RANCH LEVEL ECONOMIC IMPACTS OF WESTERN JUNIPER (*Juniperus occidentalis*) ENCROACHMENT ON SAGEBRUSH STEPPE ECOSYSTEMS IN OWYHEE COUNTY, IDAHO

A Thesis

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by

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ABSTRACT

Western Juniper (*Juniperus occidentalis*) is a native species in Oregon, California, Idaho and Nevada. The western juniper has been encroaching into sagebrush steppe ecosystems since the European settlement of the range, approximately 130 years ago. Currently juniper species occupy over 74 million acres in the United States, a tenfold increase from the 7 million acres that had been historically inhabited. As juniper cover increases from Phase I to Phase III, sagebrush and understory herbaceous vegetation decrease to less than half of their original cover, causing significant reductions in the forage available for domestic livestock. This study analyzed the economic impacts of forage reductions and ranchers' willingness to pay for juniper removal, using a dynamic multi-period linear programming model. The model maximizes the net present value of representative 300 head cow/calf ranch in the Jordan Valley area of Owyhee County, Idaho over a 40-year planning horizon using 100 price iterations whose starting points are stochastically determined. It analyzes the changes in optimal production levels and economic returns as juniper encroachment advances from Phase I to Phase III, and the economic returns when treatments are applied to reduce encroachment.

The study showed a decrease in Animal Unit Months (AUMs) of forage on a Bureau of Land Management (BLM) grazing allotment of 37% between Phase I and Phase II, and 60% between Phase I and Phase III. The net present value of the ranch's income stream was $435,983, $373,515, and $294,852 for Phase I through III, respectively. The increase in western juniper encroachment from

Phase I to Phase III reduced the net present value of the ranch income stream by 32.4%. The second portion of the study analyzed the costs and benefits to the ranch of western juniper removal. It showed that the ranch can afford to invest up to $5,648 per year ($30/acre) for juniper removal on the BLM allotment when it starts in Phase II and is converted back to a Phase I encroachment level. However, this price level drops the ranch's NPV below the NPV if the allotment was not treated. Only when the cost of treatment is dropped to $3,766 per year ($20/acre) or less does the NPV for treating the ranch become higher than when left untreated. When the allotment is in Phase III and being converted back to a Phase I the ranch can afford to pay $3,766 per year for treatment. Ranchers are the main beneficiaries of these market value increases. The non-market benefits of removal encompass factors such as sage-grouse habitat rehabilitation, other wildlife benefits and overall ecosystem stabilization. These non-market benefits are shared across all users of the range, and provide the rationale for cost sharing programs between ranchers and public agencies such as the Natural Resources Conservation Service.

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Chapter I: Introduction

Western Juniper (*Juniperus occidentalis*) is a native species in Oregon, California, Idaho and Nevada. Juniper trees have become a serious threat to the sagebrush steppe ecosystem that exists on western rangelands. Western juniper has been encroaching into sagebrush steppe ecosystems since the European settlement of the range, approximately 130 years ago (Miller and Wigand 1994, Miller and Tausch 2001). This encroachment imposes many stresses on an already compromised ecosystem.

Woodland encroachment causes a reduction in the shrub and herbaceous vegetation components of the rangeland system, impacting the ecosystem at multiple levels. Changes to the herbaceous composition of western rangelands alter its suitability as habitat for many of the wildlife species that live within these areas. Many animal and plant species can be affected by juniper encroachment. Species that are already suffering from threatened population numbers, such as pygmy rabbits, Brewer's sparrow, and greater sage-grouse, are at especially high risk from woodland encroachment (Rowland et al. 2008). Greater sage-grouse is one species that has received considerable attention and become the focus of various rehabilitation efforts due to its potential to be listed under the Endangered Species Act (ESA). Woodland encroachment has been a significant factor in population declines of greater sage-grouse populations. In a 1999 study, Commons et al. found that a year after removing juniper, sage-grouse populations, measured by males on leks, doubled. Juniper removal decreased avian predators in the area and allowed for decreased mortality.

Encroachment

Many different factors have influenced the encroachment of western juniper. Climate change, overgrazing and lack of fire are generally considered the most influential factors affecting juniper expansion. Historically juniper was contained on the ridges where limited fuels were available to support fire (Burkhardt and Tisdale 1976, Vasek and Thorne 1977, Young and Evans 1981, Holmes et al. 1986, Miller and Rose 1995, 1999). The lack of understory vegetation on these sites prevented fire from reaching them, and allowed the establishment of what are now old growth western juniper communities.

Presettlement mean fire return intervals (MFRIs) ranged between 11 and 25 years (Gruell 1999, Miller and Rose 1999). Young western juniper (less than 40 years of age) are highly susceptible to fire and this length of fire return interval killed seedlings that were growing in the more productive sagebrush-grass sites, restricting western juniper to the less productive ridgelines. MFRIs of up to 50 years were probably sufficient to limit juniper expansion into sagebrush steppe ecosystems (Burkhardt and Tisdale 1976, Miller and Rose 1999) since western juniper does not usually begin seed production until approximately 50 years after establishment (Miller and Rose 1995). This also maintained the critical shrub component of the ecosystem.

European settlement of western rangelands in the late 1800's to early 1900's greatly altered the fire regime through grazing that removed the fine fuels to carry fire and active fire suppression. The same rangelands that used to see fire approximately every 25 years may not experience a fire now for over 150 years (Miller et al. 2005). This allows the establishment of reproductively mature juniper stands on sites that were previously protected by fire.

Grazing during early European settlement was plagued with poor land management and a general lack of knowledge of ecological processes that lead to extreme overgrazing in many areas. Overgrazing reduced the fine fuels on western rangelands, contributing to increased MFRI and decreasing interspecies plant competition (Burkhardt and Tisdale 1976, Miller and Rose 1999, Miller and Tausch 2001). Climatic changes have caused wetter and milder conditions which greatly facilitate juniper growth (Antevs 1938, Wahl and Lawson 1970, LaMarche 1974, Graumlinch 1987). All of these factors have facilitated the encroachment of western juniper into surrounding communities.

Competition

Western junipers have many characteristics that make them highly competitive in arid ecosystems. Junipers have both an extensive lateral root system as well as a deeply-penetrating taproot that develop within the first 10 years of growth (Kramer 1990). The lateral roots usually have a diameter that equals the height of the tree, but they can extend up to three times that distance (Miller et al. 2005). The combination of root systems allows juniper to be highly effective at water uptake on arid rangeland systems, thereby allowing it to outcompete native shrubs, grasses and forbs (Miller et al. 1990).

Shrubs are highly sensitive to juniper encroachment. As juniper cover increases, shrub cover quickly declines and can be completely eliminated (Burkhardt and Tisdale 1976, Bunting et al. 1999, Miller et al. 2000). Declines in sagebrush and other native shrub densities are not proportionate to juniper increases; sagebrush decreases to 25% of its original cover potential as western juniper increases to 50% of its maximum cover potential (Miller et al. 2000). These declines impact the site's ability to carry fire into the tree canopy and can cause further increases in the MFRI.

Grasses and forbs are also affected by juniper encroachment, although some communities are more sensitive than others. The response to juniper encroachment differs among plant associations. Increases in juniper cover have been shown to cause significant decreases in herbaceous cover in communities characterized by Thurber needlegrass, but did not show significant declines in those characterized by Idaho fescue (Miller et al. 2000). Other studies have shown an association between the presence of western juniper and decreases in ground cover (Roberts and Jones 2000). Stebleton and Bunting, 2009, found a decrease in total herbaceous biomass from an average of 399 pounds per acre to 176 pounds per acre as juniper cover increased to maximum potential.

Classification

Miller et al. 2000 and 2005 developed a classification system for juniper encroachment. They divided it into a three phase classification system. Phase I is characterized by having juniper presence on a site, but in low enough numbers and densities that the understory sagebrush and herbaceous vegetation remains dominant. During this phase the juniper does not impact the ecological process (e.g. hydrologic, nutrient and energy cycles) on the site. Phase I maintains an intact shrub component, and contains mostly young trees.

In Phase II, juniper cover has increased to a point where it now plays a codominant role in influencing the ecological processes of the site. During Phase II, the shrub layer and herbaceous production begin to decline. The trees present on the site become more productive, actively recruiting new establishment and continuing growth and nutrient uptake.

In Phase III the western juniper now dominates the site. Junipers are the primary vegetation influencing all of the ecological process. The shrub layer is significantly decreased, if not eliminated, and herbaceous production continues to decline.

This classification system forms the basis for an economic analysis of juniper invasion, primarily through the components of forage reductions and habitat changes for domestic livestock and other species.

Economic Considerations

Currently juniper and pinyon species occupy over 74 million acres in the United States, a tenfold increase from the 7 million acres that had been historically inhabited (West 1999). Western juniper makes up 9 million of those acres in Oregon, Idaho, California and Nevada (USDA Forest Service 1981, Gedney et al. 1999, Miller and Tausch 2001, Azuma et al. 2004). As juniper cover increases to between 1/3 to 1/2 of its maximum cover potential, the understory species (sagebrush, grasses and forbs) rapidly decrease and can be reduced by 80 percent of their original cover (Bates et al. 2005, Miller et al. 2000). This decrease in understory species reduces the amount of vegetation available for forage.

The impact of western juniper encroachment to ranchers and ranching profits is economically important since ranching occurs on approximately 80% of the 270 million acres of public land in the western United States (Bhattacharyya et al. 1996). Bates et.al. (2005) found that removing juniper from range plots increased the livestock carrying capacity by nearly ten-fold, the number of acres needed to support an animal unit month (AUM) of livestock grazing went from 47 to 5 acres/AUM. This indicates that there are potentially significant economic impacts to ranchers involved with juniper encroachment and removal.

Linear programming (LP) models provide a tool for analyzing the ranch level economic impacts of rangeland changes. LP models optimize an objective function subject to various constraints that can be imposed, and can also be conducted over a specific time frame with multiple iterations. The basic framework for an LP model was developed to analyze western ranches that graze cattle on a mixture of public and private lands, with the option to use the land for crop production and/or graze crop residues. The LP model used in this study has also been used to analyze the economic impacts to ranchers of agency policy changes and associated forage allocation decisions in Idaho, Oregon, Nevada and Wyoming. The studies have mainly focused on the ranch level economic impacts of federal agency grazing allotment adjustments due to sage-grouse protection, riparian grazing strategies, supplementation decisions, threatened and endangered species concerns, and climate change/drought impacts (Rimbey et al. 2003, Ritten et al. 2010,Taylor et al. 2005, Taylor et al. 2004a, Taylor et al. 2004b, Torell et al. 2002, Torell, et al. 2010).

References

Antevs, E. 1938. Rainfall and Tree Growth in the Great Basin. Carnegie Institution of Washington Publication 469, Washington, D.C. and American Geographical Society, Special Publication No. 21, New York, NY.

Azuma, K.L., B.A. Hiserote and P.A. Dunham. 2005. The Western Juniper Resource of Eastern Oregon, 1999. Research Bulletin PNW-RB-249. Portland, OR: USDA Forest Service, Pacific Northwest Research Station; 18p.

Bates, J.D., R.F. Miller, and T. Svejcar. 2005. Long-Term Successional Trends Following Western Juniper Cutting. Rangeland Ecology and Management. 58:533-541.

Bhattacharyya, A., R. Narayanan, T.R. MacDiarmid, T.R. Harris, and W.O. Champney. 1996. Demand for Grazing on Public Lands: A Disequilibrium Approach. Land Economics. 72(4):483-499.

Bunting, S.C., J.L. Kingery and E. Stand. 1999. Effects of Succession on Species Richnes of the Western Juniper Woodland/Sagebrush Steppe Mosaic. Pages 76-81. *In* S.B. Monsen, S. Richards, R.J. Tausch, R.F. Miller and C. Goodrich (compilers). Proceedings Ecology and Management of Pinon-Juniper Communities within the Interior West. USDA Forest Service, RMRS-P-9.

Burkhardt, J.W. and E.W. Tisdale. 1976. Causes of Juniper Invasion in Southwestern Idaho. Ecology. 57:472-484.

Commons, M.L., R.K. Baydack and C.E. Braun. 1999. Sage Grouse Response to Pinyon-Juniper Management. *In*: S.B. Monsen and S. Richard (compilers). 1999. Proceedings: Ecology and Management of Pinyon-Juniper Communities within the Interior West. Ogden, UT: Rocky Mountain Research Station, USDA Forest Service Proceedings RMRS-P-9. p238-239.

Gedney, D.R., D.L. Azuma, C.L. Bolsinger and N. McKay. 1999. Western Juniper in Eastern Oregon. U.S. Forest Service General Technical Report NW-GTR-464.

Graumlich, L.J. 1987. Precipitation variation in the Pacific Northwest (1675-1975) as Reconstructed from Tree Rings. Annals of the Association of American Geographers. 77:19-29.

Gruell, G.E. 1999. Historical and Modern Roles of Fire in Pinon-Juniper. Pages 24-28. *In* S.B. Monsen, R. Stevens, R.J. Tausch and R.F. Miller (compiler). Proceedings: Ecology and Management of Pinon-Juniper Communities within the Interior West. USDA Forest Service Proceedings RMRS-P-9.

Holmes, R.L., R.K. Adams, and H.C. Fritts. 1986. Tree Ring Chronologies of Western North America: California, Eastern Oregon, and Northern Great Basin. Chronology Series VI. Laboratory of Tree Ring Research, University of Arizona, Tucson, AZ.

Kramer, S. 1990. Development and Morphology of Juvenile Western Juniper (*Juniperus occidentalis* Hook.). M.S. Thesis, Oregon State University, Corvallis, OR.

LaMarche, V.C., Jr. 1974. Paleoclimatic Inferences from Long Tree-Ring Records. Science. 183:1043-1048.

Miller, P.M., L.E. Eddlemand and S. Kramer. 1990. Allocation Patterns of Carbon and Minerals in Juvenile and Small-Adult *Juniperus occidentalis*. Forest Science. 36:734-747.

Miller, R.F., J.D. Bates, T.J. Svejcar, F.B. Pierson, and L.E. Eddlemand. 2005. Biology, Ecology, and Management of Western Juniper. Oregon State University Agricultural Experiment Station, Technical Bulletin 152, p 77. http://extension.oregonstate.edu/catalog/html/tb/tb152/

Miller, R.F. and J.A. Rose. 1995. Historic Expansion of *Juniperus occidentalis* (Western Juniper) in Southeastern Oregon. Great Basin Naturalist. 55:34-45.

Miller, R.F. and J.A. Rose. 1999. Fire History and Western Juniper Encroachment in Sagebrush Steppe. Journal of Range Management. 52:550-559.

Miller, R.F., T.J. Svejcar, and J.A. Rose. 2000. Impacts of Western Juniper on Plant Community Composition and Structure. Journal of Range Management. 53:574-585.

Miller, R.F. and R.J. Tausch. 2001. The Role of Fire in Juniper and Pinyon Woodlands: A Descriptive Analysis. Pages 15-30. *In* K.E.M. Galley and T.P. Wilson (eds.). Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: the First National Congress of Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 11, Tall Timbers Research Station, Tallahassee, FL.

Miller, R.F. and P.E. Wigand. 1994. Holocene Changes in Semiarid Pinon-Juniper Woodlands: Response to Climate, Fire and Human Activities in the U.S. Great Basin. BioScience. 44:465-474.

Rimbey, N.R., T.D. Darden, L.A. Torell, J.A. Tanaka, L.W. Van Tassell, and J.D. Wulfhorst. 2003. Ranch Level Economic Impacts of Public Land Grazing Policy Alternatives in the Bruneau Resource Area of Owyhee County, Idaho. University of Idaho Agricultural Economics Extension Series No. 03-05.

Ritten, J.P., W.M. Frasier, C.T. Bastain, S.I. Paisley, M.A. Simith and S. Mooney. 2010. A Multi-Period Analysis of Two Common Livestock Management Strategies Given Fluctuation Precipitation and Variable Prices. Journal of Agricultural and Applied Economics. 42:177-191.

Roberts, C. and J.A. Jones. 2000. Soil Patchiness in Juniper-Sagebrush-Grass Communities of Central Oregon. Plant and Soil. 223:45-61.

Rowland, M.M., L.H. Suring, R.J. Tausch, S. Geer and M.J. Wisdom. 2008. Characteristics of Western Juniper Encroachment into Sagebrush Communities in Central Oregon. USDA Forest Service Forestry and Range Sciences Laboratory, La Grande, Oregon 97850, USA. 23 pp.

Stebleton, A. and S. Bunting. 2011. Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 430. Bureau of Land Management, Denver, CO, BLM/ID/PT-09/002+2824. 81p.

Taylor, D.T., R.H. Coupal and T. Foulke. 2005. The Economic Impact of Federal Grazing on the Economy of Park County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics, Final Report. August 2005.

Taylor, D.T., R.H. Coupal, T. Foulke and D. Feeney. 2004a. The Potential Economic Impact on the Ecomony of Southeastern Wyoming from Designation of Critical Habitat for the Preble's Meadow Jumping Mouse. University of Wyoming Department of Agricultural and Applied Economics, Final Report. September 2004.

Taylor, D.T., R.H. Coupal, T. Foulke and J.G. Thompson. 2004b. The Economic Importance of Livestock Grazing on BLM Land in Fremont County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics. October 2004.

Torell, L.A., J.A. Tanaka, N. Rimbey, T. Darden, L. Van Tassell, and A. Harp. 2002. Ranch-Level Impacts of Changing Grazing Policies on BLM Land to Protect the Greater Sage-Grouse: Evidence from Idaho, Nevada, and

Oregon. Policy Analysis Center for Western Public Lands, Policy Paper SG-01-02, Caldwell, ID.

Torell, L.A., S. Murugan, and O.A. Ramirez. 2010. Economics of Flexible Versus Conservative Stocking Strategies to Manage Climate Variability Risk. Rangeland Ecology and Management. 63:415-425.

USDA Forest Service. 1981. Atlas of United States Trees. Volume I: Conifers and Important Hardwoods. USDA Forest Service Miscellaneous Publication No. 1146.

Vasek, F.C. and R.F. Thorne. 1977. Transmontane Coniferous Vegetation. Pages 797-832. *In* M.G. Barbour and J. Major (editors). Terrestrial Vegetation of California. California Native Plant Society, Special Publication No. 9.

Wahl, E.W. and T.L. Lawson. 1970. The Climate of the Mid-Nineteenth Century United States Compared to the Current Normals. Monthly Weather Review. 98:259-265.

West, N.E. 1999. Juniper-Pinyon Savannas and Woodlands of Western North America. *In*: R.C. Anderson, J.S. Fralish and J.M. Baskin (editors). Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press, London, England. P288-308.

Young, J.A. and R.A. Evans. 1981. Demography and Fire History of a Western Juniper Stand. Journal of Range Management. 34:501-505.

Chapter II: Ranch Level Economic Impacts of Western Juniper (*Juniper occidentalis*) Encroachment into Sagebrush Steppe Ecosystems

Invasive and encroaching species are an ecologically and economically important issue in many different aspects of society. Western Juniper (*Juniperus occidentalis*) is a native species in Oregon, California, Idaho and Nevada. Western juniper has become a serious threat to the natural sagebrush steppe ecosystem that exists on western rangelands. Western juniper has been encroaching into sagebrush steppe ecosystems since the European settlement of the range, approximately 130 years ago (Miller and Wigand 1994, Miller and Tausch 2001). This encroachment imposes many stresses on an already compromised ecosystem.

Historically western juniper was contained on the ridges where limited fine fuels were available to support fire (Burkhardt and Tisdale 1976, Vasek and Thorne 1977, Young and Evans 1981, Holmes et al. 1986, Miller and Rose 1995, 1999). These ridges lacked the vegetation necessary to carry fire, allowing the establishment of what are now old growth western juniper communities. European settlement of western rangelands greatly altered the fire regime through grazing that removed the fine fuels, and active fire suppression. The same rangelands that used to see fire approximately every 25 years may not experience a fire now for over 150 years (Miller et al. 2005). This allows the establishment of reproductively mature juniper stands on productive sagebrush steppe ecosystems that were previously protected by fire.

Grazing during early European settlement was plagued with poor land management and a general lack of knowledge of ecological processes leading to extreme overgrazing in many areas. Overgrazing facilitated juniper encroachment by reducing the fine fuels available on western rangelands, contributing to increased mean fire return interval (MFRI) and decreasing interspecies plant competition (Burkhardt and Tisdale 1976, Miller and Rose 1999, Miller and Tausch 2001). Climatic changes have caused wetter and milder conditions which greatly facilitate juniper growth (Antevs 1938, Wahl and Lawson 1970, LaMarche 1974, Graumlinch 1987). All of these factors have facilitated the encroachment of western juniper into surrounding sagebrush communities.

Currently juniper and pinyon species occupy over 74 million acres in the United States, a tenfold increase from the 7 million acres that have been historically inhabited (West 1999). Western juniper occupies nearly 9 million of those acres in Oregon, Idaho, California and Nevada (USDA Forest Service 1981, Gedney et al. 1999, Miller and Tausch 2001, Azuma et al. 2004). As juniper cover increases to between 1/3 to 1/2 of its maximum cover potential, the understory species (sagebrush, grasses and forbs) rapidly decrease and can be reduced by 80 percent of their original cover (Bates et al. 2005, Miller et al. 2000). This decrease in understory species reduces the amount of vegetation available for forage and alters the habitat for wildlife and other species.

Miller et al. 2000 and 2005 developed a classification system for juniper encroachment. They devised a three phase classification system. Phase I is characterized by having juniper presence on a site, but in low enough numbers and densities that the understory sagebrush and herbaceous vegetation remains dominant. During this phase the juniper does not influence the ecological processes, (e.g. hydrologic, nutrient and energy cycles), on the site. In Phase II, juniper cover has increased to a point where it now plays a codominant role in influencing the ecological processes of the site. In other words, juniper and sagebrush assume about the same levels of cover in the ecosystem. During Phase II, the shrub layer and herbaceous production begin to decline. In Phase III, western juniper now dominates the site. Junipers are the primary vegetation influencing all of the ecological processes, the shrub layer is significantly decreased, if not eliminated, and herbaceous production continues to decline. This classification system forms the basis for an economic analysis of juniper invasion, primarily through the components of potential forage reductions and habitat changes for domestic livestock and other species.

The impact of western juniper encroachment to ranchers and ranching profits is economically important since ranching occurs on approximately 80% of the 270 million acres of public land in the western United States (Bhattacharyya et al. 1996). Bates et.al. (2005) found that removing juniper from range plots increased the livestock carrying capacity by nearly ten-fold (the number of acres needed to support an animal unit month (AUM) of livestock grazing increased from 47 to 5 acres/AUM). This indicates that there are potentially significant economic impacts to ranches that managers should be aware of. This project uses the change in available forage to determine the change in costs, returns and cattle numbers as juniper encroachment advances from Phase I to Phase III on a representative ranch in southwestern Idaho.

Methods

The economic situation, available resources and production rates were defined for a representative 300 head cow/calf ranch in the Jordan Valley area of Owyhee County, Idaho, as described in Table 2.1. A linear programming (LP) model was developed to estimate the ranch-level economic impact of juniper invasion. Similar studies have also been used to analyze the economic impacts to ranchers of agency policy changes and associated forage allocation decisions in Idaho, Oregon, Nevada and Wyoming. The studies have mainly focused on the ranch-level economic impacts of federal agency grazing allotment adjustments due to a variety of reasons. Issues such as sage-grouse protection, riparian grazing strategies, supplementation decisions, threatened and endangered species concerns, climate change/drought impacts have been modeled using this type of economic models (Rimbey et al. 2003, Ritten et al. 2010,Taylor et al. 2005, Taylor et al. 2004a, Taylor et al. 2004b, Torell et al. 2002, Torell, et al. 2010).

Ranch level data were collected through group interviews (Rimbey et al. 2003) and defined average production rates and costs. A dynamic multi-period LP model was developed to determine optimal (profit maximizing) production levels, including herd size and forage usage over a 40-year planning horizon. Economic returns are calculated on an annual basis and aggregately over the planning horizon. The LP model maximized the net present value of annual ranch returns, subject to the various resource and production constraints.

Table 2.1: Characteristics and resources of the representative ranch

Description	Units	Value
Land Resources Owned		
Alfalfa Hayland	Acres	0
Native Meadow Hayland	Acres[a]	325
Convert Meadowland to Pasture	Acres[a]	325
Deeded Rangeland	AUMs	240
Land Resources Leased or Purchased		
State Trust Land	AUMs	144
BLM	AUMs	2,098
Private Leased Land	AUMs	500
Purchased Alfalfa	Tons	Unlimited
Purchased Meadow Hay	Tons	Unlimited
Livestock Resources[b]		
Animal Units Yearlong	AUY	333
Brood Cows	Head	286
Replacement Heifers	Head	65
Bulls	Head	19
Horses	Head	6
Miscellaneous Annual Income/ Expenses		
Fixed Ranch Expenses	$	24,430
Family Living Allowance	$	24,000
Off-Ranch Annual Income	$	35,000
Required Minimum Cash Reserves	$	500
Efficiency Measures		
Calf Crop	%	88
Calf Death Loss	%	4
Cow Death Loss	%	2
Bull Death Loss	%	1
Steer Calf Sale Weight	Lbs	440
Heifer Calf Sale Weight	Lbs	390
Heifer Yearling Sale Weight	Lbs	800
Cull Cow Sale Weight	Lbs	950
Cull Bull Sale Weight	Lbs	1,800

[a]/ Converting hayland to grazable pasture is not generally practiced but is a possible source of forage when public lands AUMs are reduced. This conversion would use some of the available hayland and thus would reduce the land available for crop production.

[b]/ Animal numbers reported are from the published cost-and-return publications for each state. Optimal animal numbers in the LP model will vary by vary by year as beef prices vary.

[c]/ Other production parameters used to develop the LP models are defined in the cost-and-return series publications.

Real (constant 2005) livestock prices were used and analyzed with 100 cattle price iterations per year. Averages from the price data set are shown in Table 2.2. The price data approximates a 12 year cyclic pattern of cattle prices. The starting point for each iteration is stochastically determined within the cattle cycle, with uniform probability distribution of selection, helping to minimize the effect of changing cattle prices on the results of the model.

The ranch started in year one with no initial wealth and no initial debt obligations. The initial brood cow herd and the ranch capital were assumed to have already been accrued, and was not incorporated into the debt obligations. Starting in year 2 the model can adjust the herd size and which combinations of land and forage resources to utilize during the available seasons. State land is utilized fully during its available seasons since Idaho Department of Lands requires fees to be paid whether the allotment is grazed or not. All other forage options can be utilized in any percentage during their available seasons. The ranch is assumed to have $35,000 in annual off-ranch income at their disposal. Off-ranch investment opportunities were not considered, the model maximizes net discounted returns using only the economic opportunity cost of raising cattle.

Forage availability by juniper invasion phase was calculated using herbage availability data from Bourne and Bunting, 2011, and Stebleton and Bunting, 2011. Total herbage production was converted to available AUMs per acre and incorporated into the model as AUMs available on a Bureau of Land Management (BLM) grazing allotment. Phase I was used as a baseline model and was run using the original AUMs available on the allotment (2,098 AUMs).

Table 2.2: Average simulated 2005 real beef prices as compared to average 1995 - 2006 real prices reported by CattleFax™.

Description	Units	Simulated Prices				CattleFax™ 1995 - 2006			
		Average Price	Min	Max	Standard deviation	Average Price	Min	Max	Standard deviation
400 Lb. Steer Calf	$/lb	1.07	0.57	1.59	0.18	1.14	0.66	1.47	0.18
300-400 Lb. Heifer Calf	$/lb	1.03	0.46	1.57	0.20	1.03	0.53	1.37	0.18
600-700 Lb. Purchase Steer Calves[a]	$/lb	0.95	0.56	1.34	0.14	0.97	0.61	1.28	0.13
600-700 Lb. Purchase Heifer Calves[a]	$/lb	0.90	0.55	1.25	0.14	0.90	0.52	1.22	0.13
700-800 Lb. Ranch Raised Steer yearling	$/lb	0.88	0.47	1.31	0.15	0.91	0.59	1.22	0.12
700-800 Lb. Ranch Raised Heifer Yearling	$/lb	0.89	0.40	1.36	0.18	0.87	0.52	1.17	0.12
1,000 Lb. Cull Cow	$/lb	0.43	0.20	0.68	0.09	0.43	0.29	0.60	0.06
Cull Bull	$/lb	0.58	0.32	0.85	0.11	0.55	0.41	0.71	0.07
1,000 Lb. Brood Cow	$/head	925	414	1,567	195	866	466	1,334	170
1,000 Lb. Buy Bull	$/head	2,054	1,004	3,373	401				

[a]/Calves are purchased at the 300-400 lb weight and sold at a 600-700 lb weight.

Phase II and III had 1,322 and 825 AUMs available on the same BLM grazing allotment, respectively. These forage allocations amounted to a 37% and 60% reduction in available AUMs for Phase II and III, respectively. The conversion of herbage production into available AUMs on the allotment is shown in Table 2.3. A 50% utilization rate was used to calculate the potential AUMs on the allotment. Recommended utilization rates vary greatly by vegetation type and this could be an optimistic estimate for sustainable grazing of juniper woodlands. The representative ranch has private rangeland forage (deeded land) as well as state lands available for use in the grazing system. Encroachment of western juniper onto BLM lands would likely also affect the other surrounding land, such as state and private land, although that is not considered in the model.

Table 2.3: Herbage production in lbs/ac from Bourne and Bunting (2011) and Stebleton and Bunting (2011) converted to AUMs available on BLM allotment

	Average lbs/ac	% Utilization[a]	Available lbs/ac	AUM/Allotment[b]	% Reduction
Phase 1	445.72	50%	222.86	2,098	0.00%
Phase 2	280.93	50%	140.47	1,322	36.97%
Phase 3	177.45	50%	88.73	835	60.19%

[a]/Utilization rate is the amount of available forage that was assumed to be utilized for domestic livestock consumption (Ohlenbusch and Watson, 1994)

[b]/Allotment size estimated at 7,531 acres

Additional forage sources were also considered available within the model, including privately leased land, purchased meadow hay and purchased alfalfa. Alternative feeds are considered available for specific seasons and purchased feeds were considered in unlimited availability. Hay prices were held constant at $100/ton, and privately leased land at $13.25/AUM. The option to convert meadow hayland to grazed pasture is also an available option within the model. Converting hayland to pasture is not usually practiced in ranching operations since it reduces the land available for hay production and winter feed supplies, but it can be an option to compensate for the reduction in forage on BLM lands.

LP Model Description

The model used in this analysis was developed for western ranchers that rely on a combination of private and public grazing resources. It maximizes net present value (NPV) of discounted annual returns over a T-period planning horizon. It contains various linear constraints that outline the land and cash resources available to the ranch and the transfer of resources from year to year. The following equation shows the objective function, where future income is discounted at a rate of 7% (r).

$$Max(\pi) = \sum_{t=1}^{40}(TR_t - TVC_t) * (1 + r)^{-t} + TValue_T \qquad [1]$$

Where,

$$TR_t = liveclass * salewt * saleprice$$

$$TVC_t = forage * fcst$$

Equation [1] shows that the NPV of the ranch in each time period, t, is equal to total revenue (TR) minus total variable cost (TVC). The terminal value (TValue) accounts for all future returns from the herd following the end of the 40-year planning horizon, and reduces the effect of the model assuming “perfect knowledge,” keeping the model from selling all livestock and assets in period T. TR is calculated by multiplying the number of cattle in each weight class (liveclass) by the associated sale weight (salewt) and the associated sale price (saleprice). TVC is calculated by multiplying the various types of available forage (forage) by the cost associated with each forage type (fcst).

Figure 2.1 shows the general structure of the model and its constraints during any given year, t. The ranch is modeled with a set amount of land that is allocated to either grazing or crop production, as it contributes to forage for livestock. Other crop raising activities are not considered in the model. Each land type is constrained at or below some upper limit, as well as the seasons during which it is available as forage. Seasonal availability of each land type is shown in Table 2.4. The purchase of additional forage was allowed without constraint, but surveys of ranchers in the Jordan Valley showed that they utilized all hay grown within their own operation so the sale of hay by the ranch was restricted in this model, although it could be allowed if desired. The different productivity levels of the various land types are also factored into the model, as shown in Table 2.5.

Figure 2.1: Constraint set for LP model during year t

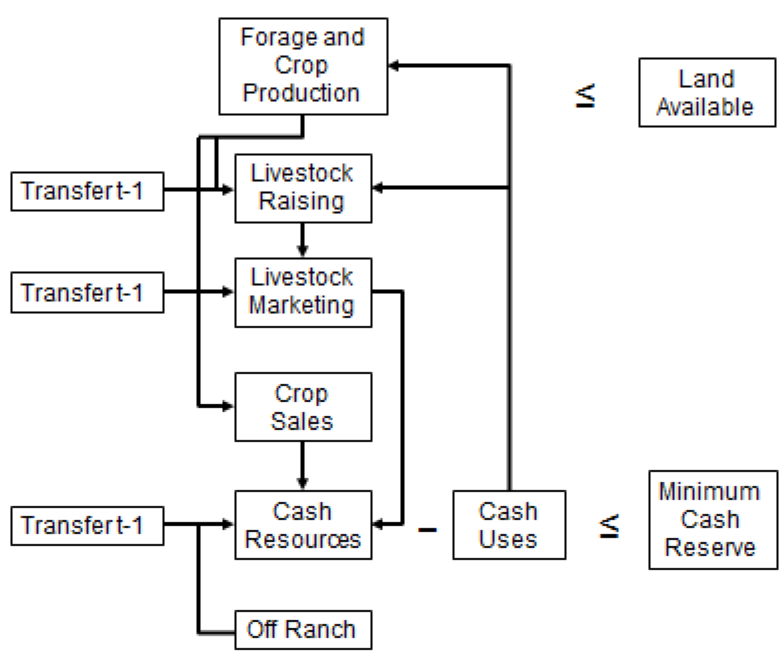


Table 2.4: Seasonal availability of hay and forage for representative ranch

	Season					
	3/1 4/15	4/15 5/15	5/15 10/15	10/15 11/15	11/15 12/15	12/15 3/1
State Trust Land		*	*			
BLM		*	*			
Private Lease		*	*	*	*	
Deeded Range	*	*	*	*	*	
Aftermath Grazing				*	*	*
Convert Meadow to Pasture		*	*	*	*	
Feed raised/purchased Hay	*	*				*

Table 2.5: Productivity measures for harvested and grazed forages

	Unit	Value
Hay Conversion to AUMs	AUMs/ton	2.42
Raised Native Hay	tons/acre	2.00
Raised Native Aftermath	AUM/acre	2.30
Pasture Native Hayland	AUMs/ton	5.50

The next set of equations transfer land availability and forage production activities into livestock raising activities. Equations that determine the ratio between certain animal classes are also included. These equations define the bull to cow ratio, the calf crop and calves available for sale at the end of the season after factoring in death loss percentages, and herd replacement. Bull numbers, replacement heifers and cull cows are determined as a percentage of the cow herd. Additional equations are included to transfer brood cows from year to year, Seasonal forage requirements for each animal type are determined by the animal unit equivalency (AUE) factors, shown in Table 2.6. The livestock marketing block of equations transfers livestock raising activities to livestock sales. Yearlings are retained from year t-1 and sold in year t.

Table 2.6: Animal unit equivalencies used to calculate seasonal forage requirements

Animal Class	Animal Unit Equivalency (AUE)
Brood Cows	1.00
Bulls	1.25
Horses	1.25
Calves	0.50
Yearlings	0.75

Revenues are obtained from livestock sales. Additional revenues could also be obtained from crop sales, if the model allowed. Cash flow equations transfer sales revenues into livestock, crop and forage raising costs. Off-ranch income, fixed expenses, family living allowance and loan obligations are also included in the cash flow equations. Excess cash is transferred within the operation from year t-1 to year t. Cash shortages can be compensated on a yearly basis by short term loans that can be obtained at a 10% interest rate and must be repaid the following year. Borrowing is not allowed during the last year of the planning horizon and all debt obligations must be repaid in full by the end of the planning horizon.

Results

Phase I encroachment level was used as the baseline model to which Phase II and Phase III were compared. The average production and usage levels for all 3 phases expressed as an annual average over 40 years with 100 different price iterations are shown in Table 2.7. In Phase I there was no reduction in herbage production on BLM lands, and all AUMs are available for use. Since herbage availability was not limiting, the herd numbers maintained at a relatively constant level, averaging 267 brood cows. Figure 2.2 shows brood cow numbers by phase. An average of 2,031 BLM AUMs was used annually, along with the total available deeded acreage and state AUMs, 240 and 144 respectively. Figure 2.3 shows the AUMs used on the BLM allotment for each phase of encroachment. Phase I is the only situation in which BLM AUMs were not limiting. Twelve AUMs of privately leased land were necessary during Phase I. The model showed that an average of 1,617 tons of raised meadow hay, along with an additional 175 tons of purchased alfalfa was also fed. The purchased alfalfa was used to provide additional nutrient quality for the critical replacement heifers and replacement heifer calves. Baseline profit, loan requirements, and variable costs were also determined. Net profits in Phase I averaged $32,009/ year, or $84/ AUY. Minimal loans were required in Phase I, averaging $16/ year, when loans were averaged over the 100 iterations and the 40 year planning horizon. The total amount of short term loans required by the model over the 40 year planning horizon, averaged by year over the 100 price iterations, were $650. Variable production costs, consisting of annual animal and forage costs, average $87,890, or $227/ AUY. In Phase I, forage costs averaged $79/ AUY, but as juniper encroachment increased the declines in available forage on the BLM allotment had to be compensated by increased use of private leased land and purchased hay, causing an increase in overall forage costs per head.

Phase II had a 37% reduction in forage production, leaving only 1,322 AUMs available on the BLM allotment. Brood cow numbers were reduced to 213 head, a 20% reduction, and AUYs were reduced to 311 AUYs, a 19.4% reduction. As cattle numbers declined, the ranch had decreasing forage

Table 2.7: Optimal Production Levels in Response to BLM AUM Reduction Due to Western Juniper Encroachment in Owyhee County, Idaho

Adjustments in optimal use levels	Phase 1	Phase2	Phase3
Percent reduction in BLM AUMs	0.0%	37.0%	60.2%
BLM available (AUMs)	2,098	1,322	835
Optimal average BLM used (AUMs)	2,031 (102)	1,317 (26)	834 (13)
Average number of brood cows (head)	267 (17)	213 (25)	188 (28)
Average number AUY	386 (30)	311 (41)	273 (46)
Percent reduction in AUY	-	-19.4%	-29.3%
Average annual variable production costs ($)	87,890 (16,137)	70,528 (13,429)	64,731 (13,380)
Average annual variable production costs ($/AUY)	227	226	238
Average annual forage costs ($)	30,661 (7,447)	26,312 (7,235)	24,350 (8,146)
Average annual forage costs ($/AUY)	79	84	88
Average annual net cash income ($)	32,009 (29,182)	25,178 (20,014)	18,674 (14,526)
Average annual net cash income ($/AUY)	84	81	68
Average change in net cash income ($/BLM AUM lost)	-	-8.80	-10.56
Deeded Range (AUMs)	1,280 (0)	1,280 (0)	1,280 (0)
State trust land (AUMs)	144 (0)	144 (0)	144 (0)
Private Lease (AUMs)	12 (52)	34 (94)	66 (136)
Meadow acres converted to pasture (acres)	13 (9)	5 (8)	33 (23)
Raised meadow hay fed (tons)	1,617 (93)	1,512 (274)	1,396 (234)
Purchased alfalfa hay fed (tons)	175 (30)	143 (34)	118 (39)
Average amount borrowed annually ($)	16 (394)	79 (887)	755 (3,606)

[a]/ Number in parenthesis is the standard deviation measured over the 100 iterations and 40 years

requirements, as shown in Figure 2.3. Deeded range and state land use remained constant at 240 and 144 AUMs respectively. An average of 34 private lease AUMs, along with 1,512 tons of raised meadow hay, and 143 tons of purchased alfalfa hay. Net cash returns were reduced to $25,178, a 21% reduction in overall profits, and a $3 decrease in returns per AUY. These decreased profits resulted in an $8.81 loss for every AUM lost by juniper encroachment. Average annual variable production costs were $70,528, or $226/ AUY. Forage costs alone were $26,312 which is an overall reduction from Phase I, but an increase of $5/ AUY due to increased purchased alfalfa and privately leased land. Phase II also required increased short term loans for sustained operation, averaging $79/ year when loans were averaged over the 100 iterations and the 40 year planning horizon. Total loans over the 40 year planning horizon amounted to $3,153.

Phase III levels of encroachment caused even further reductions in forage availability on the BLM grazing allotment, or a 60% reduction in AUMs available, leaving only 835 AUMs available for grazing. This caused a herd reduction of 29%, to an average of 273 total AUYs, and only 188 head of brood cows. As with the other two levels of encroachment, all available deeded range and state trust AUMs were utilized. An average of 66 AUMs of private lease land was needed along with 1,396 tons of raised meadow hay and 118 tons of purchased alfalfa. Net cash returns were decreased by 42% leaving an average profit of $18,674 annually ($68/ AUY). There was a $10.56 reduction in profit for each AUM lost due to juniper encroachment. Average variable production costs were $64,731, or $238/ AUY. Forage costs alone were $24,350 annually, or $88/ AUY, a $9 increase per AUY. Borrowing also increased in Phase III to an average of $755/ year when loans were averaged over the 100 iterations and the 40 year planning horizon. Total loans over the 40 year planning horizon were $30,191, an increase of almost 50 times the average amount borrowed in Phase I.

Figure 2.2: Broodcow Numbers by Phase

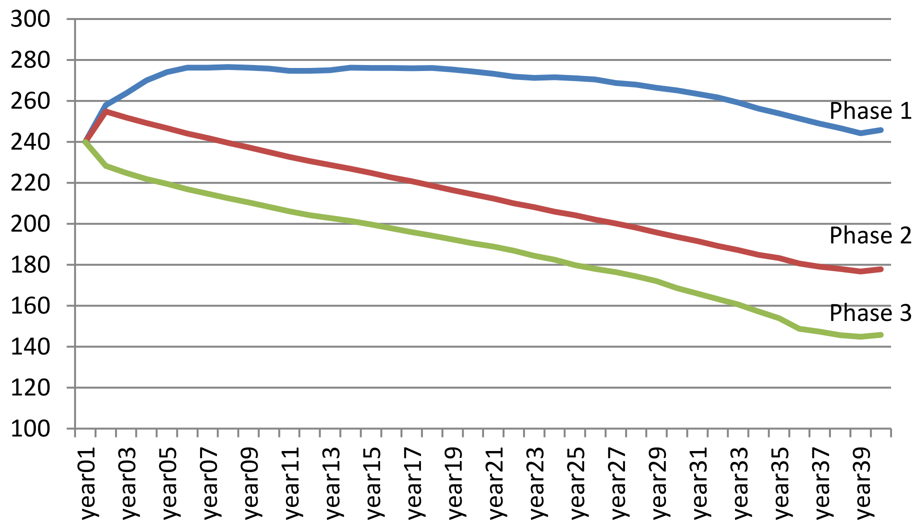
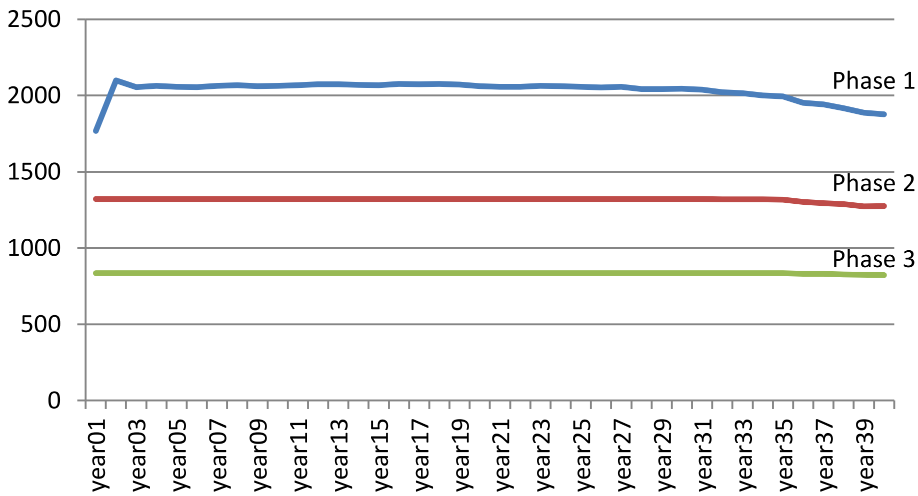


Figure 2.3: BLM AUM Usage by Phase



Sensitivity analysis was conducted on all 3 models to determine the impact of varying levels of off-ranch income. Off-ranch income was originally set at $35,000. For the sensitivity analysis, it was decreased in $5,000 increments until the model became infeasible, indicating the ranch faced insurmountable liquidity issues. Average annual net income for the 3 phases at varying levels of off-ranch income is shown in Table 2.8. At the Phase I level of encroachment, the ranch could sustain operation until off-ranch income declined to $15,000. When encroachment increased to Phase II, the ranch became unsustainable when off-ranch income declined to $20,000; Phase III encroachment levels were not operational without at least $30,000 in off-ranch income.

Table 2.8: Sensitivity analysis net income variations by off ranch income levels

	30,000	25,000	20,000
Phase 1	$30,996	$30,475	$19,827
Phase 2	$24,290	$17,185	Infeasible
Phase 3	$15,310	Infeasible	Infeasible

Conclusions and Implications

As western juniper encroaches into sagebrush steppe ecosystems, understory production decreases. Reductions in available rangeland forage were applied to BLM lands, significantly decreasing the forage available during the spring and summer months. This reduction in available forage must be compensated either through privately leased land, purchased alfalfa hay, or reductions in herd size. This analysis shows that a combination of all three would be used to maintain the ranch. As western juniper encroachment increases from Phase I to Phase III, profitability and sustainability of the model ranch declines, primarily due to the loss of spring-fall forage. The costs associated with running the ranch also increased, due to the lack of alternative forage sources during the spring-fall period.

The encroachment of western juniper causes over a 60% reduction in AUMs available on rangelands, restricting the number of cattle that can be sustained by the ranch. This caused a 29% reduction in both brood cow numbers and total AUYs. Ranch income is derived from the production and sale of an annual calf crop, which is directly impacted by brood cow numbers. This decrease in saleable product caused annual net cash income to decline 11.4%, and income per AUY to decline 19%.

Reductions in available forage not only reduced herd size, but also increased the forage costs and variable costs per head. The reduced forage on the BLM allotment during seasons 2 and 3 (mid-April through mid-October) was compensated by increased use of raised meadow hay, privately leased land, and altering the grazing seasons on deeded rangeland. During season 2, BLM use declined from 313 AUMs to 13 AUMs from Phase I to Phase III, which was compensated by an increase in raised meadow hay usage from 51 AUMs to 232 AUMs and extending the feeding season. During season 3, BLM usage declined from 1,718 to 821 AUMs, which was offset with increased usage of deeded range, by 181 AUMs, privately leased lands, by 62 AUMs, and grazed meadow pasture, by 110 AUMs. The increased use of deeded range during season 3 caused reductions during seasons 4 and 5. Purchased alfalfa, grazed meadow land, and raised meadow hay were utilized to compensate for these forage reductions in seasons 4 and 5.

The model results show that increasing levels of juniper encroachment greatly decrease ranch profitability. These decreases are caused by increased forage costs as well as decreased revenues from calf sales. The net present value of the model ranch income over the 40 year planning horizon was estimated at $435,983, $373,515, and $294,852, for phases I through III, respectively. The increase in western juniper encroachment from Phase I to Phase III reduced the net present value of the ranch income stream by 32.4%. Off-ranch income is critical to the long-term sustainability of ranches in the western U.S.

Future research should include a more dynamic study to analyze the changes in juniper encroachment over time, taking into account annual climatic variation and annual changes in understory herbaceous production. At this point no research has been found that defines a timeline for the phases of juniper encroachment. Once this research is completed, this model could be altered to analyze the changes in encroachment over time. Our analysis also shows that off-ranch income plays a critical role in the sustainability of the ranch, even in the earlier phases of juniper encroachment. An impact analysis of off-ranch income by phase is an additional area of potential future research.

References

Antevs, E. 1938. Rainfall and Tree Growth in the Great Basin. Carnegie Institution of Washington Publication 469, Washington, D.C. and American Geographical Society, Special Publication No. 21, New York, NY.

Azuma, K.L., B.A. Hiserote and P.A. Dunham. 2005. The Western Juniper Resource of Eastern Oregon, 1999. Research Bulletin PNW-RB-249. Portland, OR: USDA Forest Service, Pacific Northwest Research Station; 18p.

Bates, J.D., R.F. Miller, and T. Svejcar. 2005. Long-Term Successional Trends Following Western Juniper Cutting. Rangeland Ecology and Management. 58:533-541.

Bhattacharyya, A., R. Narayanan, T.R. MacDiarmid, T.R. Harris, and W.O. Champney. 1996. Demand for Grazing on Public Lands: A Disequilibrium Approach. Land Economics. 72(4):483-499.

Bourne, A. and S. Bunting. 2011. Guide for Quantifying Post-treatment Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 437. Bureau of Land Management, Denver, CO, BLM/ID/PT-11/003+2824. 115p.

Burkhardt, J.W. and E.W. Tisdale. 1976. Causes of Juniper Invasion in Southwestern Idaho. Ecology. 57:472-484.

Gedney, D.R., D.L. Azuma, C.L. Bolsinger and N. McKay. 1999. Western Juniper in Eastern Oregon. U.S. Forest Service General Technical Report NW-GTR-464.

Graumlich, L.J. 1987. Precipitation variation in the Pacific Northwest (1675-1975) as Reconstructed from Tree Rings. Annals of the Association of American Geographers. 77:19-29.

Holmes, R.L., R.K. Adams, and H.C. Fritts. 1986. Tree Ring Chronologies of Western North America: California, Eastern Oregon, and Northern Great Basin. Chronology Series VI. Laboratory of Tree Ring Research, University of Arizona, Tucson, AZ.

LaMarche, V.C., Jr. 1974. Paleoclimatic Inferences from Long Tree-Ring Records. Science. 183:1043-1048.

Miller, R.F., J.D. Bates, T.J. Svejcar, F.B. Pierson, and L.E. Eddlemand. 2005. Biology, Ecology, and Management of Western Juniper. Oregon State University Agricultural Experiment Station, Technical Bulletin 152, p 77. http://extension.oregonstate.edu/catalog/html/tb/tb152/

Miller, R.F. and J.A. Rose. 1995. Historic Expansion of *Juniperus occidentalis* (Western Juniper) in Southeastern Oregon. Great Basin Naturalist. 55:34-45.

Miller, R.F. and J.A. Rose. 1999. Fire History and Western Juniper Encroachment in Sagebrush Steppe. Journal of Range Management. 52:550-559.

Miller, R.F., T.J. Svejcar, and J.A. Rose. 2000. Impacts of Western Juniper on Plant Community Composition and Structure. Journal of Range Management. 53:574-585.

Miller, R.F. and R.J. Tausch. 2001. The Role of Fire in Juniper and Pinyon Woodlands: A Descriptive Analysis. Pages 15-30. *In* K.E.M. Galley and T.P. Wilson (eds.). Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: the First National Congress of Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 11, Tall Timbers Research Station, Tallahassee, FL.

Miller, R.F. and P.E. Wigand. 1994. Holocene Changes in Semiarid Pinon-Juniper Woodlands: Response to Climate, Fire and Human Activities in the U.S. Great Basin. BioScience. 44:465-474.

Ohlenbusch, P.D. and S.L. Watson. 1994. Stocking Rate and Grazing Management. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. MF-1118. www.oznet.ksu.edu

Rimbey, N.R., T.D. Darden, L.A. Torell, J.A. Tanaka, L.W. Van Tassell, and J.D. Wulfhorst. 2003. Ranch Level Economic Impacts of Public Land Grazing Policy Alternatives in the Bruneau Resource Area of Owyhee County, Idaho. University of Idaho Agricultural Economics Extension Series No. 03-05.

Ritten, J.P., W.M. Frasier, C.T. Bastain, S.I. Paisley, M.A. Simith and S. Mooney. 2010. A Multi-Period Analysis of Two Common Livestock Management Strategies Given Fluctuation Precipitation and Variable Prices. Journal of Agricultural and Applied Economics. 42:177-191.

Stebleton, A. and S. Bunting. 2011. Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 430. Bureau of Land Management, Denver, CO, BLM/ID/PT-09/002+2824. 81p.

Taylor, D.T., R.H. Coupal and T. Foulke. 2005. The Economic Impact of Federal Grazing on the Economy of Park County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics, Final Report. August 2005.

Taylor, D.T., R.H. Coupal, T. Foulke and D. Feeney. 2004a. The Potential Economic Impact on the Ecomony of Southeastern Wyoming from Designation of Critical Habitat for the Preble's Meadow Jumping Mouse. University of Wyoming Department of Agricultural and Applied Economics, Final Report. September 2004.

Taylor, D.T., R.H. Coupal, T. Foulke and J.G. Thompson. 2004b. The Economic Importance of Livestock Grazing on BLM Land in Fremont County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics. October 2004.

Torell, L.A., J.A. Tanaka, N. Rimbey, T. Darden, L. Van Tassell, and A. Harp. 2002. Ranch-Level Impacts of Changing Grazing Policies on BLM Land to Protect the Greater Sage-Grouse: Evidence from Idaho, Nevada, and Oregon. Policy Analysis Center for Western Public Lands, Policy Paper SG-01-02, Caldwell, ID.

Torell, L.A., S. Murugan, and O.A. Ramirez. 2010. Economics of Flexible Versus Conservative Stocking Strategies to Manage Climate Variability Risk. Rangeland Ecology and Management. 63:415-425.

USDA Forest Service. 1981. Atlas of United States Trees. Volume I: Conifers and Important Hardwoods. USDA Forest Service Miscellaneous Publication No. 1146.

Vasek, F.C. and R.F. Thorne. 1977. Transmontane Coniferous Vegetation. Pages 797-832. *In* M.G. Barbour and J. Major (editors). Terrestrial Vegetation of California. California Native Plant Society, Special Publication No. 9.

Wahl, E.W. and T.L. Lawson. 1970. The Climate of the Mid-Nineteenth Century United States Compared to the Current Normals. Monthly Weather Review. 98:259-265.

West, N.E. 1999. Juniper-Pinyon Savannas and Woodlands of Western North America. *In*: R.C. Anderson, J.S. Fralish and J.M. Baskin (editors). Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press, London, England. P288-308.

Young, J.A. and R.A. Evans. 1981. Demography and Fire History of a Western Juniper Stand. Journal of Range Management. 34:501-505.

Chapter III: Impacts of Western Juniper (*Juniper* occidentalis) Treatment Costs on Ranch Level Profits

Western Juniper (*Juniperus occidentalis*) is a native species in Oregon, California, Idaho and Nevada that has become a serious threat to the natural sagebrush steppe ecosystem that exists on western rangelands. Woodland encroachment causes a reduction in the shrub and herbaceous component of the rangeland vegetation, impacting the ecosystem at multiple levels. Changes to the herbaceous composition of western rangelands alter its suitability as habitat for many of the wildlife species that live within these areas, and decreases the land's productivity for domestic livestock grazing.

Many animal and plant species have been affected by juniper encroachment. Species that are already suffering from threatened population numbers, such as pygmy rabbits, Brewer's sparrow, and greater sage-grouse, are at especially high risk from woodland encroachment (Rowland et al. 2008). The greater sage-grouse (*Centrocercus urophasianus*) is one species that has received considerable attention from conservationists and others and has become the justification for various rehabilitation efforts across western rangelands. In 2010 the U.S. Fish and Wildlife Service (USFWS) listed the greater sage-grouse as a "warranted but precluded" species under the Endangered Species Act (PL 93-205; ESA). This designates the greater sage-grouse as a species eligible for listing under the ESA, but is postponed due to the need to address other species of higher priority (USFWS 2010). Woodland encroachment has been a significant factor in population declines of greater sage-grouse populations and has contributed to its potential to be listed under the Endangered Species Act (ESA). The Idaho Governor's Task Force Recommendations listed three major impediments to sage-grouse populations as invasive species, fire, and development. Juniper was listed under the invasive species as a species that has invaded approximately 600,000 acres of sage-grouse habitat to the point that it can no longer sustain sage-grouse populations (Makela and Major 2012). In a 1999 study, Commons et al. found that a year after removing juniper, sage-grouse populations, measured by males on leks, doubled. Juniper removal decreased avian predators in the area and allowed for decreased predation on sage grouse populations.

Understory composition at the time of removal and removal method are the primary characteristics determining the production response to juniper treatments. Removing western juniper at earlier stages has been shown to increase understory productivity, as much as 8 to 10 times (Bates et al. 2000, Bates et al. 2005, Bourne and Bunting 2011, Young et al. 1985). Bates et al. (2000) found an increase in soil water in cut versus uncut western juniper woodland plots, even in dry periods; nitrogen concentration was greater in cut treatments; there was twice as much biomass in the cut treatment the following year, showing that juniper removal will increase forage production and quality as well as improve the overall health of the ecosystem. Understory biomass averages 5 times higher after juniper treatment as compared to untreated areas. Of these increases in total biomass after juniper treatment, perennial grasses had the greatest recovery, increasing up to 16 times compared to untreated areas. Other grasses and perennial forbs tend to increase initially, but the increase is not sustained on a long term basis (Bates et al. 2005). The potential for invasive annuals, such as cheatgrass, to enter a site also increases when junipers are removed. The potential for cheatgrass (*Bromus tectorum*) invasion is greater in years of higher precipitation, especially after juniper removal, and also increases as more disturbances are caused to the site (Bates et al. 2005, Young et al. 1985).

Due to its impacts on sage-grouse populations as well as the overall health of the ecosystem, removal of encroaching western juniper has become increasingly important for private land owners, public land management agencies, conservation groups and others. Government agencies and conservation groups have started working in partnership with private land owners and managers to fund and manage removal of western juniper across western rangelands (Talsma, 2011).

When juniper invasion is still in the early phases (phase I or phase II when juniper covers less than one-half of its maximum cover potential for a particular site), there may be effective methods of treatment. The success of removing juniper on restoration of a desired plant community depends on pre-treatment understory composition, treatment method, and management of the site after juniper has been removed. Chainsaw cutting, prescribed fire and mastication machines are a few different methods that can be used to reduce juniper cover (Bates et al. 2005, Miller et al. 2000).

Chainsaw cutting has been the most common method used for treatment of juniper encroachment. Cutting allows the managers to be highly selective about which trees are removed from the site and to have precise control over treatment boundaries. Compared to prescribed burning, cutting provides managers with reduced liability, and can be conducted during any weather conditions. Cutting western juniper incurs a higher cost as well as potentially requiring retreatment within a few years. The cost per acre of cutting varies depending on the method and the terrain; cutting the trees and leaving them where they fall will be cheaper than cutting, limbing, and scattering the slash (Miller et al. 2000).

Fire is an effective alternative during the early stages of invasion and it allows for natural succession of desired vegetation, as long as invasive annual grasses are not an issue on the site. After juniper encroachment has passed a certain threshold, usually from phase II to phase III, fire can rarely burn hot enough to eliminate the trees, due primarily to the lack of understory vegetation and ladder fuels to carry the fire, causing it to no longer be an effective alternative for control (Allen et al. 2008, Miller et al. 2000).

The ecosystem has the highest likelihood of recovering when juniper is removed during the early phases, though removal of juniper will not likely return the ecosystem to a sagebrush steppe community without proactive management (Bates et al. 2005); both timing and the magnitude of stress that treatment will cause for desired wildlife and herbaceous species should be considered. Elimination of juniper should occur when it will have the least impact on the other desired species that exist in the ecosystem.

This study analyzes the economic feasibility of juniper removal, through chainsaw or mastication treatments, by analyzing a model ranch in the Jordan Valley area of Owyhee County, Idaho. High treatment costs were balanced against the value of increased forage available for grazing to determine the maximum the ranch would be willing to pay for juniper removal. Similar studies have also been used to analyze the economic impact to ranchers of agency policy changes and associated forage allocation decisions in Idaho, Oregon, Nevada, New Mexico, and Wyoming. The studies have mainly focused on the ranch-level economic impacts of federal agency grazing allotment adjustments due to a variety of reasons. Issues such as sage-grouse protection, riparian grazing strategies, supplementation decisions, threatened and endangered species concerns, and climate change/drought impacts have been modeled using this type of economic model (Rimbey et al. 2003, Ritten et al. 2010,Taylor et al. 2005, Taylor et al. 2004a, Taylor et al. 2004b, Torell et al. 2002, Torell, et al. 2010).

Methods

An economic model, including available resources and production rates defined for a representative 300 head cow/calf ranch in the Jordan Valley area of Owyhee County, Idaho, is outlined in Table 3.1. A linear programming (LP) model was developed to estimate the ranch-level economic impact of juniper invasion and possible control strategies over a forty year planning horizon.

Ranch level data were collected through group interviews (Rimbey et al. 2003) that defined average production rates and costs. A dynamic multi-period

LP model was developed to determine optimal (profit maximizing) production levels, including herd size and forage usage over a 40-year planning horizon. Economic returns are calculated on an annual basis and aggregately over the planning horizon. Real (constant 2005) livestock prices were used and analyzed with 100 cattle price iterations per year. Statistics from the price data set are shown in Table 3.2. The price data approximates a 12 year cyclic pattern of cattle prices. The starting point for each iteration is stochastically determined within the cattle cycle, with uniform probability distribution of selection, helping to minimize the effect of changing cattle prices on the results of the model.

The ranch is assumed to start with no initial wealth, besides the initial cow herd of 286 head and the ranch capital investment, and no initial debt obligations. Starting in year 2 the model can adjust the herd size and combinations of land and forage resources to utilize during their available seasons. All other forage options can be utilized in any percentage during their available seasons. The ranch is assumed to have $35,000 in off-ranch income at their disposal. Off-ranch investments were not considered separately and may be reflected in the off-ranch income figure. The model maximizes net discounted returns using only the economic opportunity of raising cattle.

Forage availability by phase of juniper encroachment after juniper removal was calculated using herbage availability data from Bourne and Bunting, 2011, and Stebleton and Bunting, 2011. Total herbage production was converted to available animal unit months (AUMs) per acre and incorporated into the model as AUMs available on the Bureau of Land Management (BLM) grazing allotment.

Phase II of juniper invasion into the BLM allotment was used as a baseline model and was run using the original AUMs available on the allotment (1,322 AUMs). The model was also run using Phase III as a base, with BLM forage availability starting at 825 AUMs. Forage increases due to treatments were then applied to the BLM allotment in a step-wise function, depending on the financing option chosen.

Additional forage sources were also considered available within the model, including privately leased land, state lands, purchased meadow hay and purchased alfalfa hay. Alternative feeds are considered available for specific seasons and purchased feeds were considered in unlimited availability. Hay prices were held constant at $100/ton, and privately leased rangeland at $13.25/AUM. The option to convert meadow hayland to grazed pasture was also an available option within the model. Converting hayland to pasture is not usually practiced in ranching operations since it reduces the land available for hay production and winter feed supplies, but it can be an option to compensate for the reduction in forage on federal or state lands. Costs for juniper removal were obtained for multiple treatment options from both The Nature Conservancy (TNC) and the Oregon Watershed Enhancement Board (OWEB). Treatment costs for removal of juniper ranged from $50 per acre, for Phase I - II chainsawing, to $275 per acre, for heavy phase II mastication; when the site enters a phase III encroachment level treatment options and feasibility decline (Barrett 2005, Barrett 2007, and Talsma 2011). The average cost per acre on these projects and respective phases and treatment types are shown in Table 3.3. Juniper

Table 3.1: Characteristics and resources of the representative ranch

Description	Units	Value
Land Resources Owned		
Alfalfa Hayland	Acres	
Native Meadow Hayland	Acres[a]	325
Convert Meadowland to Pasture	Acres[a]	325
Deeded Rangeland	AUMs	240
Land Resources Leased or Purchased		
State Trust Land	AUMs	144
BLM	AUMs	2,098
Private Leased Land	AUMs	500
Purchased Alfalfa	Tons	Unlimited
Purchased Meadow Hay	Tons	Unlimited
Livestock Resources[b]		
Animal Units Yearlong	AUY	333
Brood Cows	Head	286
Replacement Heifers	Head	65
Bulls	Head	19
Horses	Head	6
Miscellaneous Income/ Expenses		
Fixed Ranch Expenses	$	24,430
Family Living Allowance	$	24,000
Off-Ranch Annual Income	$	35,000
Required Minimum Cash Reserves	$	500
Efficiency Measures		
Calf Crop	%	88
Calf Death Loss	%	4
Cow Death Loss	%	2
Bull Death Loss	%	1
Steer Calf Sale Weight	Lbs	440
Heifer Calf Sale Weight	Lbs	390
Heifer Yearling Sale Weight	Lbs	800
Cull Cow Sale Weight	Lbs	950
Cull Bull Sale Weight	Lbs	1,800

[a]/ Converting hayland to grazable pasture is not generally practiced but is a possible source of forage when public lands AUMs are reduced. This conversion would use some of the available hayland and thus would reduce the land available for crop production.

[b]/ Animal numbers reported are from the published cost-and-return publications for each state. Optimal animal numbers in the LP model will vary by vary by year as beef prices vary.

[c]/ Other production parameters used to develop the LP models are defined in the cost-and-return series publications.

Table 3.2: Average simulated 2005 real beef prices as compared to average 1995 - 2006 real prices reported by CattleFax™.

		Simulated Prices				CattleFax™ 1995 - 2006			
Description	Units	Average Price	Min	Max	Standard deviation	Average Price	Min	Max	Standard deviation
400 Lb. Steer Calf	$/lb	1.07	0.57	1.59	0.18	1.14	0.66	1.47	0.18
300-400 Lb. Heifer Calf	$/lb	1.03	0.46	1.57	0.20	1.03	0.53	1.37	0.18
600-700 Lb. Purchase Steer Calves[a]	$/lb	0.95	0.56	1.34	0.14	0.97	0.61	1.28	0.13
600-700 Lb. Purchase Heifer Calves[a]	$/lb	0.90	0.55	1.25	0.14	0.90	0.52	1.22	0.13
700-800 Lb. Ranch Raised Steer yearling	$/lb	0.88	0.47	1.31	0.15	0.91	0.59	1.22	0.12
700-800 Lb. Ranch Raised Heifer Yearling	$/lb	0.89	0.40	1.36	0.18	0.87	0.52	1.17	0.12
1,000 Lb. Cull Cow	$/lb	0.43	0.20	0.68	0.09	0.43	0.29	0.60	0.06
Cull Bull	$/lb	0.58	0.32	0.85	0.11	0.55	0.41	0.71	0.07
1,000 Lb. Brood Cow	$/head	925	414	1,567	195	866	466	1,334	170
1,000 Lb. Buy Bull	$/head	2,054	1,004	3,373	401				

[a]/Calves are purchased at the 300-400 lb weight and sold at a 600-700 lb weight.

treatment on a landscape scale is a considerable financial investment that cannot be afforded by a ranch without outside financing. Rangeland improvement loans are not available on a 40 year basis, so financing was assumed to be available in 5, 10, or 20 year loans, at fixed interest rates of 5.5% 5.0% and 5.75%, respectively (Dennis Dines, personal correspondence). Since the model was run using a 40 year planning horizon, 5 year loans were obtained every 5 years for juniper treatments on an eighth (941 acres) of the BLM allotment; 10 year loans were obtained every 10

Table 3.3: Treatment Costs per Acre by Phase and Treatment Type

	Treatment Method	Method of Disposal	$/ac[a]
Phase 2	Chainsaw	Cut and Drop	63
Phase 2	Chainsaw	Cut and Pile with Post Treatment Burn	128
Phase 2	Mastication		171
Phase 3	Chainsaw	Cut and Drop	80
Phase 3	Chainsaw	Cut and Pile with Post Treatment Burn	178
Phase 3	Mastication		n/a

[a]/Barrett (2007), Barrett (2005), Talsma (2011)

years for a fourth of the allotment (1,883 acres); and 20 year loans were obtained in years 1 and 20 for half of the allotment (3,766 acres). These treatment sizes lead to AUM increases of 97, 194, and 388 for the 5, 10, and 20 year loans respectively, when the model started at a phase II encroachment level. The model was also run using phase III as a base; the 5, 10 and 20 year loan option had AUM increases of 158, 316, and 632 respectively. Every year a treatment loan is obtained, the BLM AUMs increased by the respective amount for the loan term. Loans were entered as a total loan required for the treatment: cost per acre multiplied by the acres treated in that loan period. Annual treatment loan payments were accrued as a fixed cost throughout the planning horizon.

LP Model Description

The model used in this analysis was developed for western ranches that rely on a combination of private and public grazing lands and other feed sources. It maximizes net present value (NPV) of discounted annual returns over a T-period planning horizon. It contains various linear constraints that outline the land and cash resources available to the ranch and the transfer of resources from year to year. The following equation shows the objective function, where future income is discounted at a rate of r = 7%.

$$Max(\pi) = \sum_{t=1}^{40}(TR_t - TVC_t) * (1 + r)^{-t} + TValue_T \qquad [1]$$

Where,

$TR_t = liveclass * salewt * saleprice$

$TVC_t = forage * fcst$

Equation [1] shows that the NPV of the ranch in each time period, t, is equal to total revenue (TR) minus total variable cost (TVC). The terminal value (TValue) accounts for all future returns form the herd following the end of the 40-year planning horizon, and reduces the effect of the model assuming "perfect knowledge," keeping the model from selling all livestock and assets in period T. TR is calculated by multiplying the number of cattle in each weight class (liveclass) by the associated sale weight (salewt) and the associated sale price (saleprice). TVC is calculated by multiplying the various types of available forage (forage) by the cost associated with each forage type (fcst).

Figure 3.1: Constraint Set for LP Model during Year t

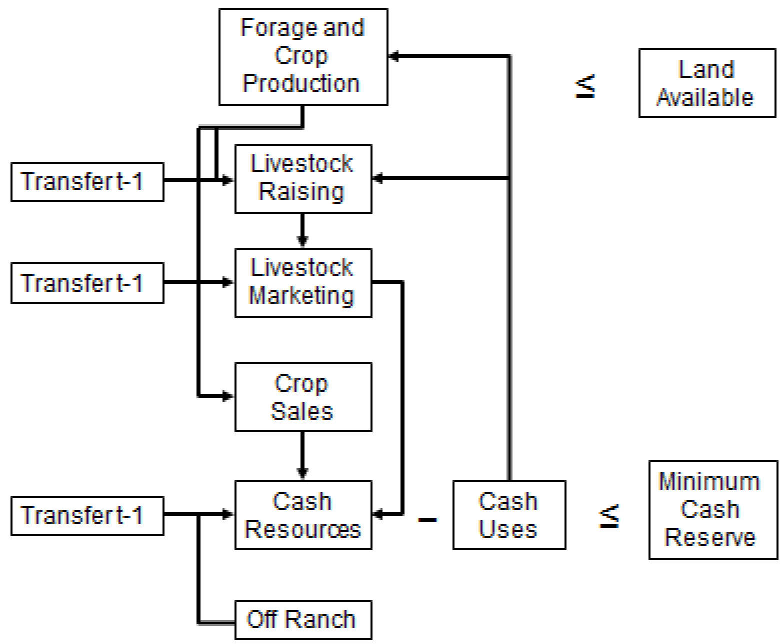


Figure 3.1 shows the general structure of the model and its constraints during any given year, t. The ranch is modeled with a set amount of land that can be allocated to either grazing or forage crop production. Other crop-raising opportunities were not considered as an option for land use in the model, due primarily to the elevational and climatic factors associated with the model ranch. Each land type is constrained at or below an upper limit, as well as the seasons during which the land type is available as for use. Seasonal availability of each land type is shown in Table 3.4. The purchase of additional leased private grazing land, alfalfa, or meadow hay was allowed without constraint. The sale of hay grown by the ranch was restricted in this model because ranch review panels revealed that hay was fed and not sold on ranches in the Jordan Valley area. The

different productivity levels of the various land types are also factored into the model, as shown in Table 3.5.

Table 3.4: Seasonal availability of hay & forage for representative ranches

	Season					
	3/1 4/15	4/15 5/15	5/15 10/15	10/15 11/15	11/15 12/15	12/15 3/1
State Trust Land		*	*			
BLM		*	*			
Private Lease		*	*	*	*	
Deeded Range	*	*	*	*	*	
Aftermath Grazing				*	*	*
Convert Meadow to Pasture		*	*	*	*	
Feed raised/purchased Hay	*	*				*

Table 3.5: Productivity measures for harvested and grazed forages

	Unit	Value
Hay Conversion to AUMs	AUMs/ton	2.42
Raised Native Hay	tons/acre	2.00
Raised Native Aftermath	AUM/acre	2.30
Pasture Native Hayland	AUMs/ton	5.50

The next components of the model transfer land availability and forage production activities into livestock raising activities. Equations that determine the ratio between certain animal classes are also included. These equations define the bull to cow ratio, the calf crop and calves available for sale at the end of the season after factoring in death loss percentages, and herd replacement. Bull numbers, replacement heifers and cull cows are determined as a percentage of the cow herd. Additional equations are included to transfer breeding livestock from year to year. Seasonal forage requirements for each animal type are determined by the animal unit equivalency (AUE) factors, shown in Table 3.6. The livestock marketing block of equations transfers livestock raising activities to livestock sales. Yearlings may be retained from year t-1 and sold in year t, although this option is not included in this model.

Table 3.6: Animal unit equivalencies used to calculate seasonal forage requirements

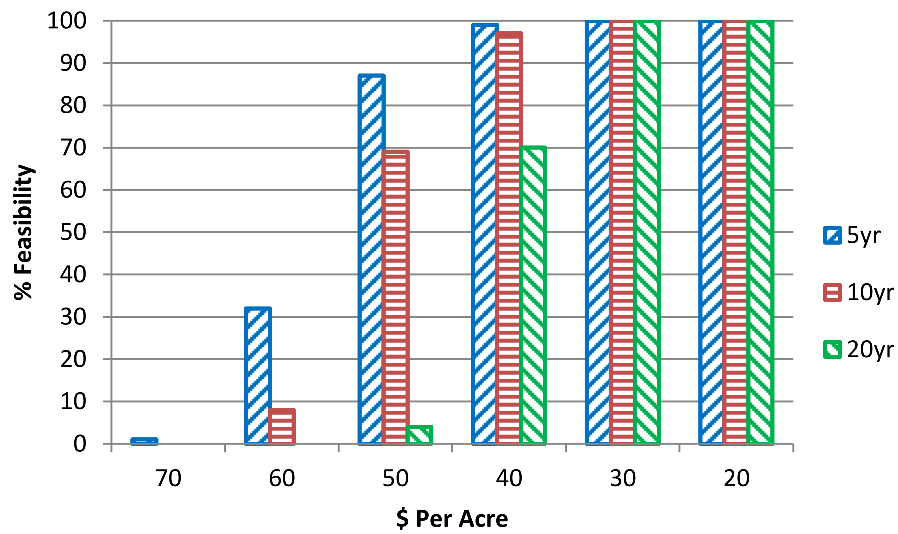
Animal Class	Animal Unit Equivalency (AUE)
Brood Cows	1.00
Bulls	1.25
Horses	1.25
Weaned Calves	0.50
Yearlings	0.75

Revenues are obtained from livestock sales, with additional revenues resulting from crop sales, if the model allowed. Cash flow equations use revenues from the sale of livestock to cover livestock, crop and forage raising costs, and transfer remaining debts or profits from year to year. Off-ranch income, fixed expenses, family living allowance and loan obligations are also included in the cash flow equations. Excess cash is transferred from year t-1 to year t. Cash shortages can be compensated on a yearly basis by short term loans that can be obtained at a 10% interest rate and must be repaid the following year. Borrowing is not allowed during the last year of the planning horizon and all debt obligations must be repaid in full by the end of the planning horizon. A complete listing of the LP model used in this analysis is included in Appendix A.

Results

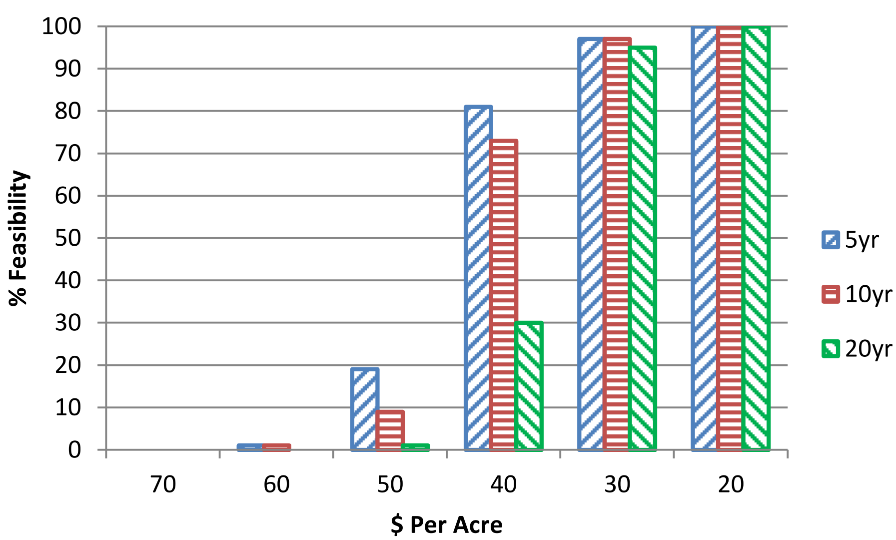
Economic feasibility of the ranch investing in juniper removal was analyzed at various costs per acre using both Phase II and III as the starting point. When Phase II was used as the base, the model showed the ranch to be feasible for 100% of the iterations and all of the loan options when treatment costs are no more than $30 per acre. The Phase III model ranch became 100% feasible at treatment costs of $20 per acre. Figures 3.2 and 3.3 show the feasibility of the Phase II and Phase III models, respectively, for treatment costs between $20 and $70 per acre.

Figure 3.2: Percent feasibility of treatment in Phase II



Net present values (NPV) were examined for the models starting at both a Phase II and Phase III encroachment level and compared with NPVs from the base models with no treatments imposed. NPVs for the Phase II and treatment costs of $30 per acre were $355,215, $353,343, and $321,865 for the 5, 10, and 20 year loan options respectively, as shown in Table 9. When the same Phase II model was used with costs reduced to $20 per acre, the NPVs were $377,207, $380,254, and $381,723 for the 5, 10, and 20 year loan options respectively. Phase II NPV with no treatment imposed was $373,515. NPVs for the model when the BLM allotment was assumed to start in a Phase III were $315,008, $329,394, and $349,579 for the 5, 10, and 20 year loan options respectively. These were compared to Phase III NPV without treatments imposed, which was $294,852. NPV, costs, revenues and cattle numbers are shown in Table 3.7 for Phase II and in Table 3.8 for Phase III. The Phase III NPV without treatment can also be considered the cost of not treating. There is a $79,000 decrease in the

Figure 3.3: Percent feasibility of treatment in Phase III



ranch's NPV if the allotment is allowed to advance from a Phase II encroachment level to a Phase III. Treating the allotment while it is in a Phase II encroachment level not only increases the ranch's NPV by $8,000, but also saves the ranch from suffering a $79,000 loss in future profits.

Costs and revenues were analyzed across the three loan options for the model starting in Phase II and Phase III and running with 100% feasibility, with treatment costs at $30 and $20 per acre respectively. When the model started in Phase II, obtaining loans every 5 years to treat an eighth of the BLM allotment had lower forage costs, short term loan costs, total costs and higher net revenues then the 10 or 20 year loan options. Forage costs were an average of $198 higher when loans were obtained every 10 years as compared to every 5 years, and $1,245 higher when loans were obtained every 20 years as compared to every 5. The amount of annual loans were an average of $430 lower when loans were obtained every 5 years versus every 10 years, and an average of $4,112 lower when compared to the 20 year option. Total costs were also an average of $1,762 and $9,363 lower for the 5 year loans versus the 10 and 20 year loan options, respectively. These increased costs contributed to reductions in annual net revenues of an average of $251 and $3,377 in the 10 and 20 year loan options respectively. Average AUYs were higher for the longer term loan options versus the shorter term loan options due to the initial increase in available AUMs. Annual average cow and AUY numbers were 251 and 360, respectively, when the Phase II model was used with the 20 year loan option, as compared to 241 cows and 346 AUYs for the 10 year loan option, and 237 cows and 341 AUYs for the 5 year loan option.

The costs and revenues were also analyzed using Phase III as the base,

Table 3.7: Optimal Production Levels in Response to Western Juniper Treatment on Phase II BLM Allotment

	$30 per acre Treatment Cost			$20 per acre Treatment Cost		
	5 Year Loan	10 Year Loan	20 Year Loan	5 Year Loan	10 Year Loan	20 Year Loan
Feasibility (%)	100	100	100	100	100	100
Treatment loan cost ($)	28,241	56,483	112,965	18,828	37,655	75,310
Treatment loan APR (%)	5.5	5.0	5.75	5.5	5.0	5.75
BLM increase (AUMs)	97	184	388	97	184	388
Net Present Value ($)	355,215 (54,548)	353,343 (58,388)	321,865 (93,452)	377,207 (41,416)	380,254 (41,585)	381,723 (45,032)
Average number of brood cows (head)	237 (15)	241 (15)	251 (18)	235 (16)	239 (15)	247 (16)
Average number AUY	341 (33)	346 (33)	360 (38)	340 (31)	345 (31)	356 (32)
Average annual forage costs ($)	27,025 (8,263)	27,223 (8,414)	28,270 (9,162)	27,282 (7,462)	27,611 (7,501)	28,293 (7,891)
Average annual forage costs ($/AUY)	79	79	79	80	80	79
Average annual net cash income ($)	24,315 (16,575)	24,064 (16,604)	20,937 (19,158)	26,322 (19,281)	26,592 (19,354)	26,649 (18,596)
Average annual net cash income ($/AUY)	71	70	58	77	77	75
Deeded Range (AUMs)	1,280 (0)	1,280 (0)	1,280 (0)	1,280 (0)	1,280 (0)	1,280 (0)
State trust land (AUMs)	144 (0)	144 (0)	144 (0)	144 (0)	144 (0)	144 (0)
Private Lease (AUMs)	33 (101)	31 (96)	39 (108)	25 (86)	21 (75)	16 (64)
Meadow acres converted to pasture (acres)	4 (6)	5 (7)	5 (8)	5 (6)	6 (7)	6 (8)
Raised meadow hay fed (tons)	256 (42)	258 (40)	267 (40)	253 (41)	255 (39)	261 (36)
Purchased alfalfa hay fed (tons)	72 (42)	72 (43)	75 (47)	75 (38)	76 (39)	78 (43)
Average amount borrowed annually ($)	1,131 (6,372)	1,743 (7,633)	5,425 (15,386)	265 (2,262)	296 (2,462)	574 (3,739)

[a]/ Number in parenthesis is the standard deviation measured over the 100 iterations and 40 years

Table 3.8: Optimal Production Levels in Response to Western Juniper Treatment on Phase III BLM Allotment

	$20 per acre Treatment Costs					
	5 Year Loan		10 Year Loan		20 Year Loan	
Feasibility (%)	100		100		100	
Treatment loan cost ($)	18,828		37,655		75,310	
Treatment loan APR (%)	5.5		5.0		5.75	
BLM increase (AUMs)	158		316		632	
Net Present Value ($)	315,008	(55,803)	329,394	(54,224)	349,579	(55,458)
Average number of brood cows (head)	219	(16)	226	(16)	239	(16)
Average number AUY	314	(32)	325	(32)	344	(34)
Average annual forage costs ($)	25,425	(8,325)	26,280	(8,273)	27,597	(8,313)
Average annual forage costs ($/AUY)	81		81		80	
Average annual net cash income ($)	21,933	(15,794)	23,068	(16,402)	24,015	(16,973)
Average annual net cash income ($/AUY)	70		71		70	
Deeded Range (AUMs)	1,280	(0)	1,280	(0)	1,280	(0)
State trust land (AUMs)	144	(0)	144	(0)	144	(0)
Private Lease (AUMs)	56	(134)	57	(131)	38	(103)
Meadow acres converted to pasture (acres)	10	(13)	8	(10)	6	(8)
Raised meadow hay fed (tons)	241	(43)	248	(43)	262	(43)
Purchased alfalfa hay fed (tons)	65	(37)	68	(39)	73	(43)
Average amount borrowed annually ($)	1,319	(6,222)	1,142	(5,814)	1,512	(7,118)

[a]/ Number in parenthesis is the standard deviation measured over the 100 iterations and 40 years

and treatment costs at $20 per acre, with the model again revealing 100% feasibility. Forage costs under this situation were also lowest when loans where obtained every 5 years. Forage costs were an average of $855 lower when loans were obtained every 5 years verses every 10 years, and an average of $2,173 lower when compared to loans obtained every 20 years. Annual short term loans that were necessary were lower on average when treatment loans were obtained on a 10 year basis, than when loans were obtained on a 5 year basis, by an average of $177 annually. Annual short term loans were $371 higher on average when treatment loans were obtained on a 20 year basis than on a 10 year basis. Though annual loans were lowest when treatment loans where obtained in 10 year increments, total costs remained lowest when treatment loans were obtained on a 5 year basis. Total costs where an average of $2,084 lower than 10 year treatment loans, and an average of $4,867 lower than 20 year treatment loans. AUYs and cow numbers were higher when the initial number of acres treated were higher, due to a larger initial increase in forage production. Treatment loans obtained on a 20 year basis had an annual average of 344 AUYs and 239 cows, which is 19 AUYs and 13 head higher than 10 year treatment loans, and 30 AUYs and 20 head higher than 5 year treatment loans. These increased cattle numbers contributed to higher average annual net revenues being obtained for the longer term treatment loans that remove juniper from a larger portion of the BLM allotment initially. Average annual net revenues were $24,015 when loans were obtained on a 20 year basis, versus $23,068 when loans were obtained on a 10 year basis and $21,933 when loans were obtained on a 5 year basis.

Conclusions and Implications

The ranch can afford to pay up to $5,648 per year, $30 per acre, for juniper removal on the BLM allotment when it starts in Phase II and is converted back to Phase I encroachment level. However, this price level drops the ranch's NPV below the NPV if the allotment was not treated. Only when the cost of treatment is dropped to $3,766 per year, $20 per acre, or less, does the NPV for treating juniper become higher than when left untreated. When the allotment is in Phase III and being converted back to Phase I, the ranch can afford to pay $3,766 per year, $20 per acre, for treatment. Once the allotment reaches a Phase III level of encroachment, treatment costs increase dramatically and the understory response to juniper removal becomes more uncertain. These numbers are presented for comparison purposes, yet show the potential "cost" of not treating juniper and allowing succession to proceed to Phase III.

When the 5, 10, and 20 year loan options are compared, the 20 year loan option yields the highest NPV when the allotment starts in either a Phase II or a Phase III at treatment costs of $20 per acre. When treatments are financed using the 20 year loan option half of the allotment is treated at once, causing the largest increase in AUMs in year 1. This initial increase in forage allows the ranch to raise greater cattle numbers from year one, increasing overall revenues and profitability. When the allotment started in a Phase II level of encroachment, the 20 year loan had an average NPV of $381,723, which is an average of $1,468 higher than the 10 year loan option, and an average of $4,516 higher than the 5 year loan option. Any treatment option provides an NPV higher than if the allotment was left untreated. There is a larger increase in NPV when the allotment is started in a Phase III encroachment level; the 20 year loan option had an average NPV of $349,579, an average of $20,186 higher than the 10 year loan option, and an average of $34,572 higher than the 5 year loan option. This shows the potential benefits, to the rancher, of removing juniper on as many acres as is financially plausible as early as possible. The greatest financial gains result from treating the areas of highest encroachment, and treating larger segments of land at once instead of small portions over time. Treatment costs and interest incurred over the long term loans, is compensated for by increased forage availability, and the ability to raise additional cattle.

Treatment costs usually average considerably higher than $20-$30 per acre, and vary depending on the type of treatment chosen, the terrain to be treated, and the phase of encroachment. Since the benefits of removal apply to more than just the ranch owner, there are multiple government agencies and conservation groups that have been working in partnership with ranchers to cover the costs of removal. U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) has programs available to cost share for juniper removal. Their maximum amount allowed per acre depends on the treatment used and the level of intensity; chainsawing or chaining on a medium intensity terrain will pay $135, while mastication is eligible for maximum payments of $280 or $360 per acre, depending on the difficulty of the terrain. Under the NRCS programs, treatments are only cost-shared in Phases I or II.

These programs are essential for rangeland improvement projects to occur. Ranchers receive most of the market benefits from juniper removal through enhanced forage production, but the non-market benefits of removal, such as sage-grouse habitat rehabilitation and overall ecosystem stabilization, are shared across all users of the range.

This study provided a detailed look at the cost of western juniper removal, but it did not take into account climatic variation and its impacts on herbaceous production. Another limitation of this research is a lack of understanding of the variation in overstory and understory production within each of the three phases. This study did not take into account the gradual increase in juniper encroachment that would occur during the advancement from Phase I to Phase II, or from Phase II to Phase III. Understory productivity was assumed to be static within each phase of juniper invasion and treatment responses were assumed to advance to a Phase I production level in the same year of treatment. Future studies should incorporate climatic variation into a dynamic look at herbaceous production levels both before and after treatment. Long term monitoring will be needed before it will be possible to estimate production variation on an annual basis. Future economic studies should try to incorporate climatic variation, overstory/understory variation within each phase of juniper invasion, and other factors into a dynamic view of the economic impacts of juniper removal.

References

Allen, E.A. and R.S. Nowak. 2008. Effect of Pinyon-Juniper Tree Cover on the Soil Seed Bank. Rangeland Ecology and Management. 61:63-73.

Barrett, R.H. 2005. OWEB Juniper Treatment Effectiveness Monitoring Final Report. CSR Natural Resources Consulting, Inc. Contract No. 204-937.

Barrett, R.H. 2007. OWEB Juniper Management Effectiveness Monitoring Phase II Final Report. CRS Natural Resources Consulting, Inc. Contract No. 204-937.

Bates, J.D., R.F. Miller, and T. Svejcar. 2000. Understory Dynamics in Cut and Uncut Western Juniper Woodlands. Journal of Range Management. 53:119-126.

Bates, J.D., R.F. Miller, and T. Svejcar. 2005. Long-Term Successional Trends Following Western Juniper Cutting. Rangeland Ecology and Management. 58:533-541.

Bourne, A. and S. Bunting. 2011. Guide for Quantifying Post-treatment Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 437. Bureau of Land Management, Denver, CO, BLM/ID/PT-11/003+2824. 115p.

Commons, M.L., R.K. Baydack and C.E. Braun. 1999. Sage Grouse Response to Pinyon-Juniper Management. *In*: S.B. Monsen and S. Richard (compilers). 1999. Proceedings: Ecology and Management of Pinyon-Juniper Communities within the Interior West. Ogden, UT: Rocky Mountain Research Station, USDA Forest Service Proceedings RMRS-P-9. p238-239.

Dines, D. February 24, 2012. Interview by A. McClain [Personal Interview].

Makela, P., and D. Major. 2012. A Framework to Identify Greater Sage-grouse Preliminary Priority Habitat and Preliminary General Habitat for Idaho. Idaho State Office, U.S. Bureau of Land Management, April, 2012, Boise, Idaho. 41 p.

Miller, R.F., T.J. Svejcar, and J.A. Rose. 2000. Impacts of Western Juniper on Plant Community Composition and Structure. Journal of Range Management. 53:574-585.

Rimbey, N.R., T.D. Darden, L.A. Torell, J.A. Tanaka, L.W. Van Tassell, and J.D. Wulfhorst. 2003. Ranch Level Economic Impacts of Public Land Grazing Policy Alternatives in the Bruneau Resource Area of Owyhee County, Idaho. University of Idaho Agricultural Economics Extension Series No. 03-05.

Ritten, J.P., W.M. Frasier, C.T. Bastain, S.I. Paisley, M.A. Smith and S. Mooney. 2010. A Multi-Period Analysis of Two Common Livestock Management Strategies Given Fluctuation Precipitation and Variable Prices. Journal of Agricultural and Applied Economics. 42:177-191.

Rowland, M.M., L.H. Suring, R.J. Tausch, S. Geer and M.J. Wisdom. 2008. Characteristics of Western Juniper Encroachment into Sagebrush Communities in Central Oregon. USDA Forest Service Forestry and Range Sciences Laboratory, La Grande, Oregon 97850, USA. 23 pp.

Stebleton, A. and S. Bunting. 2011. Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 430. Bureau of Land Management, Denver, CO, BLM/ID/PT-09/002+2824. 81p.

Talsma, A.R. 2011. Juniper Mastication to Restore Sage-Grouse Brood Rearing Habitat. Idaho Fish and Wildlife. The Nature Conservancy 2011 Completion Report. 14p.

Taylor, D.T., R.H. Coupal and T. Foulke. 2005. The Economic Impact of Federal Grazing on the Economy of Park County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics, Final Report. August 2005.

Taylor, D.T., R.H. Coupal, T. Foulke and D. Feeney. 2004a. The Potential Economic Impact on the Economy of Southeastern Wyoming from Designation of Critical Habitat for the Preble’s Meadow Jumping Mouse. University of Wyoming Department of Agricultural and Applied Economics, Final Report. September 2004.

Taylor, D.T., R.H. Coupal, T. Foulke and J.G. Thompson. 2004b. The Economic Importance of Livestock Grazing on BLM Land in Fremont County, Wyoming. University of Wyoming Department of Agricultural and Applied Economics. October 2004.

Torell, L.A., J.A. Tanaka, N. Rimbey, T. Darden, L. Van Tassell, and A. Harp. 2002. Ranch-Level Impacts of Changing Grazing Policies on BLM Land to Protect the Greater Sage-Grouse: Evidence from Idaho, Nevada, and Oregon. Policy Analysis Center for Western Public Lands, Policy Paper SG-01-02, Caldwell, ID.

Torell, L.A., S. Murugan, and O.A. Ramirez. 2010. Economics of Flexible Versus Conservative Stocking Strategies to Manage Climate Variability Risk. Rangeland Ecology and Management. 63:415-425.

U.S. Fish and Wildlife Service (USFWS). 2010. Endangered and Threatened Wildlife and Plants; 12-Month Findings for Petitions to List the Greater Sage- Grouse (*Centrocercus urophasianus*) as Threatened or Endangered. Proposed Rules 50 CFR Part 17. Federal Register 75(55): 13910-14014.

Young, J.A., R.A. Evans and C. Rimbey. 1985. Weed control and Revegetation following Western Juniper (*Juniper occidentalis*) control. Weed Science. 33: 513-517.

Chapter IV: Conclusion

As western juniper encroaches on surrounding sage brush steppe ecosystems, it adversely impacts the ecosystem in a multitude of ways. Reductions in the shrub component of the rangeland vegetation and changes to the herbaceous composition of western rangelands alter its suitability as habitat for many wildlife species as well as deceases its ability to produce forage for domestic livestock production.

The first segment of this project used the change in available forage (Bourne and Bunting 2011, Stebleton and Bunting 2011) to determine the change in costs, returns and cattle numbers as juniper encroachment advances from Phase I to Phase III on a representative ranch in the Jordan Valley area of southwestern Idaho. The reductions were applied to the available rangeland forage to BLM lands, causing significant decreases in the forage available during the spring and summer months. These reductions in summer forage were compensated through privately leased grazing land, purchased alfalfa hay, and reductions in herd size. As western juniper encroachment increases from Phase I to Phase III, profitability and sustainability of the model ranch declines, primarily due to the loss of spring-fall forage. The costs associated with running the ranch also increased, due to the lack of alternative forage sources during the spring-fall period.

The encroachment of western juniper causes over a 60% reduction in AUMs available on rangelands (Bourne and Bunting 2011, Stebleton and Bunting 2011), restricting the number of cattle that can be sustained by the ranch. This caused a 29% reduction in both brood cow numbers and total AUYs. Ranch income is derived from the production and sale of an annual calf crop, which is directly impacted by brood cow numbers. This decrease in saleable product caused annual net cash income to decline 11.4%, and income per AUY to decline 19%.

The reduced forage on the BLM allotment from April to October was compensated by increased use of raised meadow hay, privately leased land, and altering the grazing seasons on deeded rangeland. From April to May, BLM use declined from 313 AUMs to 13 AUMs between Phase I and Phase III. These declines were offset by an increase in raised meadow hay usage from 51 AUMs to 232 AUMs. From May to October, BLM forage declined from 1,718 AUMs to 821, which was offset with increased usage of deeded range, by 181 AUMs, privately leased lands, by 62 AUMs, and grazed meadow pasture, by 110 AUMs. The increased use of deeded range during October through November caused reductions in the forage available from November through March of the following year.

The model results indicate that increasing levels of juniper encroachment greatly decrease ranch profitability. These decreases are caused by increased forage costs as well as decreased revenues from calf sales. The net present value of the model ranch income over the 40 year planning horizon was estimated at $435,983, $373,515, and $294,852, for Phases I through III, respectively. The increase in western juniper encroachment from Phase I to Phase III reduced the net present value of the ranch income stream by 32.4%.

The second segment of this project analyzed the economic feasibility of juniper removal by the model ranch balancing high treatment costs against the value of increased forage available for grazing to determine the maximum the ranch would be willing to invest in juniper removal. The ecological benefits of juniper removal for wildlife sustainability and overall ecosystem health were not taken into consideration. This was strictly an analysis of the economic value of juniper removal to private ranchers. Juniper treatment on a landscape scale is a considerable financial investment that cannot be undertaken without outside financing. Rangeland improvement loans are not available on a 40 year basis, so financing was assumed to be available in 5, 10, or 20 year loans.

This study showed that the ranch can afford to invest up to $5,648 per year for juniper removal on the BLM allotment when it starts in Phase II and is converted back to a Phase I encroachment level. However, this price level drops the ranch’s NPV below the NPV if the allotment was not treated. Only when the cost of treatment is dropped to $3,766 per year or less does the NPV for treating the ranch become higher than when left untreated. When the allotment is in Phase III and being converted back to Phase I, the ranch can afford to pay $3,766 per year for treatment.

When comparing the 5, 10, and 20 year loan options, the 20 year loan option yields the highest NPV when the allotment starts in either a phase II or a phase III and treatment costs are $20 per acre. The 20 year loan options allows the manager to treat half of the allotment at once, instead of treating smaller portions of land over a longer period of time. The initial increase in AUMs from the larger treatment area associated with the 20 year loan option allows for greater cattle numbers from the start of the planning horizon, increasing overall revenues. When the allotment started in a Phase II encroachment, the 20 year loan had an average NPV of $381,723, which is an average of $1,468 higher than the 10 year loan option, and an average of $4,516 greater than the 5 year loan option. There is a larger increase in NPV when the allotment is started in a Phase III encroachment level; the 20 year loan option had an average NPV of $349,579, an average of $20,186 higher than the 10 year loan option, and an average of $34,572 higher than the 5 year loan option. This shows the potential benefits, to the rancher, of removing juniper on as many acres as is financially plausible as early as possible. The greatest financial gains result from treating the areas of higher encroachment.

Treatment costs usually average considerably higher than $20-$30 per acre, and vary depending on the type of treatment chosen, the terrain to be treated, and the phase of encroachment (Barrett 2005, Barrett 2007, Talsma 2011). Since the benefits of removal apply to more than just the ranch owner, there are multiple government agencies and conservation groups that have been working in partnership with ranchers to cover the costs of removal. The USDA's Natural Resources Conservation Service (NRCS) has programs available to cost share for juniper removal. Their maximum payout per acre depends on the treatment used and the level of intensity; chainsawing or chaining on a medium intensity terrain will pay $135, while mastication is eligible for maximum payments of $280 or $360 per acre, depending on the difficulty of the terrain.

These programs are essential for rangeland improvement projects to occur. The measurable market value of western juniper removal is mainly contained in the increased forage production that is achieved after treatment. Ranchers are the main beneficiaries of these market value increases. The non-market benefits of removal encompass factors such as sage-grouse habitat rehabilitation, other wildlife benefits and overall ecosystem stabilization. These non-market benefits are shared across all users of the range, and provide the rationale for cost share programs between ranchers and public agencies such as the NRCS. Removal of western juniper benefits the land, the ecosystem, and the economy, and cost share programs allow the public to partner with private ranchers to eradicate the problem.

This research was done using a linear model; a more dynamic study should be conducted in the future to analyze the changes in juniper encroachment over time. At this point, no research has been found that defines a timeline for the phases of juniper encroachment. Once this research is completed, this model could be altered to analyze the changes in encroachment over time. This study assumed at least 40 years between phases, implying that within our 40 year planning horizon the ranch would remain in the same phase of juniper invasion. However, this does not take into account the gradual increase in juniper encroachment that would happen during the advancement from Phase I to Phase II, or from Phase II to Phase III, nor climatic variation and its impacts on herbaceous production. Understory productivity was assumed to be static within each phase of juniper invasion, which does not take into account annual variations in climate, or potential wildfire hazards. Treatment responses were assumed to advance to a Phase I production level in the same year of treatment, though the recovery of herbaceous plants would likely take 1-2 years, or longer depending on the environmental health of the site. Future studies should incorporate climatic variations into a dynamic look at herbaceous production levels both before and after treatment.

References

Barrett, R.H. 2005. OWEB Juniper Treatment Effectiveness Monitoring Final Report. CSR Natural Resources Consulting, Inc. Contract No. 204-937.

Barrett, R.H. 2007. OWEB Juniper Management Effectiveness Monitoring Phase II Final Report. CRS Natural Resources Consulting, Inc. Contract No. 204-937.

Bourne, A. and S. Bunting. 2011. Guide for Quantifying Post-treatment Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 437. Bureau of Land Management, Denver, CO, BLM/ID/PT-11/003+2824. 115p.

Miller, R.F., J.D. Bates, T.J. Svejcar, F.B. Pierson, and L.E. Eddlemand. 2005. Biology, Ecology, and Management of Western Juniper. Oregon State University Agricultural Experiment Station, Technical Bulletin 152, p 77. http://extension.oregonstate.edu/catalog/html/tb/tb152/

Stebleton, A. and S. Bunting. 2011. Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin. Technical Note 430. Bureau of Land Management, Denver, CO, BLM/ID/PT-09/002+2824. 81p.

Talsma, A.R. 2011. Juniper Mastication to Restore Sage-Grouse Brood Rearing Habitat. Idaho Fish and Wildlife. The Nature Conservancy 2011 Completion Report. 14p.

APPENDIX A: TREATMENT MODEL GAMS CODE

```
******************************************************************************
*                 Public Land Policy Impact Model                            *
*                                                                            *
******************************************************************************
$Title Idaho High Desert - Owyhee County, Jordan Valley 300 head Max Net
Income
$ONTEXT
SIZE = Medium/Small
Debt = None
Grazing Fee = Current
Available Public AUMs = Current
Season of Use = Current
$OFFTEXT

$OFFSYMLIST OFFSYMXREF

file returns /1020T3JVcost.txt/;          returns.pc=5;
* Returns is a file that summarizes costs and returns by year
file foragsum /1020T3JVland.txt/;           foragsum.pc=5;
* Foragsum is a file that summarizes forage use by year
file raisesum /1020T3JVraise.txt/;          raisesum.pc=5;
* Raisesum is a file that summarizes the number of raised animals by year
file risum /1020T3JVobjfn.txt/;             risum.pc=5;
* Filesum is a file that summarizes the Obective Function (ranch income) by year
file lndsum /1020T3JVlanduse.txt/;          lndsum.pc=5;
* Lndsum is a file that summarizes seasonal land use by year
file feedsum /1020T3JVfeeduse.txt/;         feedsum.pc=5;
* Feedsum is a file that summarizes seasonal feed use by year

Scalars  totdays        Total days defined by various seasons
       calfcrop       Calf Crop Percentage at birth   /0.88/
       minrepl        Required min cow repl rate      /0.15/
       Bullrepl       Required bull replacement rate  /0.25/
       minhyear         Required min heifers for sale   /0.12/
       maxrepl         Max % heifer calves kept       /1.00/
       cowbull        cow to bull ratio               /18.0/
       Rho            discount rate                   /0.07/
       Commiss         Commission % cost to sell cow   /0.03/
       Yardage         Yardage and trans Charge($ per day)  /1.50/
       Salefeed        Sale feed charge ($ per cwt)    /.30/
       Offranch        Off ranch income                /35000/
       Family         family living allowance          /24000/
*Family living allowance set at $24,000 for all ranchers
       Fixed          Fixed ranch expenses             /24430/
```

```
*Fixed include machinery and equipment insurance and taxes, property tax,
*depreciation and interest
        Iwealth        Initial cash position          /0/
        Endval         Final year net return          /1/
        Stloanr        Short term borrowing rate      /0.10/
        Savrate        Interest return on Savings acct /0.03/
        Trtcost        Total treatment cost           /37655/
*Total treatment cost equals $ per acre times total acres treated
        Trtloan        Treatment loan rate            /.050/
*Loan rates= 5.5% APR for 5 year loan, 5.0% APR for 10 year loans,
*5.75% APR for 20 year loans
        Trtyear        Years of loan                  /10/
*Treatment loans available in 5, 10, or 20 year durations
        AUMinc5        AUM increases w 5 year loan     /158/
*5 year loan treats 97 AUMs when allotment starts in phase 2
*and 158 AUMs when allotment starts in phase 3
        AUMinc10       AUM increases w 10 year loan    /316/
*10 year loan treats 194 AUMs when allotment starts in phase 2
*and 316 AUMs when allotment starts in phase 3
        AUMinc20       AUM increases w 20 year loan    /632/
*20 year loan treats 388 AUMs when allotment starts in phase 2
*and 632 AUMs when allotment starts in phase 3
        ;
Set T Time periods /year01*year40/
    TLAST(T)  Last Period

Set seasonON grazing season start date /seas1*seas7/
Set iter iteration /iter001*iter100/

Set season(seasonON) grazing season /seas1*seas6/
Set land types of land available
   /state, blm, usfs, privleas, deedrang, rmeadow, gmeadow,
     raisealf, purchalf, pmeadhay/
Set Crop(land) /rmeadow, raisealf, purchalf, pmeadhay/
Set landitem /number, aumac, cropyld, conver, usefac, forcost/
Set date1 /m, d, y, serial, days, months/
Set livclass /broodcow, cullcow, bull, horse, scalf, hcalf, syear, hyear,
     purscalf, purhcalf, rephcalf, rephyear, buybcow, sellbcow, buybull/
Set livecl(livclass) /cullcow, bull, scalf, hcalf, syear, hyear, purscalf,
     purhcalf, sellbcow/
Set livpara /buywt, salewt, deathlss, animcost, hayuse/
Set Costsum /forcost, animcost, loancst, totcost, gross, net, netdisc, cashtr,
     accumsav, stborrow, repayst/
Set out1 /used, slack, total, shadow, value/

parameter cropsale(crop) crop sale prices
```

```
    /rmeadow   0
     raisealf  0/;
parameter buypric(T,livclass);
parameter salepric(T,livclass);
parameter Econ(iter,T,costsum)      Economic Variables;
Parameter Landsum(iter,Land,T,out1) Land Use Summary;
Parameter Landseas(iter,Land,T,season)  Seasonal land use summary;
Parameter Feedseas(iter,Crop,T,season) Seasonal Crop use summary;
Parameter anim(iter,T,Livclass)     raised animals summary;
parameter AUY(iter,T)               AUY on ranch;
parameter ri(iter)                  Ranch Income Summary;
parameter MS(iter)                  Model status by iter;
parameter TRTAUMINC5(Land,T)        AUM increase with 5 year treatment;
parameter TRTAUMINC10(Land,T)       AUM increase with 10 year treatment;
parameter TRTAUMINC20(Land,T)       AUM increase with 20 year treatment;

$Include
"c:\Users\Owner\Documents\Thesis\beefprice_2005_100iter_40years.txt";

* compute the number of days in each grazing season and assure total
* is 365 or 366. Uses date functions from GAMs Model library calendar.gms.
* Season 7 must close out the year in the following year.

table onday(seasonON,date1)
                m      d      y
seas1           3      1    2009
seas2           4     15    2009
seas3           5     15    2009
seas4          10     15    2009
seas5          11     15    2009
seas6          12     15    2009
seas7           3      1    2010
;

* "Serial" is number of days past Jan. 1, 1900
onday(seasonON,"serial") = jdate(onday(seasonON,"y"),
  onday(seasonON,"m"),onday(seasonON,"d"));

onday(seasonON,"days") $ (ord(seasonON)LT card(seasonON)) =
   onday(seasonON+1,"serial") - onday(seasonON,"serial");

onday(season,"months") = onday(season,"days")/30.41667;

totdays = sum(season, onday(season,"days"));

if ((totdays = 365 or totdays = 366), display totdays;
```

```
else abort "Total season days not 365 or 366, adjust dates";

* put a one (1) in the seasons when grazed forages are to be available
table avail(land, season) seasonal forage availability

            seas1  seas2  seas3  seas4  seas5  seas6
state                1      1
blm                  1      1
usfs
privleas             1      1             1      1
deedrang     1       1      1             1      1
rmeadow                            1      1      1
gmeadow              1      1             1      1
raisealf
;

* put a one (1) in the seasons when hay can be fed.
table cropaval(crop, season) seasonal crop feeding availability
            seas1  seas2  seas3  seas4  seas5  seas6
rmeadow      1      1             1
raisealf
purchalf     1      1             1
pmeadhay     1      1             1
;

* Enter aumac=1 when units are AUMs
* Add $20/ton to market prices for purchased hays as a delivery cost

* Units of forage types
*    ACRES: State, deedrang, rmeadow, gmeadow, raisealf
*    AUM: blm, USFS, Privleas
*    TON: purchalf, pmeadhay
* cropyld is tons per acre
* conver = conversion factor Tons to AUMs
* usefac = percentage of amount available that can be used in this run - used for
policy analysis
* forcost is in units of landtype.  For hays, it is times the cropyld.
*rmeadow acrage at increased yeild

table forage(land,landitem) forage sources

             number    aumac   cropyld  conver   usefac   forcost
state        144.        1.0              1.0      4.80
blm          825.        1.0              1.0      1.35
usfs         000.        1.0              1.0      1.35
privleas     500.        1.0              1.0      10.00
```

deedrang	1280.	0.1875		1.0	0.00	
rmeadow	325.	2.3	2.0	2.42	1.0	50.0
gmeadow	325.	5.5		1.0	40.0	
raisealf	000.	0.30	4.5	2.42	1.0	450.0
purchalf	1000.	0.0	1.0	2.42	1.0	150.0
pmeadhay	1000.	0.0	1.0	2.42	1.0	100.0

;

```
*Treatment Equations
TRTAUMINC5(Land,T)=0;
TRTAUMINC5("blm",T)=auminc5$(Trtyear EQ 5 AND (ORD(T) GT 0 AND
ORD(T) LE 5))
        + (2*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 6 AND ORD(T) LE 10))
        + (3*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 11 AND ORD(T) LE 15))
        + (4*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 16 AND ORD(T) LE 20))
        + (5*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 21 AND ORD(T) LE 25))
        + (6*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 26 AND ORD(T) LE 30))
        + (7*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 31 AND ORD(T) LE 35))
        + (8*auminc5)$(Trtyear EQ 5 AND (ORD(T) GE 36 AND ORD(T) LE 40));
TRTAUMINC10(Land,T)=0;
TRTAUMINC10("blm",T)=auminc10$(Trtyear EQ 10 AND(ORD(T) GT 0 AND
ORD(T) LE 10))
        + (2*auminc10)$(Trtyear EQ 10 AND (ORD(T) GE 11 AND ORD(T) LE 20))
        + (3*auminc10)$(Trtyear EQ 10 AND (ORD(T) GE 21 AND ORD(T) LE 30))
        + (4*auminc10)$(Trtyear EQ 10 AND (ORD(T) GE 31 AND ORD(T) LE
40));
TRTAUMINC20(Land,T)=0;
TRTAUMINC20("blm",T)=auminc20$(Trtyear EQ 20 AND(ORD(T) GT 0 AND
ORD(T) LE 20))
        + (2*auminc20)$(Trtyear EQ 20 AND (ORD(T) GE 21 AND ORD(T) LE
40));
```

table aue1(livclass,season) AUE for animal classes by season in year T

	seas1	seas2	seas3	seas4	seas5	seas6
broodcow	1.00	1.00	1.00	1.00	1.00	1.00
sellbcow	1.00	1.00	1.00	1.00	1.00	
cullcow	1.00	1.00	1.00	1.00	1.00	
bull	1.25	1.25	1.25	1.25	1.25	1.25
horse	1.25	1.25	1.25	1.25	1.25	1.25
scalf			0.50			
hcalf			0.50			
purscalf	0.50	0.50	0.75			
purhcalf	0.50	0.50	0.75			
syear			0.50	0.50	0.50	
hyear			0.50	0.50	0.50	

```
rephcalf                          0.50        0.50     0.50
rephyear                          0.50        0.50     0.50
;


table aue2(livclass,season) AUE for animal classes by season in year T+1

           seas1     seas2    seas3     seas4   seas5     seas6
broodcow
cullcow
bull
horse
scalf
hcalf
purscalf
purhcalf
syear        0.75     0.75     0.75      0.75
hyear        0.75     0.75     0.75      0.75
rephcalf
rephyear     0.75     0.75     0.75      0.75    1.00      1.00
;

*animcost = use gross margin divided by brood cows, cull cows, and replacement
yearlings
* enter same animal cost for all 3 classes.

* hayuse is the percentage that alfalfa hay must be used to feed that class.

table Animal(livclass,livpara) sale weights and costs by animal class

          buywt     salewt   deathlss    animcost   hayuse
broodcow                      0.02          100.77
cullcow              9.50     0.02          100.77
bull                 4.50     0.01          0.0
* assumptions for bull 1800 lb but kept 4 years so (18.00/4) = 4.5
scalf                4.40     0.04          0.0            1
hcalf                3.90     0.04          0.0            1
*syear normally not raised on ranch
syear                0        0.06          0.0            1
hyear                8.00     0.06          0.0            1
* owned yearling death loss should include both calf and yearling losses
purscalf   5.00      6.99     0.04          1500.0
purhcalf   5.00      6.59     0.04          1500.0
rephcalf                      0.04          0.0            1
rephyear                      0.02          100.77         1
buybcow    1.00
```

```
sellbcow              1.00    0.02
buybull       1.00
;

PARAMETERS
    DF(T)     Discount factor at time T;
    DF(T) = (1+RHO)**(-1*(ORD(T)));
    TLAST(T)  = YES$(ORD(T) EQ CARD(T));

POSITIVE VARIABLES
    Landuse(land,season,T)       Acres or AUMS of land used in year T
    slacklnd(Land,T)             Unused land resources
    raise(livclass,T)            Raise livestock of class in year T (head)
    selllive(livecl,T)           Sell livestock of class in year T (cwt)
    sellcrop(crop,T)             Sell forage crop in year T
    feedcrop(Crop,season,T)      Feed forage crop AUMs in year T
    FORCOST(T)                   Forage harvest costs
    ANIMCOST(T)                  Animal production costs
    GROSS(T)                     Gross livestock returns
    STBORROW(T)                  Short Term Borrowing
    REPAYST(T)                   Repay Short Term Loan
    LOANCST(T)                   Principal and Interest Payments
    TRTANPAY(T)
;

VARIABLES
    Ranchinc                     Ranch Income
    NET(T)                       Net livestock returns undiscounted
    NETDIS(T)                    Net livestock returns discounted
    CASHTR(T)                    Cash transfered to next period
    AccumSav(T)                  Accumulated Savings
    TERM                         Terminal Value
;

EQUATIONS
     LANDAVAL(LAND, T)   Land Use Equation
     MEADOW(LAND, T)     meadow use equation
     AUMAVAIL(T, season) Total AUMS available
     CROPPROD(crop,T)    Production of crops
     HAYCALF(T,season)   Force calves to eat alfalfa
     BULLRAT(T)          Set Bull to cow ratio
     CULLRATC(T)         Set cull cow to raised cow ratio
     COWTRAN(T)          Cow transfer between years
     BULLTRAN(T)         Bull transfer between years
     REPTRAN(T)          Calf replacement transfer to yearling replacement
     MINREPLC(T)         Minimum cow replacement rate
```

```
     MAXREPLC(T)        Maximum cow replacement rate
     MINHYRC(T)         Minimum additional replacements sold
     RSCALFC1(T)        Raise steer calf ratio year 1
     RSCALFC2(T)        Raise steer calf ratio year NE 1
     RHCALFC1(T)        Raise heifer calf ratio year 1
     RHCALFC2(T)        Raise heifer calf ratio year NE 1
     SALES(livclass,T)  Sales transfer
     COSTFORC(T)        Forage Production costs at T
     COSTANIC(T)        Animal production costs at T
     GROSSRET(T)        Gross Livestock returns at T
     NETRET(T)          Net Livestock returns at T
     NETRETD(T)         Discounted net returns at T
     INCOME             Ranch Income definition
     CASHSOUR(T)        Transfers of Cash
     SAVING1(T)         Accumulated Savings at time 1
     SAVING2(T)         Accumulated Savings at time T
     STREPAY(T)         Force repayment of Short-term loans
     LOANPAY(T)         Loan Repayment Calculation
     TERMVAL            Terminal Value (Net R infinitely discounted)
     TRTANPAYeq         Annual Payment on Treatment Loan
;


*Forage demand and supply equations

LANDAVAL(LAND,T)..  SUM(season,landuse(land,season,T))+
slacklnd(land,T)=E=

(forage(land,"number")*forage(land,"usefac")+TRTAUMINC5(Land,T)+TRTAUMI
NC10(Land,T)+TRTAUMINC20(Land,T));
MEADOW("rmeadow",T)..  SUM(season,landuse("rmeadow",season,T))+
SUM(season,landuse("gmeadow",season,T))=L=
   forage("rmeadow","number");
CROPPROD(CROP,T).. sum(season,feedcrop(crop,season,T)) +
sellcrop(Crop,T) =L=
   sum(season,landuse(crop,season,T))* forage(crop,"cropyld");
AUMAVAIL(T, season).. SUM(livclass, raise(livclass,T)*aue1(livclass,season))*
   onday(season,"months")
   + SUM(livclass, raise(livclass,T-1)* aue2(livclass,
season))*onday(season,"months")
   =L= SUM(land,forage(land,"aumac")*landuse(land,season,T)*
avail(land,season))
   + SUM(crop,feedcrop(crop,season,T)*forage(crop,"conver")*
cropaval(crop,season));
```

```
HAYCALF(T, season)$ (ORD(Season) EQ 1 OR ORD(SEASON) EQ 6)..
SUM(livclass, raise(livclass,T)*
    aue1(livclass,season)*animal(livclass,"hayuse"))* onday(season,"months")
    + SUM(livclass, raise(livclass,T-1)*aue2(livclass, season)*
animal(livclass,"hayuse"))
    *onday(season,"months")
    =L= feedcrop("purchalf",season,T)*forage("purchalf","conver")
    +feedcrop("raisealf",season,T)*forage("raisealf","conver");

*Cattle transfer equations

COWTRAN(T)$(ORD(T) GT 1).. raise("broodcow",T) + raise("cullcow",T) +
raise("sellbcow",T)
   =L= raise("broodcow",T-1)*(1-Animal("broodcow","deathlss")) +
   raise("rephyear",T-1)*(1-Animal("rephyear","deathlss")) + raise("buybcow",T);
BULLTRAN(T)$(ORD(T) GT 1).. raise("bull",T) =L= (1-bullrepl)*raise("bull",T-1)*
(1-animal("bull","deathlss")) + raise("buybull",T) ;
REPTRAN(T)$(ORD(T) GT 1).. raise("rephcalf",T-1)*(1-
animal("rephcalf","deathlss"))
   =E= raise("rephyear",T);
BULLRAT(T)..  raise("broodcow",T)+ raise("cullcow",T) + raise("rephyear",T)
   =E= cowbull*raise("bull",T);
CULLRATC(T)..  raise("cullcow",T) =e= minrepl*(raise("broodcow",T) +
raise("rephyear",T));
MINHYRC(T)..  Raise("hyear",T) =G= minhyear*raise("rephyear",T);
MINREPLC(T)$(ORD(T) GT 1).. minrepl*(raise("broodcow",T)/(1-
Animal("broodcow","deathlss"))+
   raise("cullcow",T)/(1-Animal("cullcow","deathlss"))) =L=
   raise("rephyear",T-1)*(1-Animal("rephyear","deathlss"))+raise("buybcow",T);
MAXREPLC(T).. raise("rephcalf",T) =L= maxrepl *(raise("hcalf",T) +
raise("hyear",T)+ raise("rephcalf",T));
RSCALFC1(T)$(ORD(T) EQ 1)..  raise("scalf",T) + raise("syear",T) =L=
calfcrop/2*(raise("broodcow",T)
    + raise("rephyear",T));
RSCALFC2(T)$(ORD(T) GT 1)..  raise("scalf",T) + raise("syear",T) =L=
calfcrop/2*(raise("broodcow",T)
    + raise("rephyear",T-1));
RHCALFC1(T)$(ORD(T) EQ 1).. raise("hcalf",T) + raise("hyear",T) +
raise("rephcalf",T) =L=
    calfcrop/2*(raise("broodcow",T) + raise("rephyear",T)) ;
RHCALFC2(T)$(ORD(T) GT 1).. raise("hcalf",T) + raise("hyear",T) +
raise("rephcalf",T) =L=
    calfcrop/2*(raise("broodcow",T) + raise("rephyear",T-1)) ;

*Livestock sales and costs
```

```
SALES(livecl,T).. selllive(livecl,T) =L= (1-Animal(livecl,"deathlss"))*
   Animal(livecl,"salewt")* raise(livecl,T);

COSTFORC(T).. FORCOST(T) =E=
SUM(season,SUM(land,landuse(Land,Season,T)* forage(land,"forcost"))) ;
COSTANIC(T).. ANIMCOST(T) =E= SUM(livclass,animal(livclass,"animcost")
*raise(livclass,T))
   + SUM(livclass,buypric(T,livclass)*animal(livclass,"buywt") * raise(livclass,T));
GROSSRET(T).. GROSS(T) =E= SUM(livecl,selllive(livecl,T)*salepric(T,livecl))
   + SUM(CROP,SELLCROP(crop,T)*cropsale(crop));
LOANPAY(T)..  LOANCST(T) =E= (1+Stloanr)*repayst(T);
CASHSOUR(T).. CASHTR(T) =E= NET(T) + Offranch - family - fixed - trtcost;
NETRET(T).. NET(T) =E= GROSS(T)-FORCOST(T)-ANIMCOST(T)-
LOANCST(T);
NETRETD(T).. NETDIS(T) =E= NET(T)*DF(T);
INCOME ..  Ranchinc =e= sum(T, NETDIS(T))+ TERM;

*calculation of annual payment of treatment loan

TRTANPAYeq(T).. TRTANPAY(T)=E= (TRTCOST * TRTLOAN)/(1 - ((1 +
TRTLOAN)**(-Trtyear)));

SAVING1(T)$(ORD(T) EQ 1).. AccumSav(T) =e= IWEALTH + NET(T) +
OFFRANCH
   - Family - fixed - trtanpay(T) + STBORROW(T);
*next line changed to keep it from putting everyting into savings by adding 0.5
after =e=
SAVING2(T)$(ORD(T) GT 1).. AccumSav(T) =e= 0.5*AccumSav(T-1)*(1 +
savrate)
   + NET(T) + OFFRANCH - Family - fixed - trtanpay(T) + STBORROW(T);
STREPAY(T).. STBORROW(T-1) =L= REPAYST(T);

TERMVAL(TLAST)..  TERM =E=
((raise("BROODCOW",TLAST)+raise("CULLCOW",TLAST)
    +raise("rephyear",TLAST)+raise("rephcalf",TLAST))*Endval)/RHO*(1-
1/((1+RHO)** CARD(T)));


*************** Set bounds for selected variables *********************

* accumsav is the minimum accumulated savings
* need to ensure that stborrow year matches your price set
* the year01 numbers set an initial endowment of animals
* the year40 numbers limit the number of replacements for the terminal value

accumsav.lo(T)= 1.;
```

```
stborrow.up(T)= 100000;
slacklnd.up("State",T)=0;
raise.up("sellbcow",T)$(ORD(T) EQ 1) = 0;
raise.up("broodcow",T)$(ORD(T) EQ 1) = 240;
raise.up("rephyear",T)$(ORD(T) EQ 1) = 65;
raise.up("rephcalf",T)$(ORD(T) EQ 1) = 72;
raise.lo("horse",T)=6;
ranchinc.up=5000000;
**************************************************************************
* You can change the name of the model to match your area.  Need to change
the
* name in the solve equation as well.

model Jordbase base level model / all /;

option lp=minos5;
option limrow = 60;
option limcol = 00;
option SOLPRINT=off;

******************* Start Loop************Start Loop*********************
loop(iter,

salepric(T,"cullcow")  = salep(iter,T,"cullcow");
salepric(T,"bull")     = salep(iter,T,"bull");
salepric(T,"scalf")    = salep(iter,T,"scalf");
salepric(T,"hcalf")    = salep(iter,T,"hcalf");
salepric(T,"purscalf") = salep(iter,T,"purscalf");
salepric(T,"purhcalf") = salep(iter,T,"purhcalf");

*assumes %commission of (Commiss), daily yardage fee of YARDAGE, Feed of
* $SALEFEED/cwt
salepric(T,"sellbcow") = salep(iter,T,"cullcow")*Animal("sellbcow","salewt");
buypric(T,"buybcow") = salep(iter,T,"buybcow");
buypric(T,"buybull") = 154.09 + 2.0549*buypric(T,"buybcow");

display buypric;
display salepric;

SOLVE Jordbase USING LP MAXIMIZING ranchinc ;

display ranchinc.l;
display
    landuse.l
    raise.l
    feedcrop.l
```

```
    selllive.l
    sellcrop.l
    TRTANPAY.l  ;

Econ(iter,T,'forcost')  = forcost.L(T);
Econ(iter,T,'animcost') = animcost.L(T);
Econ(iter,T,'loancst')  = loancst.L(T);
Econ(iter,T,'totcost')  = forcost.L(T) + animcost.L(T) + loancst.L(T);
Econ(iter,T,'gross')    = gross.L(T);
Econ(iter,T,'Net')      = Net.L(T);
Econ(iter,T,'netdisc')  = Netdis.L(T);
Econ(iter,T,'cashtr')   = cashtr.L(T);
Econ(iter,T,'accumsav') = accumsav.L(T);
Econ(iter,T,'stborrow') = stborrow.L(T);
Econ(iter,T,'repayst')  = repayst.L(T);

if ((totdays = 365 or totdays = 366), display totdays;
else abort "Total season days not 365 or 366, adjust dates";

Landsum(iter,Land,T,'used')   = sum(season,landuse.L(land,season,T));
Landsum(iter,Land,T,'value')  =
sum(season,landuse.L(land,season,T))*forage(land,"forcost");
Landsum(iter,Land,T,'Slack')  = slacklnd.L(land,T);
Landsum(iter,Land,T,'Total')  = sum(season,landuse.L(land,season,T)) +
slacklnd.L(land,T);
Landsum(iter,Land,T,'Shadow') = slacklnd.m(land,T);

Landseas(iter,Land,T,'seas1') = landuse.L(land,'seas1',T);
Landseas(iter,Land,T,'seas2') = landuse.L(land,'seas2',T);
Landseas(iter,Land,T,'seas3') = landuse.L(land,'seas3',T);
Landseas(iter,Land,T,'seas4') = landuse.L(land,'seas4',T);
Landseas(iter,Land,T,'seas5') = landuse.L(land,'seas5',T);
Landseas(iter,Land,T,'seas6') = landuse.L(land,'seas6',T);

Feedseas (iter,Crop,T,'seas1') = Feedcrop.L(crop,'seas1',T);
Feedseas (iter,Crop,T,'seas2') = Feedcrop.L(crop,'seas2',T);
Feedseas (iter,Crop,T,'seas3') = Feedcrop.L(crop,'seas3',T);
Feedseas (iter,Crop,T,'seas4') = Feedcrop.L(crop,'seas4',T);
Feedseas (iter,Crop,T,'seas5') = Feedcrop.L(crop,'seas5',T);
Feedseas (iter,Crop,T,'seas6') = Feedcrop.L(crop,'seas6',T);

anim(iter,T,"broodcow") = raise.L("broodcow",T);
anim(iter,T,"cullcow")  = raise.L("cullcow",T);
anim(iter,T,"bull")     = raise.L("bull",T);
anim(iter,T,"horse")    = raise.L("horse",T);
anim(iter,T,"scalf")    = raise.L("scalf",T);
```

```
anim(iter,T,"hcalf")    = raise.L("hcalf",T);
anim(iter,T,"syear")    = raise.L("syear",T);
anim(iter,T,"hyear")    = raise.L("hyear",T);
anim(iter,T,"purscalf") = raise.L("purscalf",T);
anim(iter,T,"purhcalf") = raise.L("purhcalf",T);
anim(iter,T,"rephcalf") = raise.L("rephcalf",T);
anim(iter,T,"rephyear") = raise.L("rephyear",T);
anim(iter,T,"buybcow")  = raise.L("buybcow",T);
anim(iter,T,"sellbcow") = raise.L("sellbcow",T);
anim(iter,T,"buybull")  = raise.L("buybull",T);

AUY(ITER,T) = sum(season, sum(livclass,
raise.L(livclass,T)*aue1(livclass,season))*
onday(season,"months")+ SUM(livclass, raise.L(livclass,T-1)* aue2(livclass,
season))*
onday(season,"months"))/12;

ri(iter)=ranchinc.L;
MS(iter)=jordbase.modelstat;

display feedseas;
options decimals=1; display econ;

put returns 'year' 'iter';
loop(costsum, put costsum.tl);
loop(iter,
loop(T,
 put / T.te(T);
 put iter.te(iter);
 loop (Costsum, put Econ(iter,T,costsum))));

put foragsum 'Landtype' 'year' 'iter';
loop(out1, put out1.tl);
loop(iter,
 loop(land, loop(T,
    put / Land.te(Land), T.te(T), iter.te(iter);
         loop(out1, put landsum(iter,Land,T,out1)))));

put lndsum 'landtype' 'year' 'iter';
 loop(season, put season.tl);
 loop(iter,
 loop(land, loop(T,
 put / Land.te(Land), T.te(T);
 put iter.te(iter);
 loop (season, put Landseas(iter,Land,T,season)))));
```

```
put feedsum '      ''crop' 'year' 'iter';
 loop(season, put season.tl);
 loop(iter,
 loop(Crop, loop(T,
 put /''hay'' Crop.te(Crop), T.te(T);
 put iter.te(iter);
 loop (season, put Feedseas(iter,Crop,T,season)))));

put raisesum 'Year' 'iter' 'AUY';
loop(livclass, put livclass.tl);
loop(iter,
  loop(T, put / T.te(T);
put iter.te(iter);
put AUY(ITER,T);
    loop(livclass, put anim(iter,T,Livclass))));

put risum 'iter' 'ObjFun' 'Model status';
loop(iter,
put / iter.te(iter), ri(iter),MS(ITER));
```