zone carrying capacity).

The decline scenarios explore ranch economic incentives to implement management strategies to prevent the decline of riparian zones when the upland range is managed under a conservative continuous grazing system. The improvement scenarios explore the benefits and costs of implementing management strategies to improve riparian zones whose grazing capacity has already been reduced. Sensitivity to costs, discount rates, decline rates and improvement rates are examined. Drought buffering values of riparian zones and model sensitivity to cattle price shocks are also presented.

Results and Discussion

Figures 2 through 15 present an overview of results from the ranch simulation models. Decline scenarios have the ranch starting with over 500 cow-calf units. Improvement scenarios start with less than 500 cow-calf units. Economic results are presented on a per hectare basis to allow comparisons across scenarios. A key caveat is that all costs or benefits are attributed to the riparian zone and that there are no additional benefits or costs to the upland range.

Decline Scenario Outcomes.

The decline scenarios compare outcomes with no decline in the grazing capacity of the riparian zone to a ranch under conservative upland grazing strategies that still result in overuse or damage to the riparian zone. The key drivers in these simulation scenarios are the annual FYI function and rates of decline. Figure 2 provides an overview of the decline scenario's long-run mean rates of zone decline. Rates from 6% to under 1% are modeled and 90% confidence intervals (CI) are also shown.[2] This series of mean decline rates captures the essence of the extension and academic literature on possible rates of riparian zone decline.

The NPV results associated with no decline in riparian zone forage production versus riparian zone decline are reported in Figure 3. These results illustrate the economic differences when the riparian zone size is varied and no remedial costs are included. The lost economic value per hectare compared to no decline is relatively insensitive to the size of the riparian area, but highly sensitive to the rate of decline.

The economic results are highly sensitive to the size of the riparian zone area when costly management strategies related to distributional practices and additional fencing costs (MT+2W+1/2F) for a riparian zone of 122 m width are included (Figure 4). At a 6.1% or a 5% rate of decline the expected NPV is positive when the riparian area is 109 ha (i.e. 5% of the ranch area). For less sensitive riparian zones, this management strategy results in negative expected NPVs. A 2185 ha ranch with 109 ha in the riparian zone is much higher than the average riparian area expected in rangeland. The benefits per hectare decrease as the zone area

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[2] 90% CI is the standard output from the simulation spreadsheet software used.

decreases. The 90% CI on the 55 ha (2.5% ranch area in the zone) scenario indicates there is about a 50% probability that the management strategy will result in a positive net benefits to the ranch if the mean rate of zone decline with no management change is 6.1%.

Table 3, Figure 3 and Figure 4 combine to provide an overview of model sensitivities to riparian shape, area and direct costs. The larger the area or the wider the zone the more likely that implementing costly management strategies will lead to positive NPV. A key policy implication arises from these results. Range recommendations or research on riparian zones from earlier literature (i.e. Platts and Wagstaff 1984) suggested that a significant fencing component was required to manage these areas and prevent decline. Under these types of recommendations even with no change in stocking rates, the higher NPV on-ranch economic strategy for relatively low rates of riparian zone decline (i.e. under 3%) is to allow the riparian zone to decline. The smaller the riparian area relative to the ranch size, the less the on-ranch economic impact of allowing the riparian zone to decline. This relationship holds regardless of the rate of expected decline. The rational economic strategy for a rancher (higher NPV) is to manage the uplands and ignore the riparian zone when rates of zone decline are low or the zone represents a small portion of the ranch area.

The remaining scenarios presented here explore a specific size and shape for the riparian zone. The size is 122 m wide rectangular riparian zone comprising 55 ha (2.5% of the ranch area). Unless stated otherwise a 10% discount rate is used. 90% model CI bounds can be placed around any of these results, but for ease of presentation only selected results show the CI.

Economic models are highly sensitive to the discount rate used. Figure 5 illustrates the discount rate sensitivity for the 55 ha rectangular riparian zone under the MT+2W+1/2F management strategy. A 7% discount rate, combined with mean annual rates of decline of 0.8%

or 1.6% still suggest the on-ranch value enhancing strategy is to allow the riparian zone to decline.

Two final scenarios are illustrated here for the riparian zone starting in good range condition. Figure 6 provides an overview of the impact of short run price expectations on economic incentives to deliberately overgraze the riparian zone *after* investing in off-stream waterers and fencing (i.e. fencing and waterers are a sunk cost).. That is, the riparian zone can be managed separately from the uplands. The riparian zone is deliberately stocked in the decline alternative at 30% over the long-run carrying capacity. This is compared to the situation where the riparian zone is not overstocked and there is no long-run decline in riparian zone forage production. The impact of short-run changes in expectations on cattle price is also included. Under low rates of expected zone decline there are economic incentives to overstock the zone. An expected positive price shock (i.e. short-run prices $30 higher than the long-run average calf price) increases the incentives to overstock the zone. A negative price shock decreases the incentive to overstock the riparian zone..

Figure 6 emphasizes an important policy issue for range researchers. Ex poste, after adding off-stream waterers and new fencing, the higher on ranch wealth strategy may be to deliberately overgraze the riparian zone. The incentives to overgraze the zone decrease as the zone sensitivity to overgrazing increases or as calf prices decrease. Hence, penalty functions on publicly owned rangeland, such as modeled by Tanaka et al. (1999), may be required to prevent zone decline after investing in waterers and fencing.

Expert opinion, when consulted about the value of riparian areas in a ranch, claimed that one of the benefits of having these areas are their ability to buffer ranch grazing when dry weather reduces forage production on upland range. The short-run FYI used in the simulation determined when to undertake short-run destocking (i.e. rent additional pasture). A lower FYI cutoff implies a greater buffering capacity, or a riparian area less sensitive to fluctuation in annual precipitation. The FYI cutoff was varied from 90 to 50 and the resulting NPVs compared to a FYI cutoff of 100 (i.e. highly sensitive to lower precipitation). Riparian zones that are relatively insensitive to annual precipitation can contribute up to $50/ha in present value to the riparian zone (Figure 7). This value includes only the drought buffering capacity and excludes the extra value a riparian area adds to a ranch due to its higher expected grazing capacity. Alternatively the results in Figure 7 can be interpreted as the loss in value of a riparian zone as it loses its drought buffering capacity, but still maintains the same carrying capacity with median to above median precipitation. The greater the market charges for pasture rental, the greater the present value of this buffering capacity. Again these results implicitly assume the ranch can already manage the riparian zone separately from the uplands.

Riparian Zone Initial Period Condition: Fair or Poor

Range managers and policy makers are not only concerned with stopping the decline in riparian zones in good condition, but also with developing strategies to improve riparian zones that are already damaged through over-grazing. A separate simulation model, very similar to the riparian zone in good condition, was created to assess the on-ranch economics of strategies that improve riparian zones. Figure 8 provides an overview of the set of mean expected rates of improvement scenarios. Most improvement scenarios are compared to no management changes with continued decline in the riparian zone at an expected rate of 4.9% per year. The rapid improvement scenario upper CI bound would encompass the recovery rates implicitly provided by Adams and Fitch (1998) in their Callum Creek case study, a creek located in the region covered by these models.

The on-ranch economics associated with a low cost (MT+2W) and a medium cost (MT+2W+1/2F) management strategy when the riparian zone starts in fair condition are presented in Figure 9. Under the low cost scenario the expected benefit of implementing these strategies is positive even if the strategy only stops the zone decline. Riparian zone improvements expected to be less that 4%/year result in negative benefit under the medium cost scenario. Only at higher rates of rangeland improvement does the present value of the expected benefits exceed the present value of the costs. However the 90% CI on the medium cost strategy with an annual improvement rate of 7% shows a 5% chance that the expected benefits of implementing the strategy will be under-$100/hectare. Weather and price variability contributes to a wide range of possible economic outcomes.

Alternative scenarios may include high cost management strategies requiring reductions in stocking rates in the zone. Three different rates of mean improvement and five different period 1 stocking rate assumptions are shown in Figure10. This is compared to “do no change in the management system” and allow the riparian zone in fair condition to continue to decline at an expected rate of -4.9% per year. Stocking rates translated into total animal unite increase as the riparian zone improves as illustrated in Figure 11. All scenarios that require a reduction in the stocking rate to 0.99AUM/ha or lower, combined with the MT+2W+1/2F result in an expected negative economic ranch benefit. If the stocking rate is cut from 1.24 to 0.74 AUM/ha, there is only a 5% chance the ranch will have a positive economic benefit under high (i.e. 7.3%) zone improvement rates.

Results where the riparian zone starts in poor range condition are presented in Figures 12, and 13. These scenarios are similar to the ones described for riparian zones starting in fair condition. Starting from poor range conditions there are even lower on-ranch economic incentives to implement costly management strategies. For example, under low cost management scenarios with 55 ha in the zone, there is no economic incentive to maintain or improve the riparian zone (Figure 12). In contrast, ranches with zones in fair condition have an economic incentive to implement low cost improvement strategies even if this only stops continued zone decline. The riparian zone in poor condition makes a minor contribution to the on-ranch economics. Implementing medium cost strategies will not increase the economic wealth of the business. As with all results reported, these conclusions are sensitive to the rates of improvement or decline, zone size, zone shape and starting carrying capacity. This group of poor scenarios also assumes that recovery of the grazing capacity in the riparian zone is possible. Batabyal and Godfrey (2002) propose a state and transition model on rangeland dynamics that formally includes poor conditions from which rangeland cannot recover.

Cash Flow Projections

NPV calculations are problematic in simulation modeling exercises since risk is being accounted for two times. First, the discount rate (e.g. 10% in the base models) already incorporates a risk factor. Second, adding stochastic cattle prices and FYI components to the simulation directly models risk. Thus, while the mean or expected NPV is reported in the results above, other measures such as comparing cash flow differences each period over the 5,000 iterations may be more appropriate for capturing rancher’s risk preferences.

To address this concern, selected strategies are examined by comparing differences in cash flows over time. Figures 14 and 15 illustrate scenarios of improvement with high costs versus continued zone decline from fair or poor range condition. Three different period one stocking rates are compared. The net cash difference (i.e. annual gross margin), not discounted, illustrates the pattern of these differences in cash flow. It takes until period 9 before there is about a 50% chance that the cash flow from the riparian zone with an initial stocking rate 0.74 AUM/ha will exceed the no management action strategy under fair range starting conditions (Figure 14).

The tracking of cash flows over time does not allow specific conclusions about which strategy should be preferred by a ranch manager, but it does indicate the impact on annual cash surplus (i.e. gross margin) in the business that adopts different management strategies. Ranchers facing high demand on the cash surplus, such as debt repayment or family cycle living expenses, may find it difficult to choose an improvement strategy where expected cash flows decrease. There are non-zero probabilities of superior outcomes as measured by higher expected wealth and higher net cash flows in early periods with no management change. Rancher specific profit-utility preferences and different time preferences (i.e. use of different discount rates) may cause ranchers to choose different strategies. This should be an important issue for future research.

Implications for Riparian Zone Management and Policy

Simulation models of a ranch in Southern Alberta were constructed to evaluate the private economic impacts of adopting various range management strategies applied to riparian zones. The models incorporated forage production risk and cattle price risk on a 2185 hectare ranch. Rangeland research suggests there is a large set of possible long-run riparian zone forage production response functions to management changes. Consequently, the simulation models explored a number of different scenarios. These scenarios evaluated outcomes with changes in rates of riparian zone decline, rates of zone improvement, zone area, shape, and management costs. All scenarios assumed the upland range was managed conservatively and did not require changes in management or fencing. Riparian zones starting in good, fair or poor range condition were modeled. The objective was to provide an economic analysis of ranch grazing strategies designed to maintain or improve riparian areas on the ranch. Public benefits or costs were not incorporated into the model.

Management recommendations in the 1960s and 1970s on how to maintain riparian zones included adding fencing and possibly reducing stocking rates. Other references suggest that the decline in some riparian zones grazing capacity has been very slow. Our results indicate that with slow rates of zone decline and prior period zone management recommendations, the higher value on-ranch economic response would be to ignore the riparian zone. Implementing strategies with modest mitigation costs (i.e. placement of off-stream waterers) to maintain the zone in good condition was not the optimal economic response if the rates of zone decline were less than 1.5% per year and if the zone represented about 1% of total model ranch range area (i.e. 22 ha). Lumpy capital costs and ranches with small riparian zone area as measured in total hectares essentially make the costs of implementing strategies too high relative to their long-run economic benefits. Even with larger zone areas (i.e. 55 hectares or 2.5% of the model ranch), implementing these prior period management recommendations would at best be wealth neutral when slow rates of riparian zone decline are anticipated.

The benefits of higher cost management strategies, such as additional fencing around riparian zones more sensitive to grazing pressure (i.e. higher rates of zone decline), may be economically justified in some situations. However, areas of the riparian zone on a ranch in southern Alberta are typically 1% to 3%. For small ranches this will translate into relatively few hectares in the riparian zone. Only in the most sensitive riparian zones will strategies that require significant waterer and fencing investments provide an economic benefit to a ranch under conservative management. The net benefits decrease as the area of the zone decreases. These results reinforce the need to continue research on low cost ways to manage riparian zones.

Changing cattle distribution habits in the riparian zone through ranch manager training (i.e. education), is one low cost policy. However, whether this leads to the significant adoption of riparian grazing management strategies is an open question.

The shape of the riparian zone also has impacts on the economic incentives to implement costly fencing strategies. When total riparian zone shape is assumed to be rectangular and area is held constant, perimeter length increases quickly as the width of the zone decreases. Zone fencing costs increase at an increasing rate as the width declines. The length of the perimeter relative to the zone area has a significant impact on the ranch economics of fencing strategies designed to maintain riparian zones in good condition. Again only larger riparian zones that are highly sensitive to grazing (i.e. rapid decline in grazing capacity with overgrazing) economically justify the cost of additional fencing.

These results are sensitive to the discount rates used in models. The model used 10% discount rates and lower discount rates would reduce the disincentives to implement costly management strategies to maintain riparian zones. Torell et al. (2001) suggest that due to quality of life issues, many ranch owners exhibit discount rates much lower than 10% in their overall ranch investment decision. However, the issue of whether these ranchers would implement costly management changes would depend upon the influence of environmental amenities in their utility function.

Many riparian zones are already degraded and are no longer in good range condition. Simulations to evaluate improvement strategies for zones in fair or poor condition were conducted. The ranch area in the zone was 55 ha or 2.5% of the model ranch area. Low cost strategies for zones in fair range condition that include some management training and up to two off-stream waterers provide an expected positive economic return, even if this only stopped zone decline. Rate of annual zone decline was an expected –4.9%, well above the slow rates of declined discussed above. The same management strategy situation where the zone starts in poor condition would not be expected to provide a net economic benefit to the ranch where there are low rates of zone improvement expected.

Management recommendations where riparian zones are already degraded may include reduced stocking rates. Stocking rate reductions of 20% or more combined with additional fencing of a 55 ha riparian zone provide negative economic benefits to the ranch. Scenarios where the stocking rate in the zone in fair condition are reduced by 40% take at least 9 years until there is a 50% chance that annual cash flow will be greater than cash flows with no management change. This scenario assumed an expected 4% per year improvement in zone carrying capacity compared to continued zone decline at –4.9%.

The simulation results covered a wide range of possible riparian zone responses. There are net positive economic incentives to maintain riparian zones in good condition if these management strategies can be implemented at low costs. Policies providing more explicit economic incentives may be required to induce ranch managers to implement costly strategies such as fencing and reduced stocking rates when the riparian zone is already in fair or poor condition. The size of the incentive may have to increase inversely with the current carrying capacity (i.e. range condition) of the zone.

Based on the Norton et al. (1994) model, compensation may be required to induce ranchers in these situations to adopt regenerative strategies. The simulation results provide some guidelines to the upper bound of financial support required for the ranch modeled in this paper. Alternative simulations can be developed to evaluate different scenarios. The environmental preferences for on-ranch environmental amenities held by individual ranchers may reduce the dollar amount of this direct support. Similarly the early period cash flow constraints may require additional access to long term debt if costly zone management changes are required.

Our results also highlight issues related to risk perceptions and forecasting outcomes. Mean expected net benefits had wide confidence bounds with the 90% bound often covering an interval of $200 to $300 NPV per hectare. Few management strategies with expected positive net economic benefits had 90% confidence intervals that did not include zero. In theory the discount rate in the model, 10%, should account for ranch owner risk and any positive mean NPV should provide incentives for adoption. Rancher risk perceptions and their long-run production response function forecasts could significantly limit ranch adoption of costly riparian zone management strategies. Further, given the lack of knowledge surrounding long-run riparian zone response functions, there may exists a high degree of uncertainty as to which model assumption or scenario are appropriate on any specific ranch. Other research (e.g.. Shortle and Miranowski 1986) and economic theory suggest that higher risk may negatively influence adoption. Specific riparian zone improvement projects in a ranch setting may have expected positive risk adjusted on-ranch benefits as viewed by the extension agency, but would still exhibit low adoption due to individual risk preferences, different rancher forecasts, or other ranch specific financial constraints.

Several caveats regarding the model and conclusions need to be highlighted. Reliable research on the rate of riparian zone decline or improvement is not available. Consequently, expert opinion was solicited for these components of the model and incorporated best guesses of the researchers. Scenario analysis provided an overview of a series of possible outcomes. The simulation also represented a single ranch situation located in southwestern Alberta. Models specific to different regions may exhibit different outcomes and only a small number of the large number of outcomes were presented here. A 10% discount rate, based on market risk, was used in most model scenarios. Torell et al. (2001) might argue that a market related discount rate is too high based on observed rancher investment behaviour. Finally these simulation models assumed the upland ranch areas were conservatively managed. There may exist higher net NPV situations that involve deliberate overgrazing strategies.

Despite these caveats, simulation modeling can be used to demonstrate the impact of different assumptions on the economic returns from a ranch operation and aspects of the economic value of riparian areas. Simulation results could have significant value in demonstrating the impact of different management strategies on the long run economic viability of a cattle ranch enterprise. These findings are elements in designing effective economic instruments to foster the adoption of sustainable grazing management systems. However, research on long run riparian zone production functions and on understanding the environmental preferences of individual cattle producers need to be conducted.

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Figures

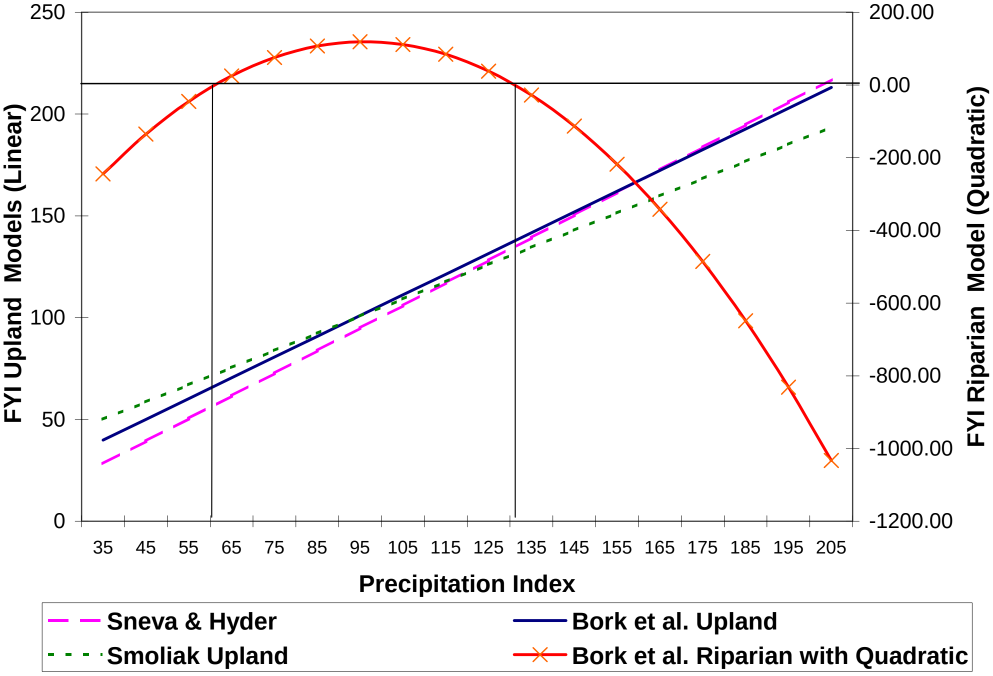

Figure 1 FYI Model Comparisons: Forage index model forecasting comparison with models derived from different research data. Median Precipitation=100. Riparian model includes a quadratic precipitation index term.

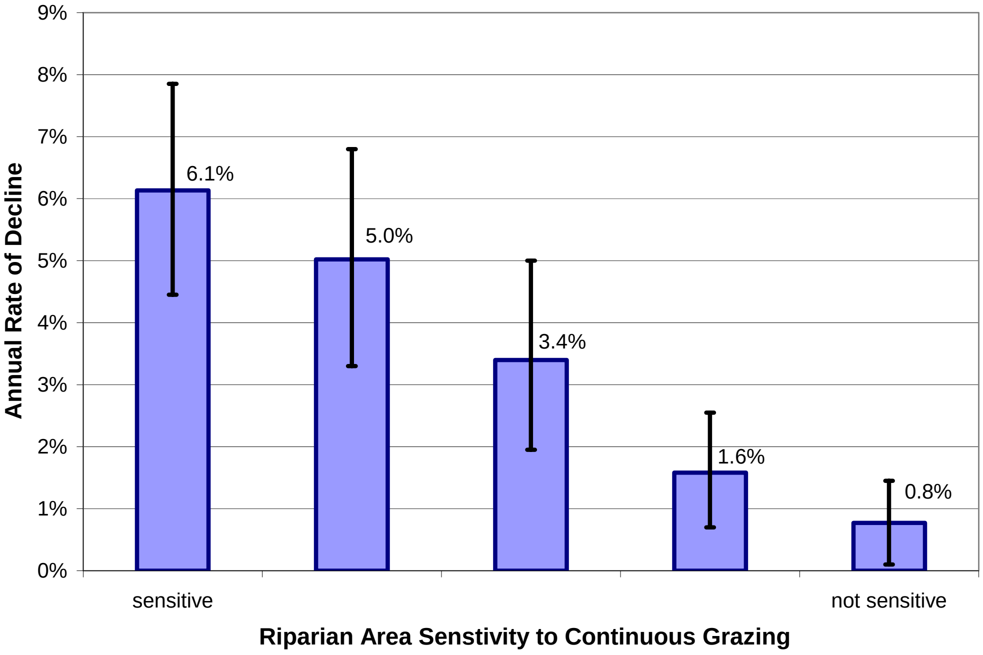

Figure 2 Decline Scenarios: Mean annual rates of riparian zone decline for different scenarios with 90% CI around mean. Riparian zone starting in good range condition.

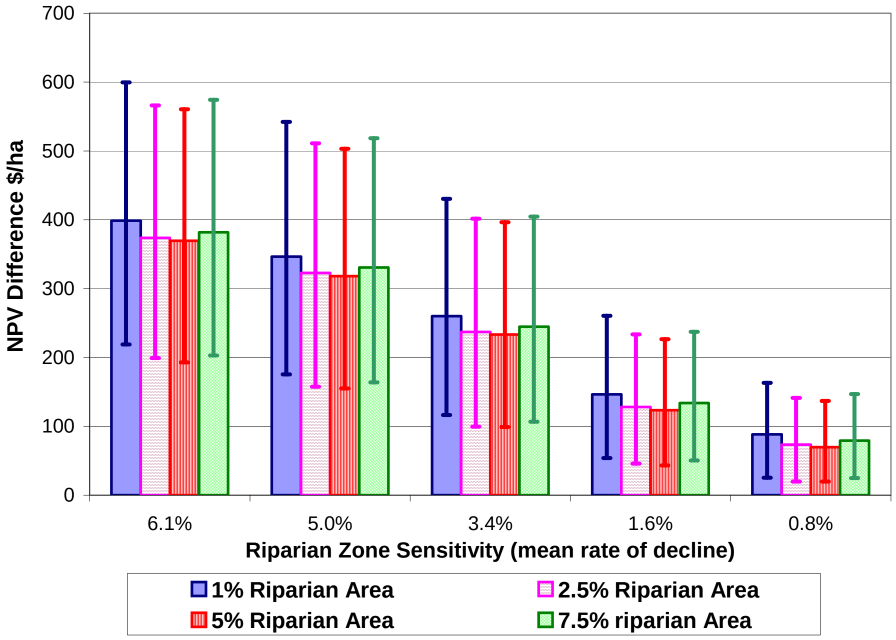

Figure 3 Maintaining Riparian Zone with 0 Additional Management Cost and Zone Condition is Good: Difference in NPV with no riparian zone decline versus decline in riparian zone carrying capacity. Ranch under conservative management and no additional ranch costs to manage riparian zone in any scenario. Zone starting in good condition in all scenarios, varying ranch area in riparian zone and varying zone decline rates. 90% CI around mean. 10% discount rate used.

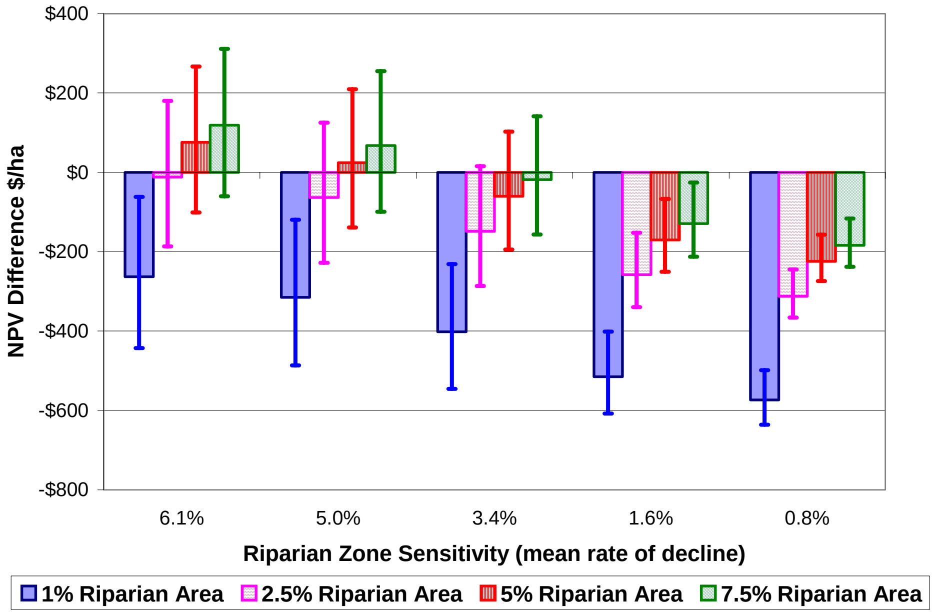

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Figure 4 Maintaining Riparian Zone with Additional Management Costs and Zone Condition is Good: Difference in NPV with no riparian zone decline versus zone decline. Zone is 122 m wide. Ranch under conservative management and no zone decline scenario (i.e. maintain zone carrying capacity) requires implementing MT+2W+1/2F management strategy. Zone starting in good condition in all scenarios, varying ranch area in riparian zone and varying zone decline rates. 90% CI around mean. 10% discount rate used.

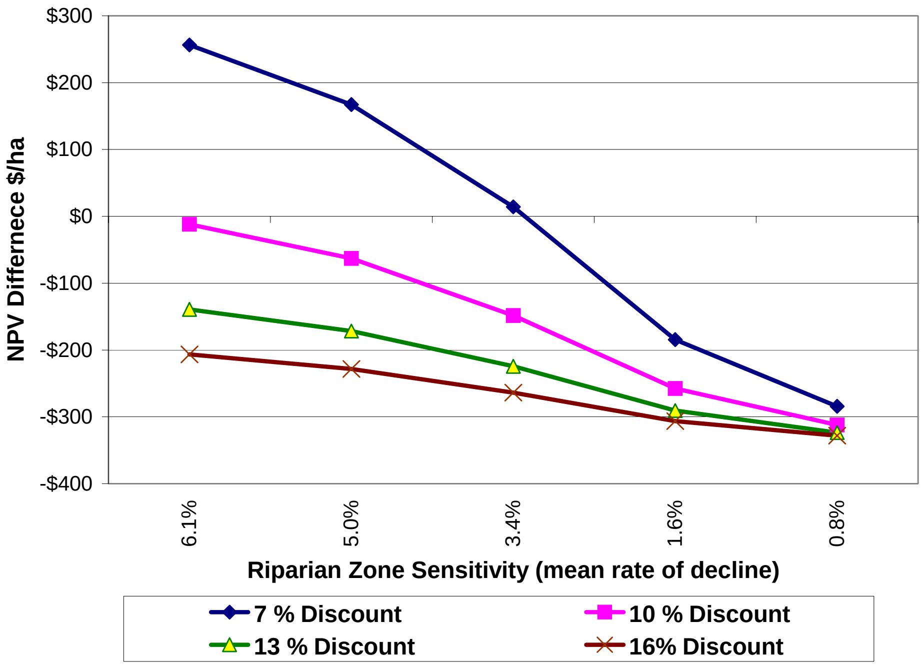

Figure 5 Discount Rate Sensitivity and Zone Condition is Good: Difference in NPV with no riparian zone decline versus zone decline. Zone is 122 m wide and 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and no zone decline scenario (i.e. maintain zone carrying capacity) requires implementing MT+2W+1/2F management strategy. Zone starting in good condition in all scenarios, varying NPV discount rate and varying zone decline rates.

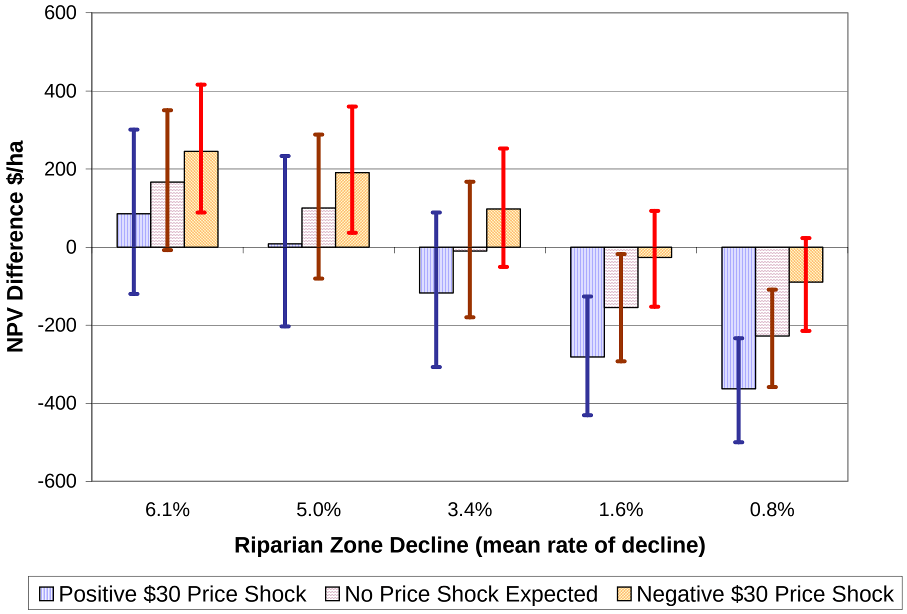

Figure 6 Cattle Price and Overstocking Sensitivity : Difference in NPV with no riparian zone decline versus zone decline. Zone is 122 m wide and 55 ha (2.5% of ranch area) in zone. No decline scenario is under conservative management and no additional ranch costs to manage zone. Decline scenarios overstocked at 30% starting in period 1. Zone starting in good condition in all scenarios. Varying short-run price expectations and rates of zone decline. 90% CI around mean. 10% discount rate used.

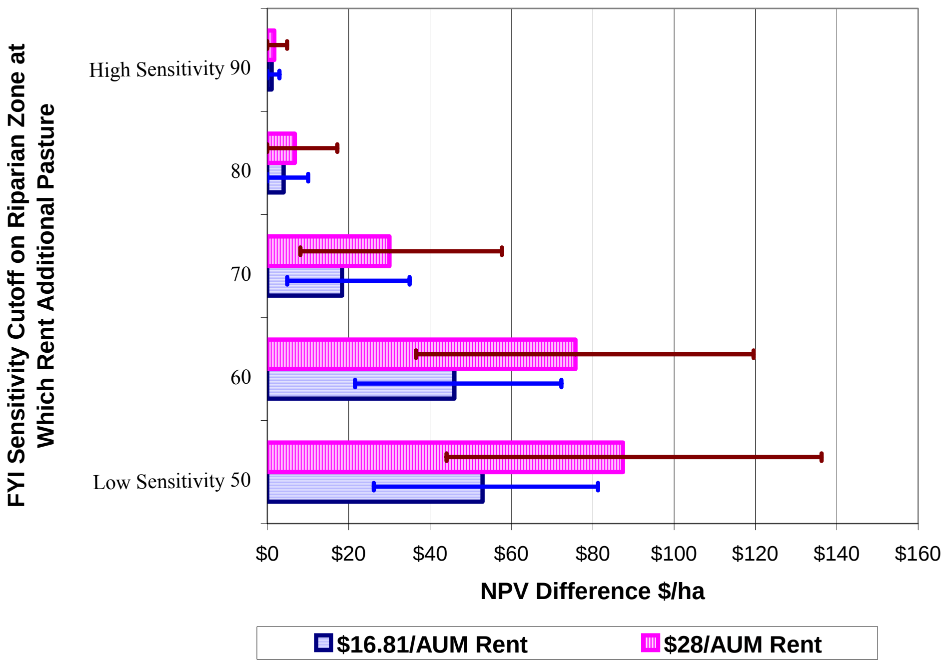

Figure 7 Riparian Zone Drought Buffering Value: Difference in NPV with buffering capacity versus no buffering capacity (i.e. FYI cutoff=median of 100). Zone is 122 m wide and 55 ha (2.5% of ranch area) in zone. Two pasture rental rates used. Increasing zone buffering capacity (i.e. decreasing FYI sensitivity cutoffs at which rent additional pasture). Assumes ability to manage zone separately from uplands at no additional cost. 90% CI around mean. 10% discount rate used.

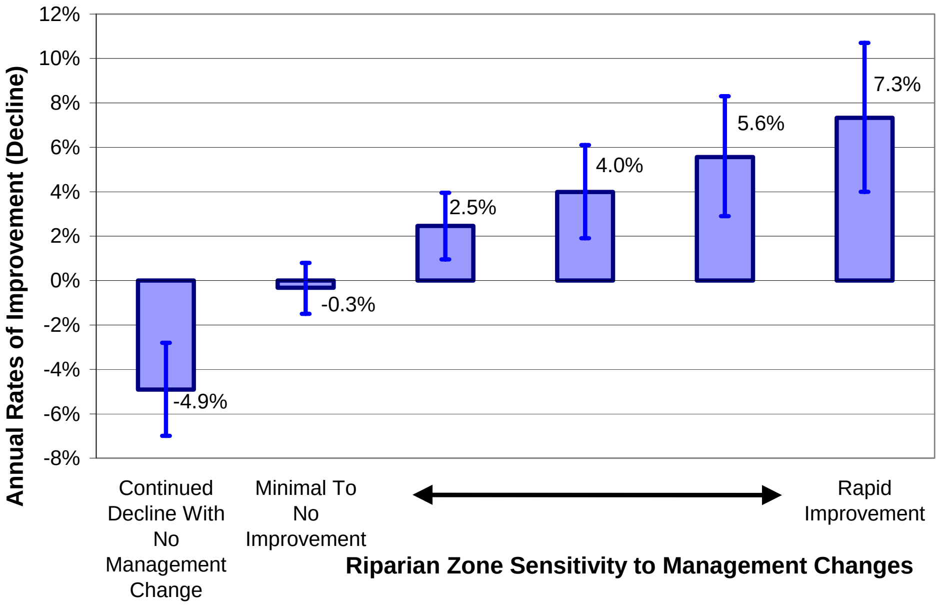

Figure 8 Improvement Scenarios: Mean annual rates of riparian zone improvement (decline) for different scenarios from simulation with 90% CI around mean. Riparian zone starting in fair or poor condition.

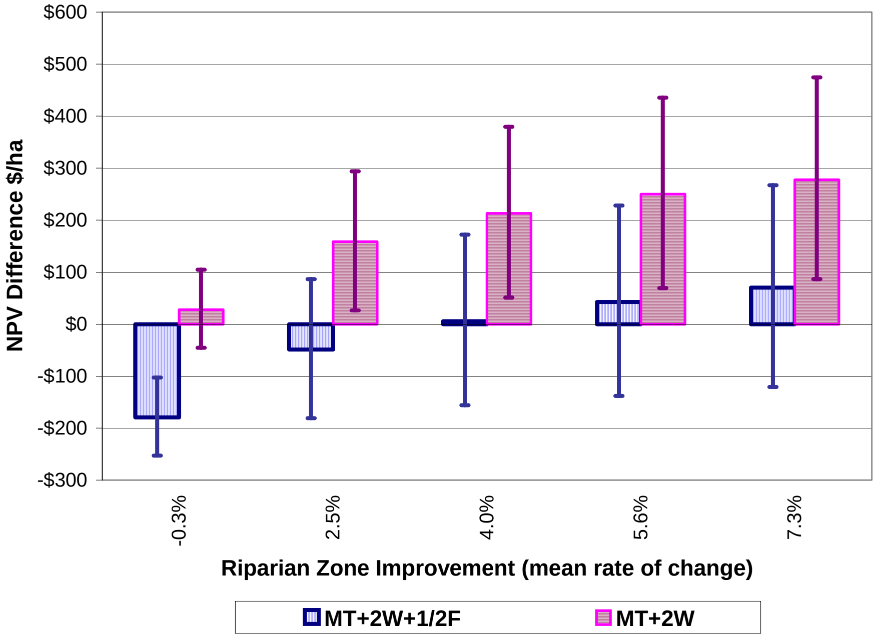

Figure 9 Improving Riparian Zone with Medium or Low Management Costs and Zone Condition is Fair: Difference in NPV with riparian zone improvement versus continued zone decline at -4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing medium cost, MT+2W+1/2F, or low cost, MT+2W, management strategy. Zone starts in fair condition in all scenarios, 1.24 AUM/ha period 1 stocking rate in all scenarios and zone improvement rate scenarios vary. 90% CI around mean. 10% discount rate used.

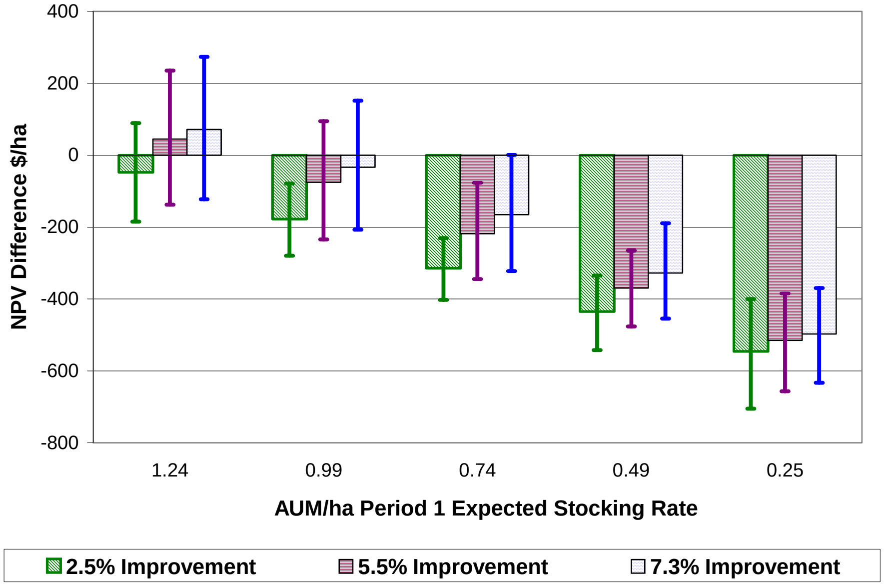

Figure 10 Improving Riparian Zone with High Management Costs and Zone Condition is Fair: Difference in NPV with riparian zone improvement versus continued zone decline at -4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing MT+2W+1/2F and lowering stocking rate. Zone starts in fair condition in all scenarios. Improvement scenarios vary period 1 stocking and zone improvement rates. 1.24 AUM/ha period 1 stocking rate in decline scenario. 90% CI around mean. 10% discount rate used.

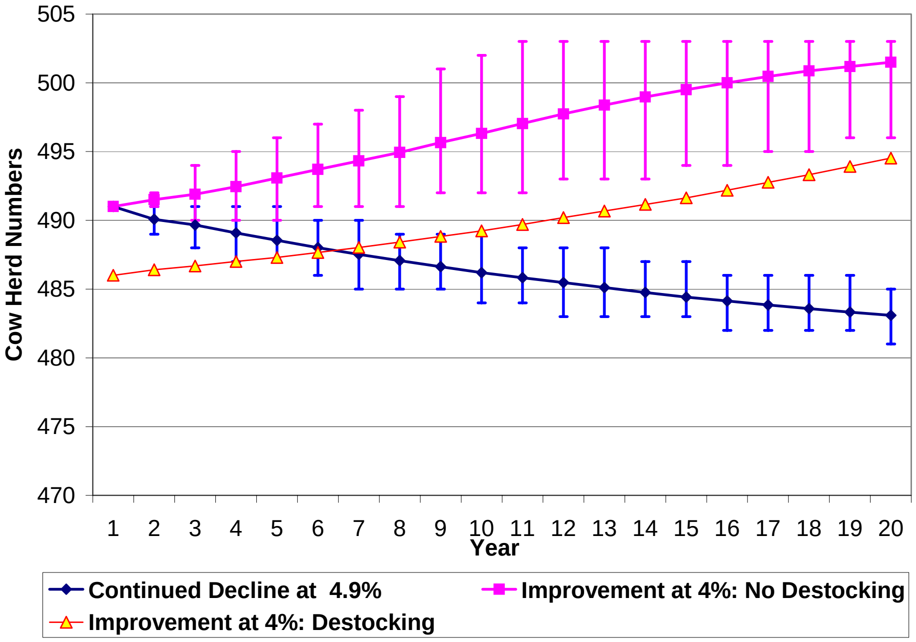

Figure 11: Cow Herd Changes. Examples of how cow-herd size changes through time when riparian zone starts in fair condition. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management. Decline and improvement scenarios with no destocking start with initial 1.24 AUM/ha in the riparian zone and have 90% CI. Improvement with destocking starts at 0.74 AUM/ha. 503 cow-calf units are the maximum ranch carrying capacity under these improvement scenarios.

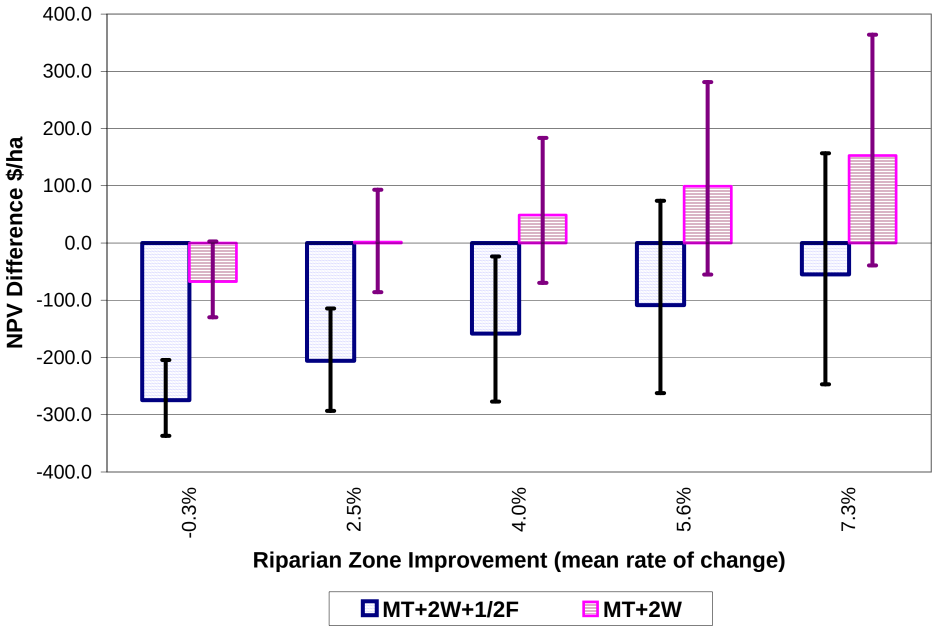

Figure 12: Improving Riparian Zone with Medium or Low Management Costs and Zone Condition is Poor: Difference in NPV with riparian zone improvement versus continued zone decline at -4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing medium cost, MT+2W+1/2F, or low cost, MT+2W, management strategy. Zone starts in poor condition in all scenarios, 0.74 AUM/ha period 1 stocking rate in all scenarios and zone improvement rate scenarios vary. 90% CI around mean. 10% discount rate used.

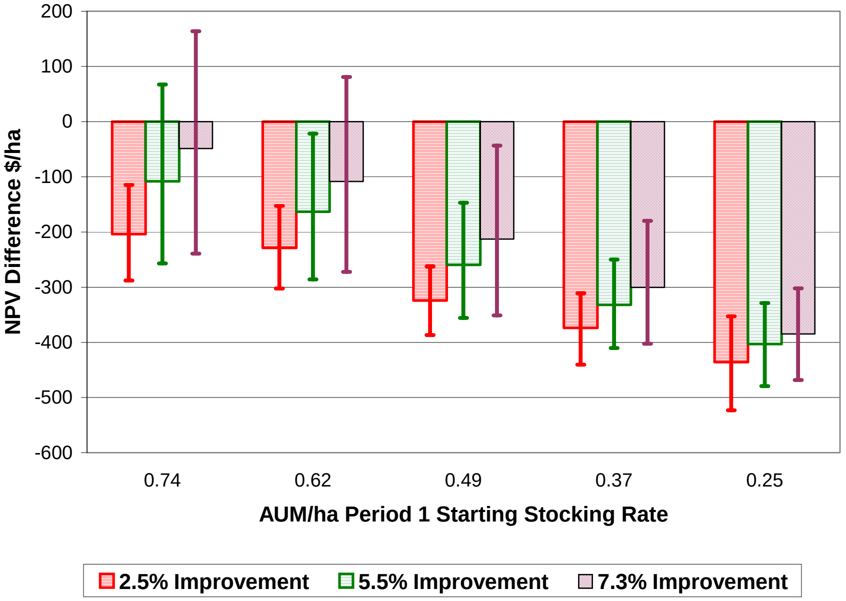

Figure 13: Improving Riparian Zone with High Management Costs and Zone Condition is Poor: Difference in NPV with riparian zone improvement versus continued zone decline at -4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing MT+2W+1/2F and lowering stocking rate. Zone starts in Poor condition in all scenarios. Improvement scenarios vary period 1 stocking and zone improvement rates. 0.74 AUM/ha period 1 stocking rate in decline scenario. 90% CI around mean. 10% discount rate used.

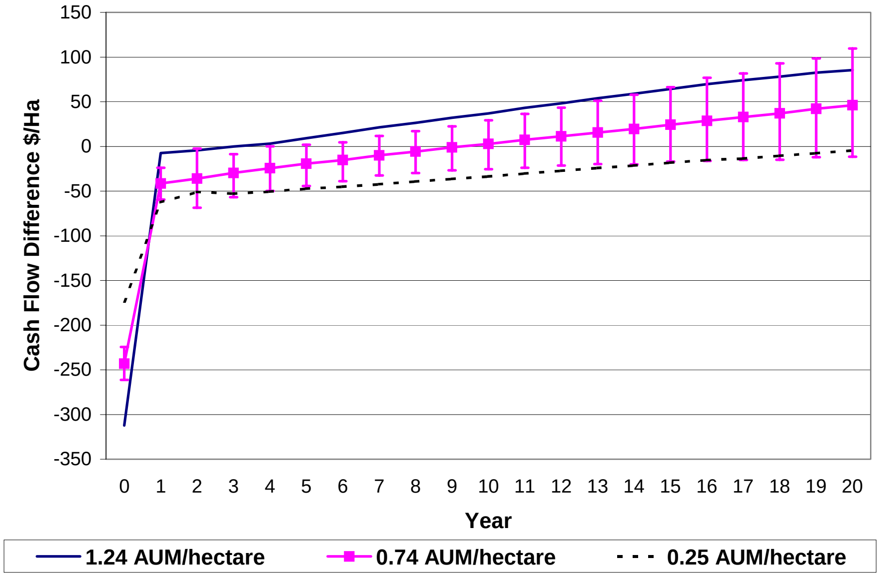

Figure 14 Cash Flow Difference with High Management Costs and Zone Condition is Fair: Per period cash flow difference with riparian zone improvement at 4% versus continued decline at –4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing MT+2W+1/2F and lowering stocking rate. Zone starts in fair condition in all scenarios. Improvement scenarios vary period 1 stocking rate. 1.24 AUM/ha period 1 stocking rate in decline scenario. 90% CI around mean for 0.74 AUM scenario. 10% discount rate used.

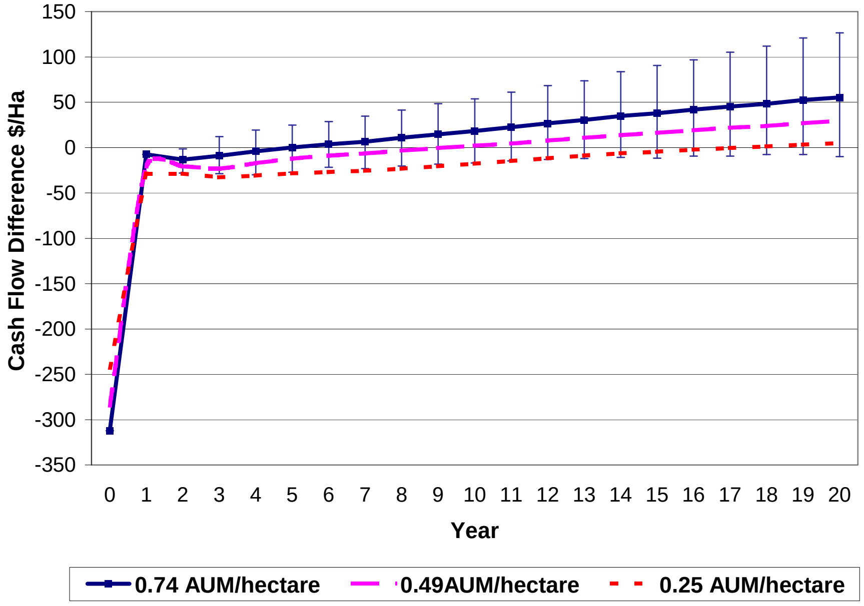

Figure 15 Cash Flow Difference with High Management Costs and Zone Condition is Poor: Per period cash flow difference with riparian zone improvement at 4% versus continued decline at –4.9%. Zone is 122 m wide. 55 ha (2.5% of ranch area) in zone. Ranch under conservative management and zone improvement scenarios (i.e. increasing zone carrying capacity) requires implementing MT+2W+1/2F and possibly lowering stocking rate. Zone starts in poor condition in all scenarios. Improvement scenarios vary period 1 stocking rate. 0.74 AUM/ha period 1 stocking rate in decline scenario. 90% CI around mean for 0.74 AUM scenario. 10% discount rate used.

Table 1. Parameter Estimates for Cattle Price Equations Used in Whole Ranch Model

Variable	Parameter or correlation estimate (Standard errors)			
	Steer (1)	Heifer (2)	Bred Heifer (3)	Cull Cow (4)
Constant	49.447 (10.610)*	47.007 (9.884)*	56.056 (13.571)*	17.621 (4.626)*
Price_{t-1}	0.444 (0.091)*	0.405 (0.089)*	0.799 (0.132)*	0.319 (0.094)*
Price_{t-2}	0.554 (0.091)*	0.568 (0.086)*	0.288 (0.174)	0.719 (0.067)*
Price_{t-3}	-0.384 (0.087)*	-0.379 (0.086)*	-0.436 (0.128)*	-0.317 (0.092)*
Equation Std. Dev.	20.8	17.8	15.9	10.0
ρ_{12}	0.976			
ρ_{13}	-0.059			
ρ_{14}	0.869			
ρ_{23}	-0.020			
ρ_{24}	0.861			
ρ_{34}	-0.006			
R^2	0.9441			

* Signifies statistical significance at the 5% level or beyond

Table 2. Upland Forage Index Model estimated from the Bork, Thomas and McDougall data

Model	Constant*	Precipitation Coefficient	R-Squared
Bork et al. Upland Index Model (N=12)	4.19 (25.7)	1.02 (0.273)	0.58
Bork et al. Production Function (kg/ha)**	131 (not reported)	10.2 (not reported)	0.58

* Standard deviation in brackets.

**Linear production function estimates reported by Bork, Thomas and McDougall where actual precipitation and forage yields are used and not an index.

Table 3: Comparison of PV of Riparian Zone Capital Costs Plus Maintenance Costs at a 10% Risk Adjusted Discount Rate. (Excludes any changes to short-run stocking rate)*

	Management Scenarios				
Riparian Zone Width If Rectangular (Meters)	MT ($/ha)**	MT+1W ($/ha)	MT+2W ($/ha)	MT+2W+1/2 F ($/ha)	MT+2W+FF ($/ha)
1% Ranch Area is Riparian Zone or 22 hectares					
30.5	46	246	446	1,257	2,068
61.0	46	246	446	857	1,267
121.9	46	246	446	662	877
182.9	46	246	446	601	756
243.8	46	246	446	575	703
304.8	46	246	446	561	676
Circular	46	246	446	539	633
2.5 % Ranch Area is Riparian Zone or 55 hectares					
30.5	18	98	178	987	1,796
61.0	18	98	178	585	991
121.9	18	98	178	386	593
182.9	18	98	178	321	464
243.8	18	98	178	290	402
304.8	18	98	178	273	367
Circular	18	98	178	237	296
5 % Ranch Area is Riparian Zone or 109 hectares					
30.5	9	49	89	897	1,705
61.0	9	49	89	494	898
121.9	9	49	89	294	497
182.9	9	49	89	228	364
243.8	9	49	89	196	298
304.8	9	49	89	177	260
Circular	9	49	89	131	157
7.5 % Ranch Area is Riparian Zone or 164 hectares					
30.5	6	33	59	867	1,675
61.0	6	33	59	464	869
121.9	6	33	59	263	467
182.9	6	33	59	197	334
243.8	6	33	59	164	269
304.8	6	33	59	145	230
Circular	6	33	59	94	128

*Costs are assumed to be Management Training (MT) $1000, offsite Waterers (W) $3500/waterer and Fencing (F) at $1.97/meter ($0.60/foot).

**MT=management training; MT+W is management training plus 1 offsite waterer; MT+2W is management training plus two offsite waterers; MT+2W+1/2F is management training plus 2 offsite waterers plus half of the riparian zone perimeter is fenced; and MT+2W+FF includes fencing the entire perimeter of the riparian zone.