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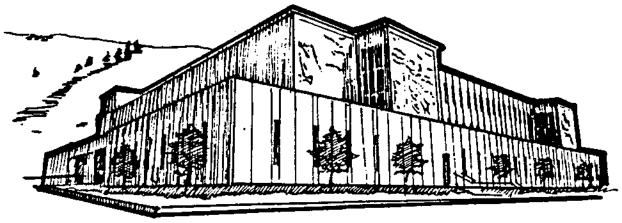

EFFECTS OF CATTLE GRAZING ON THE REGENERATION OF LODGEPOLE PINE (*PINUS CONTORTA*) SEEDLINGS IN WESTERN MONTANA

By

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Effects of Cattle Grazing on the Regeneration of Lodgepole Pine (*Pinus contorta*) Seedlings in Western Montana

Director: Dr. E. Earl Willard E.E.W.

The purpose of this study was to identify the effect of cattle grazing on regenerating lodgepole pine seedlings. The study area is located in northwestern Montana in the Garnet Resource Area (GRA) of the Bureau of Land Management (BLM). Two sets of fenced and unfenced paired plots were established in 1980 by the BLM. The data for this study were taken from these established plots in the summer of 1988. The study site is under a rest rotation grazing system.

Cattle grazing was found to have an impact on lodgepole pine seedlings, in terms of significantly increased mortality and reduced height growth. Indirectly, grazing influenced seedlings through reduced soil infiltration rates and changed vegetation composition. When the grazed and non-grazed plots were projected to the future through the prognosis model, there was a significant difference in timber volume between the two stands at rotation.

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Multiple-use is a key factor in management of our national lands. Hormay (1970) described multiple-use as management of all the various renewable surface resources of the land so that they are utilized in the combination that will best meet the needs of the American people with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output. Conflicts arise among the various uses, and one use can be detrimental to another. For example, use of young plantations for cattle grazing can be harmful to conifer seedlings (Borrecco and Black 1990). Since public forested lands are an important forage resource for ranchers, in addition to being an important source of logs for local mills, there is a need to manage both resources in a compatible manner. Traditionally, ranchers have viewed forage as a limitless resource so that excessive grazing has damaged other resources, including tree regeneration. Considerable damage has occurred on the western range over the past one hundred years (Hormay 1970).

Livestock were first introduced into western Montana in the mid-1800's (Willard et al. 1983). Since that time, the demand for forage has greatly increased, including that produced on forested ranges. In Montana, twenty-two million acres are classified as forests and about one-half of these lands is used for grazing livestock three to six months each year (Bedunah and Willard 1987). The majority of forested range used in western Montana is transitory range (Willard et al. 1983). These are clearcut or partially cut forests in transition toward forests. Transitory ranges produce forage for a time but become less productive as the area is reclaimed by trees (Willard et al. 1983).

Those type of forests commonly recognized as constituting the major forest grazing resource are those in the ponderosa pine (Pinus ponderosa) zone or the drier associations of the Douglas-fir (Psuedosuga menziesii) zone. The most extensive forest type in the western United States and Montana is dominated by ponderosa pine forest (Reid 1965). Most studies deal with the effects of livestock grazing on these drier forest types. The lodgepole pine (Pinus contorta) ecosystem is the second most extensive in Montana with fifty-six percent of it being grazed (Herbel et al. 1981).

There is a need, then to study the effects of livestock grazing on conifer regeneration. This study evaluated the effects of cattle grazing on a lodgepole pine plantation.

Literature Review

The results of research on grazing and tree regeneration are so varied and controversial that one can come up with literature to support whatever one wants to believe (Wellner 1969). Both beneficial and harmful effects of grazing on conifer regeneration have been identified through research and casual observations. Negative effects include soil compaction, seedling damage through browsing and trampling, and removal of the litter layer. Benefits include reduced competition from herbaceous and shrubby species, increased exposed mineral soil for seedling establishment, and reduced fire hazard (Willard et al. 1983). A study in Colorado compared the effects of heavy grazing verses moderate and light grazing on young ponderosa pine plantations. Seedling damage and reduced height growth were greatest on the areas that were heavily grazed (Currie et al. 1978).

All renewable rangeland values are tied to the vegetation (Hormay 1970). Sustaining a high-level production of renewable resources depends on proper management of the vegetation. Many inferior plants have replaced the desirable plants as they die (Hormay 1970). It is believed that excessive grazing is the major cause of range deterioration (Hormay 1970). Even with proper stocking levels, livestock graze selectively by species and area which can result in overgrazing. The same plants and species are grazed each year, leading to eventual reduction or complete removal of the preferred species. Livestock then graze less desirable species, leading to eventual deterioration of the range.

Hormay (1970) suggested using rest-rotation grazing to prevent range damage. Kingerly et al. (1987) also observed less damage and mortality where rotation grazing was practiced. He concluded that the intensity of livestock use can influence tree seedling establishment. The rest-rotation system uses periodic rest of the range from grazing. The purpose of the rest treatment is to allow plants to recover vigor, allow seeds to ripen, allow seedlings to become established, and to allow litter to accumulate (Hormay 1970). This will ultimately improve and maintain the vegetation and soil fertility.

With one study where rotational grazing management was practiced, damage to tree seedlings was not significantly different among livestock grazing utilization levels of light, medium, and heavy (Kingerly et al. 1987). On areas of heavy utilization that didn't practice rotational grazing, overall damage was the greatest.

Hormay (1970) stated that in order to meet the objective of maximum production of vegetation and high level yield of livestock for grazing management and other multiple-use values, the range must be rested periodically. The amount of rest varies by range and objectives of management. Generally more than one year of rest is needed for the establishment of seedlings (Hormay 1970).

According to Kingery et al. (1987) grazing intensity may be associated with damage to first-year establishment of tree seedlings. Through proper livestock management, the impacts can be minimal. The seedlings need to be large enough to withstand trampling and impacts of grazing which Hormay (1970) believes is reached after two seasons of root growth. Cleary (1978) found grazing to reduce growth and prolong the establishment period by two years in the Oregon coast range. He felt trees on interior sites would have even lower survival and take longer to reach a height of three feet if grazed during the establishment period. He concluded that, with few exceptions, cattle should not be grazed on a plantation during the establishment period. Kosco and Bartolome (1983) felt successful tree regeneration can be limited due to damage from browsing animals.

Three of the most important factors affecting the amount of conifer tree damage are water, available forage, and stocking rate (Hill 1917, Cassidy 1937). Adams (1975) stated that controlled grazing may be compatible with tree establishment on sites that are favorable to regeneration. On other sites where regeneration is hard to obtain, grazing is not compatible until adequate stocking of trees large enough to withstand grazing is obtained (US Forest Service 1980).

According to Koch (1982), cattle damage to plantations and natural regeneration may be a significant cause of reduced regeneration in the Garnet Resource Area (GRA) of the Bureau Of Land Management (BLM) in the Butte District, Montana. This study was established to investigate the influence of cattle grazing on the growth and health of lodgepole pine seedlings in a plantation in the GRA. The long term goal is reforestation for timber production, and livestock grazing is but a temporary use. Is the long term goal potentially being sacrificed by this temporary use? According to Kingerly et al. (1987), accumulative effects of continuous and heavy grazing could be substantial in later years.

Methods

Site Description

The study area is located in northwestern Montana in the GRA of the BLM. It is in the Alpine fir (Abies lasciocarpa)/Dwarf huckleberry (Vaccinium caespitosum) habitat type which is one of the major habitat types of the GRA (Pfister et al. 1977). The major forage species associated with the forest type are pinegrass (Calamagrostis rubescens) and elk sedge (Carex geyeri). The elevation is 1,830 meters and annual precipitation averages 50.8 cm. Soils are of tertiary sediment origin. They have been classified as mollic cryoboralf, clayey-skeletal, mixed (McDaniel et al. 1982). The surface soil is a silt loam to clay loam with 20 percent to 30 percent coarse fragments. There is a clayey B horizon within 36 cm of the soil surface.

A complete description of the soil profile is shown in Table 1.

Table 1. Soil Profile Description

Horizon	Depth (cm)	Textural Class	Description
O	0 - 5		
A21	5 - 15	silty clay loam	(10YR4/3) 28% clay
A22	15 - 36	silty clay loam	(10YR5/3)
B21t	36 - 53	heavy silty clay loam	(10YR6/3) 33% clay
B22t	53 - 61	silty clay, gravely clay loam	(10YR6/4) 15% gravel, > 35% clay
B23t	61 +	heavy clay	(10YR7/4)

B horizon varies from clay skeletal to clay.

Two sets of fenced and unfenced paired plots were established in 1980 by the BLM. At that time, all trees were removed from within the plots and 121 lodgepole pine seedlings (2-0 bare root) were planted in each plot. The trees were planted with a 2.4 X 2.4 meter spacing, with 11 rows of 11 trees. Corresponding plots are located beside one another approximately 30 meters apart. Plots were located in areas of relatively uniform cattle use. The fence limits cattle access but not that of wildlife. The exclosure integrity was maintained throughout the experiment.

The grazing history of the area was obtained from the BLM Allotment Management Plan files and from conversing with specialists from the BLM in the GRA. The study area is under the Ram Mountain Allotment Management Plan (AMP). It was implemented in 1969 (based on a 1965 range survey) and updated in 1976. Grazing is managed under a four-pasture rest-rotation grazing system on 7,000 acres of public and private lands. The total grazing capacity in animal unit months (AUM's) for the allotment is 994. The grazing system was set up for 160 cow-calf pairs for 5-1/2 months for a total use of 880 AUM's. Total authorized grazing cannot exceed 1,070 AUM's which is 15 percent greater than the estimated carrying capacity. Table 2 shows actual grazing (AUM'S) and grazing capacity in each pasture.

The homestead pasture is to be used as a spring pasture, and the other three will be managed under a rest-rotation grazing system. The grazing sequence is June 1 - July 31 and Aug 1 - Oct 31. The third year is to be a rest year.

The purpose for early grazing is to allow the plant a chance for regrowth after being grazed. When grazed after August 1, plants have an opportunity to set seed.

Table 2. Pasture use.

Pasture	Use (AUM'S)	Carrying Capacity (AUM'S)
Homestead	160 AU x ½ month = 80	155
Hoodoo	160 AU x 3 months = 480	243
	160 AU x 2 months = 320	243
Mill	160 AU x 3 months = 480	319
	160 AU x 2 months = 320	319
Scotchman	160 AU x 3 months = 480	277
	160 AU x 2 months = 320	277

According to this grazing schedule, the Homestead Pasture is grazed only at one-half its grazing capacity each year. Hoodoo is overgrazed two years out of every three. Mill is overgrazed one out of every three years, and Scotchman is overgrazed two years out of every three.

The study site is located in the Scotchman pasture. The current use in the Scotchman pasture by 160 pairs for two months is 320 AUM's and for three months is 480 AUM's. Based on the 1965 range survey, 277 AUM's is the carrying capacity, therefore, the pasture is being overgrazed. In 1972 there was a 331-acre timber sale on BLM land. These cutover areas which have occurred since the survey are woodland areas and don't provide much additional AUM's of forage. It is on these areas that the actual study site is located. Scotchman's pasture is based on a stocking rate of 8.5 ac/AUM. According to Eddleman (1972), a suggested stocking rate for a pine/Douglas-fir forest type with forage species of pinegrass and elk sedge is 10 ac/AUM's.

Previous grazing history of the area included horses, cattle, and domestic sheep with no control over livestock. Most of the allotment was in "fair" condition in 1965.

The main objectives of the AMP are to 1) obtain better livestock distribution and utilization of forage, 2) improve the vegetative composition by changing the present composition of grassland communities from a seral state (caused by overgrazing) back toward a climax state, and

3) enhance the bighorn sheep, mule deer and elk habitat.

In 1976 an Environmental Assessment was written for the AMP. It stated there was a continual decline in range condition. It showed Scotchman's pasture to be in a downward trend. The pasture went from 41 percent non-vegetative cover in 1970 to 68 percent non-vegetative cover in 1976. Both forbs and grasses decreased. These results were based on sampling the open parks within the pasture. A 1990 survey of the AMP concluded that all pastures showed heavy forage utilization in excess of allocations due to incompatible season lengths and animals. Grazing history of the Scotchman pasture since 1978 is summarized in Table 3.

Table 3. Grazing history of Scotchman pasture

Year	Dates Grazed	Cattle Grazing
1978	6/01/78 - 8/01/78	140 pair authorized
1979	8/01/79 - 10/30/79	140 pair authorized
* 1980	7/15/80 - 8/15/80	10 - 20 pair trespass
1981	6/01/81 - 8/01/81	140 pair authorized
1982	8/25/82 - 10/30/82	160 pair authorized
* 1983	season long	20 pair trespass
1984	6/01/84 - 7/30/84	140 pair authorized
1985	8/01/85 - 10/30/85	20 pair trespass
* 1986	Rest	
1987	6/01/87 - 10/30/85	160 pair authorized
1988	8/02/88 - 11/01/88	160 pair authorized
* 1989	Rest	
1990	6/01/90 - 8/01/90	

* indicates deferred years

All of my data were collected during the summer of 1988, eight years after the exclosures were established.

Data Collection

Four variables were assessed: lodgepole pine seedling height growth, vegetation composition, edaphic characteristics, and lodgepole pine seedling mortality. A one-hundred percent sample of all trees in each of the fenced and unfenced areas was taken for annual and cumulative height growth. Annual height growth was collected for each of the four years from 1985 through 1988. Prior to 1985, annual height growths were not detectable.

Vegetation composition data were collected from eight microplots on each of the fenced and unfenced areas. A random sampling method was used. Data were collected in 1m X 1m microplots randomly distributed in each area. All vegetation within each microplot was clipped, oven-dried, and weighed by species. Plant biomass was recorded in each of seven categories: pinegrass, elk sedge, Kentucky bluegrass (Poa pratensis), wild strawberry (Fragaria virginiana), slender wheatgrass (Agropyron caninum), cured plant biomass and forbs (Appendix 1). The cured plant biomass included detached plant biomass (litter) and attached cured vegetation.

Edaphic conditions were analyzed through infiltration rates and bulk density sampling. Random sampling was used to locate microplots. Infiltration rates were measured with a double ring infiltrameter (Nimlos 1988). 1000 ml. of water is poured into both rings simultaneously. The outer ring wets the soil below it to reduce the amount of lateral movement from the water in the inner ring. The amount of time it took the water to disappear from the inner ring was timed. These numbers were used to compare infiltration rates.

Samples for bulk density were taken from three areas: the grazed plots, non-grazed plots, and a control plot. The control sample was taken from the surrounding stand. The stand is composed of 90- to 100-year-old lodgepole pine trees. It has never been harvested and considerable downfall from a beetle kill has kept cattle traffic out of the area. Bulk density was measured using the saran method for bulk density determination of soil clods (Soil Conservation Service 1984). A sharp knife was used to remove clod samples from the soil profile. Three clod samples were removed from each microplot. The samples were taken from the following depths: 0-7, 7-14, and 14-21 centimeters. A fine wire was tied around each clod to hold it together and to suspend it in the saran (a mixture of resin and methyl ethyl ketone). Each clod was labeled for identification, dipped in the saran and hung to dry. Clods were oven-dried, then weighed in air and weighed while immersed in water. Lastly, coarse fragments were removed from the clods since their density is about double that of porous soil. The clods were opened and sieved off in a screen to retain all material greater than two millimeters. These fragments were oven-dried and weighed. Volume of coarse fragments was calculated and subtracted from the clod weight. Bulk density was then calculated as follows:

$$\text{Bulk Density} = \frac{\text{clod weight in air (gm)}}{\text{clod volume (cc)}}$$

Tree seedling mortality was determined by examining all of the original 484 trees. A tree was classified as dead if it was missing or without any photosynthetic material.

Data Analysis

A T-test was used to compare height growth, vegetation composition, and infiltration rates on grazed verses non-grazed areas. The chi-square analysis was used for the mortality variable. Bulk density was assessed through use of analysis of variance (ANOVA) procedure. The prognosis model (Wylcoff et al. 1982) was used to compare the expected future stand growth and yield of the grazed plots compared to the non-grazed plots. The significance level was 0.05. Statistical analyses are described by Norusis (1987).

Results

Cattle grazing was found to have an impact on lodgepole pine seedlings, in terms of significantly increased mortality and reduced height growth. Indirectly, grazing influenced seedlings through reduced infiltration rates and a changed vegetation composition. Bulk density was the only variable where no statistically significant difference was found between the grazed and non-grazed areas.

Mortality was twice as high on the grazed areas compared to non-grazed areas. Sixty-eight out of 242 trees were dead on grazed plots compared to 34 out of 242 trees on ungrazed plots (Table 4).

There was a significant difference in the total tree seedling height growth between grazed and non-grazed plots (Table 4). Seedlings on ungrazed plots showed a significant increase ($p \leq 0.05$, $t=2.91$) in total height over that of seedlings on grazed sites. Mean height for seedlings on ungrazed plots was 127.61 cm (standard deviation) (s.d.=38.01) while that of seedlings under grazing was 116.19 cm (s.d.=38.63).

There was a significant difference in annual height growth for the years 1985, 1987, and 1988 (Table 4). There was not a statistical difference noted in the annual seedling height growth in 1986 even though the mean height growth for that year of the control plots was slightly greater than that of the grazed plots.

Mean infiltration rates were five times as long on the grazed areas as those on the non-grazed areas (Table 4). The mean infiltration rate for the grazed area was 20.24 minutes compared to 4.19 minutes on the control plots.

There was a significant difference in the total weight of vegetation between the areas (Table 4). The mean weight of vegetation collected on the grazed areas was 21.06 gm compared to 26.73 gm on the nongrazed areas. There was a significant difference in both amount of cured plant biomass and amount of forb biomass between the two treatments. The mean amount of cured plant biomass on the grazed treatment was 13.19 gm compared to 53.42 gm on the nongrazed. Forb biomass was greater on the grazed plots (38.99 gm) than on the ungrazed sites (27.14 gm). There was not a statistically significant difference in the following vegetation: elk sedge, pinegrass, wild strawberry, slender wheatgrass, and Kentucky bluegrass.

Although the mean bulk density of the grazed sites wasgreater than that of non-grazed sites, there was no significant difference at the 95 percent probability level.

Table 4. Descriptive variables comparing grazed and nongrazed plots. Separate variance estimates were used for grazed and nongrazed groups.

Variable	Status	Mean	Std.Dev.	T-test Std.Error	T	D.F.	2-tailed prob.
Total Ht. (cm)	G	116.2	38.6	2.9	2.91	368.41	.004
	NG	127.6	38.0	2.6			
1988 ht. growth (cm)	G	28.99	10.39	.79	3.14	365.26	.002
	NG	32.33	10.28	.71			
1987 ht. growth (cm)	G	21.42	9.54	.73	2.22	351.64	.027
	NG	23.51	8.67	.60			
1986 ht. growth (cm)	G	14.30	6.33	.48	.86	358.38	.391
	NG	14.86	6.12	.42			
1985 ht. growth (cm)	G	13.61	5.56	.44	2.06	351.00	.04
	NG	14.87	6.02	.42			
Infiltration (minutes)	G	20.24	9.29	3.79	4.13	5.49	.007
	NG	4.19	2.05	0.84			
Elk sedge (# gm)	G	15.20	5.18	1.50	1.88	15.87	.079
	NG	21.62	10.72	3.09			
Kentucky Bluegrass (# gm)	G	24.50	9.23	2.31	1.49	19.61	.146
	NG	19.32	10.35	2.59			
Pinegrass (# gm)	G	20.77	8.83	2.79	.38	16.65	.079
	NG	19.21	9.13	3.04			
Slender Wheatgrass (# gm)	G	10.46	1.39	.80	-.74	2.41	.527
	NG	12.39	4.33	2.50			
Strawberry (# gm)	G	14.10	4.26	1.06	-1.40	21.87	.176
	NG	17.20	7.50	1.94			
Cured Biomass (# gm)	G	13.19	4.21	1.05	-4.15	15.36	.001
	NG	53.42	38.55	9.64			
Forbs	G	38.99	14.71	3.68	2.55	27.65	.017

Table 4. (continued)

(# gm)	NG	27.14	10.98	2.83			
Total Veg (# gm)	G	21.06	12.57	1.33	-2.04	132.03	.043
	NG	26.73	22.60	2.44			
				ANOVA			
Bulk Density	G	1.35	.26		.9314		.931
Top (0-7 cm)	NG	1.31	.21				
g/cm^3	control	1.31	.20				
Middle	G	1.41	.12		1.74		.0853
(7-14 cm)	NG	1.30	.16				
g/cm^3	control	1.65	.38				
Bottom	G	1.48	.23		1.42		.1747
(14-21 cm)	NG	1.43	.21				
g/cm^3	control	1.220	.04				
				CH1 SQUARE			
		Dead		Alive			
Mortality	G	68		174			.0002
	NG	34		208			

Based on the measurements from the grazed and non-grazed plots the prognosis model predicted future growth and yield volumes for representative sample stands. The mean annual increment (MAI) culminated around age 110 for the grazed and age 100 for the non-grazed stands. The present net value (PNV) was greatest at age 70 for both stands. The merchantable board feet at this age were used to compare the two stands. The mean for the grazed stand was 6.439 MBF/acre (s.d.=0.166 MBF) and 8.527 MBF/acre (s.d.=.213 MBF) for the non-grazed (Table 5). The difference between the two means is 2.088 MBF/acre.

Table 5. Prognosis results of grazed and nongrazed stands.

Grazed

Rotation Age 70 (Board Foot)	Rotation Age 80 (Board Foot)
6213	8878
6617	9133
6466	9152
6171	9146
6323	8700
6531	8972
6611	8986
6466	8869
$\bar{X}$ = 6.439 MBF/ac.	$\bar{X}$ = 8.962 MBF/ac.
S.D. = 0.166 MBF/ac.	S.D. = 0.159 MBF/ac.

Rotation Age 90 (Board Foot)	Rotation Age 100 (Board Foot)
11421	13837
11699	14273
11585	14014
11769	14120
11336	13863
11482	13940
11713	14253
11319	13610
$\bar{X}$ = 11.523 MBF/ac.	$\bar{X}$ = 13.973 MBF/ac.
S.D. = 0.166 MBF/ac.	S.D. = 0.214 MBF/ac

Table 5. (continued)

Non-Grazed

Rotation Age 70 (Board Foot)	Rotation Age 80 (Board Foot)
8807	11761
8682	11557
8554	11462
8137	10862
8444	11266
8245	11014
8646	11335
8601	11539
8585	11286
$\bar{X}$ = 8.527 MBF/ac.	$\bar{X}$ = 11.342 MBF/ac.
S.D. = 0.213 MBF/ac.	S.D. = 0.278 MBF/ac.

Rotation Age 90 (Board Foot)	Rotation Age 100 (Board Foot)
14513	17311
14364	16980
14052	16472
13683	16280
14182	16757
13690	16159
13822	16417
14449	17083
14090	16728
$\bar{X}$ = 14.093 MBF/ac.	$\bar{X}$ = 16.687 MBF/ac.
S.D. = 0.314 MBF/ac.	S.D. = 0.387 MBF/ac.

Discussion

Vegetation

Food habits of livestock are influenced by the vegetative type and time of year. Perennial plants have a better potential for regrowth if grazed during the early part of the season before soil moisture and their ability for regrowth declines. According to Hormay (1970), once a plant is half grown it begins storing food, its growth rate declines and its regrowth is negligible. Even at a relatively late growth stage, defoliation of the plant anytime up to the time food storage is completed is harmful. After reserves are stored, grazing doesn't significantly affect the growth of herbaceous plants because reserves and growing parts are below ground, out of reach of grazing animals.

Under this rest-rotation system, pastures are either grazed early or late, or left ungrazed year-long. When grazed during the early season, plants have a chance to regrow, once cattle are removed from the pasture. Grazing after August 1 gives plants a chance to develop seed before being grazed. This later grazing season is followed by a year of rest year to give plants a chance to recover.

Cattle will eat preferred forage first and then eat less palatable forbs and browse for the remainder of the grazing season (Hormay 1970). On this site, pinegrass, elk sedge and Kentucky bluegrass are the primary forage species.

Kentucky bluegrass is generally the most preferred species of these three, although there appears to be no preference for one species over another on the grazed site because all were grazed to within 2-5 cms of the soil surface. Pinegrass is not necessarily preferred by cattle but they will eat it during early spring when lush, before it loses its palatability (Prange 1991). Elk sedge maintains its succulence longer than other plants so it is used into the fall (Eddleman 1972, Bedunah and Willard 1987).

In an Idaho study, livestock grazing was found to cause retrogression of plant succession within the herbaceous layer (Zimmerman and Neuenschwander 1984). Seral species replaced the climax grass species. On the grazed site of my study, one would expect to see pinegrass and elk sedge in the climax vegetative state. The increase in Kentucky bluegrass and the number of forbs on this site indicate the pasture is in a seral state. Kentucky bluegrass will invade and form a sod in areas that are heavily grazed (Willard et al. 1983). Echert and Spencer (1986) found that total perennial forbs increased on grazed sites. Because these forbs included a number of species, it is difficult to determine how individual species responded.

Vegetation composition is affected through removal of vegetation. Grazing can slow forest succession by keeping the understory vegetation in a seral state (Peek et al. 1978). This can affect the seedlings in two ways. First, with less vegetation, there are more chances of degradation of the soil surface, resulting in clogged pores and reduced infiltration. When this seral state is combined with continual soil disturbance from livestock, it creates ideal habitat for pocket gophers (Graham et al. 1991). According to Graham and Kingery (1990) pocket gophers are the major cause of mortality and damage of conifer plantations on transitory ranges.

Bulk Density

It wasn't surprising that no statistical difference was found in bulk density due to treatment. Considering the fact that the area had been uncontrollably grazed since the 1900's, compaction has occurred over many years. The study site has always been open to grazing, but when clearcut in 1972, it was opened more to grazing.

Even though there was no significant difference in the mean bulk density between the grazed, ungrazed, and control plots, the mean bulk density of the control sample from the 7-14 cm depth was greater than either the grazed and non-grazed samples. This seems a bit odd because one would expect the bulk density to be less on this site for all depths. The lower the depth within the soil profile the longer it takes bulk density to recover. Fifty to 100 years ago the forest was much more open, without much downfall timber. This was prior to the beetle infestation that resulted in increased downfall approximately 50 years ago.

Grazing was extensive over the entire area, and the numbers of sheep, horses, and cattle were much higher than they are today. Compaction could have occurred then, and over the years it is slowly recovering.

Why is the bulk density still higher in the controlled area? Possibly the forces that reduce compaction, that of freezing and thawing, are more drastic in the open areas than in the closed canopy. Also, there is a lot less understory vegetation resulting in fewer roots penetrating the soil and possibly less organic matter mixing into the soil profile of the control area. Even though the mean bulk density of the control 7-14 cm depth is 1.65 g/cm^3 and that of the grazed plot is 1.41 g/cm^3 there was not a significant difference, and possibly the difference observed is not that drastic when comparing bulk density. Another explanation for the difference could be in the sampling methods. Because the sampling is so tedious and time consuming, a minimum amount of samples were extracted. Further sampling would be beneficial.

Eight years (which is the amount of time the exclosures have been established) is probably not enough time for complete recovery of this site. However, there appears to be some recovery, since the bulk density in the non-grazed plot was 1.34 gm/cm^3 compared to 1.41 gm/cm^3 on the grazed area. However, the implications of this must be stressed. There is no evidence about how long the compacted soils will require for recovery. Eight years are a long time in the life of an establishing seedling. It appears that compacted soils can have a significant impact on tree development as evidenced by the overall height growth of trees in this study.

Increased bulk density can reduce tree growth through reduced water availability. Bulk density gives an indication of the volume of passages available into which water may move (Thurow et al. 1986). Thus, if bulk density increases, macropores are reduced but micropores aren't necessarily reduced. Instead, the number of micropores would increase proportionally which would result in a reduced soil moisture holding capacity. The rate of infiltration and amount of total pore space are highly correlated with bulk density (Laycock and Conrad 1981). Results from studies of bulk density vary depending on seasons, soils, and disturbance levels (Reynolds and Packer 1963). Some investigators have found significant differences in bulk density, even between levels of stocking (Reed and Peterson 1961), whereas others have not found a difference in bulk density between trampled areas and areas protected from grazing (Daubenmire and Colwell 1942). Lull (1959), Reynolds and Packer (1963), and Linnartz et al. (1966) found bulk density to be higher in grazed than in similar ungrazed areas.

Infiltration

Bulk density and infiltration rates are interrelated, yet there was a significant difference in infiltration rates but not in bulk density. This can be explained by two factors which come into play. First, the amount of litter definitely affects infiltration rates. Also, the upper 2-5 cm of a soil surface recover the quickest from compaction. It is in this upper level where weather, digging of animals, and root action operate to reduce compaction.

Just because the infiltration rates were faster on the nongrazed site, does it follow that water is passing into the soil faster? Perhaps the litter absorbs water and leads one to assume that the water was infiltrating the soil at an accelerated pace. Because I was testing for bulk density (another indicator of how swiftly water passes into the soil), I did not remove the organic layer and test for infiltration rates on the mineral soil. I wanted to see what happens to the water as it hits the natural setting which includes the litter layer. In the testing of infiltration rates, 1000 ml. of water was used. I do not think that the amount of water the litter absorbed could have significantly affected the overall rates.

Litter can benefit a site in several ways. It will absorb moisture quickly but also lose it quickly through evaporation. In spring time when soils are saturated, litter can reduce soil moisture loss; water must evaporate first from the litter layer before being reduced in the soil. Litter can provide shade and protection against increased soil temperatures and wind to reduce evaporation.

Besides absorbing moisture and holding it on the site, litter protects the integrity of the pores of the soil surface. Without that litter layer and an adequate cover of standing plant biomass, the soil surface can be degraded from the impact of raindrops. I assume that with the large amount of soil surface exposed on this site as recently as 1980, the soil surface pores have been clogged. Yet the nongrazed areas have had a chance to recover. The same processes that help to reduce soil bulk density will help open pathways for water to enter the soil.

There was not a statistical difference in the mean bulk density of the upper soil layer (0 cm - 7 cm) between grazed and control plots (Table 4). However, the mean bulk density for the grazed (1.35g/cm3) was greater than the mean bulk density for the nongrazed (1.31g/cm3). Perhaps there is a trend toward improvement of bulk density.

Alderfer and Robinson (1947) found that a reduction in litter and the correlated increase in bare soil due to grazing contributed to a reduction in infiltration rates. He also reported an increase in runoff as litter is removed and a higher percent of bare mineral soil is exposed.

Soil compaction can cause drier soils. Water remains on the surface longer and has more opportunity to evaporate

or run off. When more than one-half the herbage is removed through grazing, surface runoff and soil losses will increase (Currie et al. 1978). Cover helps to decrease the impact of rain drops before they strike the soil surface. It acts as a protective layer by dissipating the raindrop and maintaining the pore integrity of the soil surface. Without cover the pores can become clogged with disaggregated soil particles (Skovlin et al. 1976).
I believe this happened to this site. However, eight years of nongrazing on the exclosures has lead to a significant recovery in infiltration rates.

Another indicator of compaction and its effect on tree growth is root growth of seedlings on grazed and ungrazed plots. The root weights can be compared to determine if one was more developed than the other. The results of this study lead me to believe there could be a difference in the root development because of the reduced height growth of seedlings on the grazed sites.

Height Growth and Mortality

The most significant findings were a reduction in overall height growth and higher percentage of tree mortality on the grazed areas. These two factors must be considered if the primary goal of the stand is timber production, with grazing being secondary. Loss in potential timber volume is substantial just from mortality alone.

There was 28 percent mortality on the grazed sites compared to 14 percent mortality on the nongrazed sites. Grazing has doubled the natural rate of mortality on this site.

The mean height growth of the seedlings was significantly different after eight years of growth. If this difference is to continue for the life of the stand, there would be substantial timber volume lost.

It was interesting that there was a significant difference in mean annual height growth for three of the four years. Differences between annual heights of trees on the nongrazed and grazed acres do not appear to be very great, ranging from 1.26 cm to 3.34 cm. During 1986, the difference was 0.56 cm (not significant), with the grazed mean annual height being less than the nongrazed. This lack of statistical significance in 1986 may be related to drought that year.

When researchers are looking to capture genetic gain, they select for the observed differences. The small apparent differences in height growth may become important over time. In the tenth year in the life of these lodgepole pine seedlings, the average height of seedlings on grazed plots is 91 percent of the average height of seedlings on ungrazed plots. How long this difference will last is not certain. Research on the long term effects of grazing on tree growth appears to be limited.

The prognosis model (Wyholf et al. 1982) has been a useful tool for managers of the Northern Rocky Mountain forests in comparing different stand treatments. The northern Idaho/Western Montana variant of the prognosis model was used to predict future growth and yield of the sampled grazed and non-grazed plots. This particular variant was developed based on stand examination growth of sample trees. The Bitterroot National Forest growth equation was used. Rather than rely on the results of a single simulation, the data were run through prognosis nine times using different random numbers to determine if the observed difference in MBF/acre at rotation was consistant (Hamilton 1991).

It appears that mortality had the biggest impact on the observed difference in MBF/acre at any given age. When comparing average tree heights and diameters as projected by the model, there does not appear to be much difference between the two treatments after age 20 (Appendix 2 and 3). For example, at rotation age 80 the average difference in diameters was 0.09 inches (Table 6). Also, the tree heights were very similiar, only 0.67 foot difference (Table 6). There were on the average 73 trees/acre less on the grazed stands. Therefore, one would be led to believe the initial mortality was the major factor affecting the difference in volumn at rotation.

Table 6. Prognosis results of individual tree comparison at rotation age 80.

Grazed			Nongrazed		
Height Feet	Diameter Inches	# Trees	Height Feet	Diameter Inches	# Trees
60	8.1	314	61	8.1	390
61	8.0	312	61	8.1	387
60	8.1	314	61	8.1	388
61	8.0	316	61	8.1	382
61	8.0	310	61	8.1	387
59	7.9	322	60	8.0	384
60	8.0	313	61	8.1	385
61	8.0	314	62	8.1	388
61	8.0	310	62	8.2	390

$\bar{X}$ Height=60.44 s.d.=0.53

$\bar{X}$ Diameter=8.01 s.d.=0.003

$\bar{X}$ # Trees=313.89 s.d.=13.11

$\bar{X}$ Height=61.11 s.d.=0.36

$\bar{X}$ Diameter=8.1 s.d.=0.0025

$\bar{X}$ # Trees=386.78 s.d.=7.19

A question arises as to whether the trees on the grazed plots are really growing slower than those on the non-grazed plots, or is the observed difference in MBF/acre at rotation primarily due to the difference in the number of trees? It is interesting that a significant difference in height growth was observed in 3 of the 4 years that measurements were taken. I am unsure whether the trees will overcome this initial setback and put on similiar volume as that of trees within the exclosure. It appears from the prognosis model that the individual trees on the grazed plot are growing similiar to those of the non-grazed trees after age

20. When considering the observed difference in volume at rotation, all factors including soil compaction, reduced infiltration rates and reduced litter, in addition to mortality, could have an influence on the reduced volume observed at rotation through the prognosis model.

Economics is not the driving factor when dealing with multiple-use, but it is a factor managers may want to consider when making decisions. Three scenarios were analysed. 1) Is the timber volume lost at rotation worth the initial cost of electric fencing to protect tree seedlings from grazing? 2) If grazing wasn't allowed on the area for the initial establishment period, is the lost revenue from grazing fees worth the potential timber volume gained at rotation? 3) If an area was taken totally out of grazing for the life of the stand, would the potential timber volume gained at rotation be worth the loss of grazing fees?

The following costs were used to determine PNV of each stand. All costs and revenues were brought to their PNV in 1990 dollars. Current Forest Service planning uses 4% as the flat discount rate. The average annual real price increases for timber is 1.2 percent (United States Government Printing Office 1991). Real price increases for grazing is 0.6 percent per year. The value of an AUM in 1990 dollars (U.S. Forest Service 1990) was established as $6.37. The market-clearing price of the sawtimber at rotation was $113.6/MBF (U.S. Forest Service 1990). Cost for electric fencing is based on BLM costs of $12.87/acre for materials and $8.00/acre for labor. Administrative costs associated with grazing leases was 20 cents/acre based on BLM costs. Four economic analysis were done to answer the senarios (Table 7).

Table 7. Economic analysis of grazing versus timber production.

Economic Analysis #1: Grazed and Fenced

Description: Pasture is fenced for eight years, grazed for the next twelve years until the stand is 20 years old when grazing forage would be negligible.

Year	Cost
1980-1988	1. Fencing Materials $12.87/ac x 1.535 (GNP deflator) = $19.76/ac Fencing Labor $8.00/ac x 11.447 (discount factor)=$91.57/ac
1989-2000	2. Administration $0.20/ac x 9.4 = $1.88/ac. Total Costs = $113.22/ac.

Year	Revenue
1989-2000	1. AUM's $0.75/ac x 10.40 (4% discount rate + appreciation of 0.6%/year) = $7.80/ac 2. Timber (Assume 4% discount rate + 1.2% real value increase) Age 70 $113.6/MBF x $(1.04)^{-58}$ = $11.68/MBF 8.5273MBF x 11.68 = $99.60/ac. Age 80 $113.6/MBF x $(1.04)^{-68}$ = $7.89/MBF 11.3424MBF x 7.89 = $89.49/ac. Age 90 $113.9/MBF x $(1.04)^{-78}$ = $5.34/MBF 14.0938MBF x 5.34 = $75.26 Age 100 $133.9/MBF x $(1.04)^{-88}$ = $3.61/MBF 16.6874MBF x 3.61 = $60.24

Table 7. (continued)

Discounted Revenues minus Discounted Costs = PNV

Rotation Age	Timber	+	AUM			-	Electric Fencing + Administration		
70	$99.60	+	$7.80	=	$107.4	-	$113.22	=	$-5.82/ac.
80	$89.49	+	$7.80	=	$97.29	-	$113.22	=	$-15.93/ac.
90	$75.26	+	$7.80	=	$83.06	-	$113.22	=	$-30.16/ac.
100	$60.24	+	$7.80	=	$68.04	-	$113.22	=	$-45.18/ac.

Economic Analysis #2: Grazed and Nonfenced

Description: Pasture is grazed for 20 years.

Year	Cost
1980-2000	1. Administration $0.20 x 20.8 = $4.16

Year	Revenue
1980-2000	1. AUM's $0.75/ac x 21.847 = $16.38

2. Timber

Age 70 $\$113.6 \times (1.04)^{-58} = \$11.68$/MBF

6.4392MBF x 11.68 = $75.21/ac.

Age 80 $\$113.6 \times (1.04)^{-68} = \$7.89$

8.9625MBF x 7.89 = $70.71

Age 90 $\$113.6 \times (1.04)^{-78} = \$5.34$

11.5233 x 5.34 = $61.53

Age 100 $\$113.6 \times (1.04)^{-88} = \$3.61$

13.9738 x 3.61 = $50.45

Discounted Revenues minus Discounted Costs = PNV

Rotation Age	Timber	+	AUM			-	Administration	=	PNV
70	$75.21	+	$16.38	=	$91.59	-	$4.16	=	$87.43/ac.
80	$70.71	+	$16.38	=	$87.09	-	$4.16	=	$82.93/ac.
90	$61.53	+	$16.38	=	$77.91	-	$4.16	=	$73.75/ac.
100	$50.45	+	$16.38	=	$66.83	-	$4.16	=	$62.62/ac.

Table 7. (continued)

Economic Analysis #3: Grazing after Initial Eight Years of Rest

Description: The cattle are kept off during the established period, in this case for eight years, through other methods besides fencing.

Year	Cost
1989-2000	1. Administration $0.20 x 9.4 = $1.88/ac.

Year	Revenue
1989-2000	1. AUM's $0.75 x 10.40 = $7.80/ac.

2. Timber

Age 70 \$113.6/MBF x $(1.04)^{-58}$ = \$11.68/MBF
8.5273MBF x 11.68 = $99.60/ac.
Age 80 \$113.6/MBF x $(1.04)^{-68}$ = \$7.89/MBF
11.3424MBF x 7.89 = $89.49/ac.
Age 90 \$113.9/MBF x $(1.04)^{-78}$ = \$5.34/MBF
14.0938MBF x 5.34 = $75.26
Age 100 \$133.9/MBF x $(1.04)^{-88}$ = \$3.61/MBF
16.6874MBF x 3.61 = $60.24

<u>Discounted Revenues</u> minus <u>Discounted Costs</u> = PNV

Rotation Age	Timber	+	AUM		-	Administration	=	PNV
70	$99.60	+	$7.80	= $107.4	-	$1.88	=	$105.52/ac.
80	$89.49	+	$7.80	= $97.29	-	$1.88	=	$95.41/ac.
90	$75.26	+	$7.80	= $83.06	-	$1.88	=	$81.18/ac.
100	$60.24	+	$7.80	= $68.04	-	$1.88	=	$66.16ac.

This scenario was set up for options such as resting a pasture that contained the harvested stand for the establishment period instead of fencing.

Table 7. (continued)

Economic Analysis #4: No Grazing

Costs
No Administration costs.
No Fencing costs.

Revenue
No AUM revenue.
1. Timber

Age 70 $\$113.6/\text{MBF} \times (1.04)^{-58} = \$11.68/\text{MBF}$
8.5273MBF x 11.68 = $99.60/ac.

Age 80 $\$113.6/\text{MBF} \times (1.04)^{-68} = \$7.89/\text{MBF}$
11.3424MBF x 7.89 = $89.49/ac.

Age 90 $\$113.9/\text{MBF} \times (1.04)^{-78} = \$5.34/\text{MBF}$
14.0938MBF x 5.34 = $75.26

Age 100 $\$133.9/\text{MBF} \times (1.04)^{-88} = \$3.61/\text{MBF}$
16.6874MBF x 3.61 = $60.24

Discounted Revenues minus Discounted Costs = PNV

Rotation Age	Timber = PNV
70	$99.60/ac.
80	$89.49/ac.
90	$75.26/ac.
100	$60.24/ac.

Rotation age 70 was used as the comparision age because PNV continued to decline beyond this age and prior to this age stands were not of sawtimber value. The one shortcoming with the overall economic analysis is the fact that the estimated market-clearing price of sawtimber has not been estimated beyond the year 2040 (U.S. Forest Service 1990). The estimated value of timber in the year 2040 was the value used for all the economic analysis. Age 70 occurred in the year 2048. Beyond this age the volume/acre on any stand did not increase faster than the decrease in value. Possibly the value of the timber would increase as the individual trees increased in size. This difference in value of individual tree size has not been built into the published estimates of future timber values. There are no data currently available to deal with this difference.

The highest PNV at rotation age 70 was $105.52/acre (economic analysis #3 Table 7) in the stand that had no grazing for the first 8 years and then had grazing for the next 12 years. The stand that had no grazing for its life (economic analysis #4, Table 7) had the next highest PNV ($99.60/acre) at age 70. The stand that was grazed without fencing (economic analysis #2 Table 7) had a PNV of $87.43/acre, and the grazed, fenced stand (economic analysis #1 Table 7) had the lowest PNV of -$5.82/acre.

In scenario 1, the grazed stand (economic analysis #1, Table 7) was compared to the electric-fenced stand (economic analysis #2, Table 7) to determine if the potential timber volume lost at rotation was worth the intial electric fencing costs. The grazed stand was grazed for 20 years, during which time AUM revenue was collected. The fenced stand was fenced for the initial 8 years, then had AUM revenue for the next 12 years while being grazed. PNV at 70 years was greatest on the grazed (non-fenced) stand, being $87.43/acre compared to -$5.82/acre on the fenced stand. The increased timber production did not pay for the fencing costs.

Scenario 2 considered the potential increase in timber volume by keeping cattle off of an area throughout the establishment period, (economic analysis #3 Table 7) compared to annual grazing all the time. Scenario 2 is similiar to scenario 1, except that the means of keeping cattle off of the pasture were not through electric fencing, so there was no initial cost. The cattle were kept off during the establishment period (in this case for 8 years). AUM revenue was not collected for this 8-year period. The PNV for the stand that kept grazing off for the initial 8-year period was greater than the PNV for the grazed stand. The difference was $18.09/acre. The lost revenue from grazing fees was worth the timber volume gained at rotation.

Scenario 3 considered the loss in grazing revenue by not grazing a stand compared to grazing the stand. Again the MBF gained at rotation was worth the lost revenue from grazing fees. The difference was $12.17/acre.

It is not feasible that grazing will ever be totally excluded from forested lands. Certain areas or pastures could be taken out of grazing use while the trees become established. The only problem with this is the fact that timber sales fall where they may and are not necessarily within one grazing pasture. Therefore, it would be highly unlikely that entire allotments would be turned down to grazing for several years while the trees become established.

The increased timber production did not pay for the initial fencing costs. This makes one question whether the fencing is worth it. Maybe it is not worth using electric fences to protect stands if the return in the future will not cover the up-front costs. Some things need to be considered. The difference in the volume at rotation age 70 between the grazed, fenced stand and the grazed, nonfenced stand was 2088 MBF (Table 5). This is a substantial amount of one resource being sacrificed for another. Do we really know the worth of this timber in the future? Secondly, the BLM is only using electric fences for 3 years and not 8 years. Therefore, the cost of electric fencing will not be as great as it was in scenario 1. The differences in volume would also not be as great after only 3 years of protection. It appears 3 years is just not enough time for seedling establishment on some sites. The BLM may want to consider electric fencing for longer than 3 years. The length of time should be site specific.

General Observations

While taking my tree measurements I observed considerable terminal bud nipping on the seedlings on the grazed plots. On the non-grazed plots there were very few terminal buds missing. According to Graham et al. (1991)

removal of the terminal bud of a seedling can reduce tree height growth. It appeared that the majority of the terminal buds had been nipped around 1984. There is a question as to why terminal buds were browsed this particular year and not others. Perhaps the height of the trees at that time contributed to their susceptibility to being nipped. Tree seedlings could have been at a particular height that was easy for cattle to eat indiscriminately as they were grazing. The time of nipping occurred after a rest year of the pasture. In 1984, the cows were let onto the pasture in June. According to Graham et al. (1991) seedlings are more susceptible to being browsed in the spring because the new growth is more palatable. The increase in standing dead litter on the site after the rest year may have caused the trees to be hidden within the forage.

The nipping could also have been done by wildlife in the early spring when the tree tips were exposed above the snow. However, I do not feel this happened because those trees within the exclosure were not nipped. Since the wildlife were not excluded from the fenced areas, I would suspect a more uniform amount of nipping between the exclosures and grazed areas. Because the nipping occurred outside of the exclosures, I feel there is a correlation between the cattle grazing and the nipping.

Even with a small number of plots the difference in infiltration rates between the grazed and non-grazed treatments was evident. When collecting samples for bulk density in the field, I felt there was a real difference between the control samples and the other two grazed areas. However, the statistical analysis showed no significant difference.

The enclosures are designed to keep cattle out exclusively. Wildlife, including small rodents, are still able to get into the enclosure, resulting in an uncontrolled source of variation. One problem may be that the enclosure has increased desirable forage and cover for rodents and other wildlife species, therefore leading to increased use, although this was not seen as a detrimental factor in the growth of the seedlings.

Conclusion

The real key to multiple-use is maintaining a delicate balance among the uses. There is a need to manage for both timber production and livestock grazing. According to the U. S. Forest Service (1980), cattle grazing on the Lolo National Forest is expected to increase 39 percent over the next 50 years. This could be similar on other western Montana lands (Bedunah and Willard 1987). If we are already observing conflicts in the two uses, at the present amount of grazing, what does the future hold with this expected increase in grazing?

The results of this study show that grazing can have an impact on the regeneration of lodgepole pine seedlings. The cumulative effects of grazing such as increase in mortality, increase in soil compaction, reduced infiltration rates and reduced litter cover, probably all contribute to the results observed in this study. One variable alone cannot account for the resulting reduced height growth. The combination of all the variables has affected the growth of the seedlings. Proper livestock management is the only way to reduce seedling damage.

Some of the differences between these two sites primarily resulting from the exclusion of grazing pressure are subtle at present. Eight years were not enough time to express a significant difference in compaction. According to Kingerly et al. (1987), compaction can last a long time into the life of a stand. It appears that many more years of grazing protection will be required for the pasture to recover completely.

According to Potter (1913) and Arrola (1978) damage that occurs to trees from livestock is due to poor management. Forest grazing must be controlled if it is to coexist with tree regeneration (Graham et al. 1991, Adams 1975). The first year of seedling growth is generally considered to be the most crucial period of seedling survival (Kingerly et al. 1987).

According to several sources it seems the height of the tree is the critical element in damage susceptability.

Graham et al. (1991) believe trees generally greater than 4 feet are less likely to have terminal bud removal by browsing, therefore allowing trees to maintain height growth. Adams (1975) also believes keeping cattle off the site until the seedlings are above browse height will reduce trampling damage. Cleary (1978) referenced 3 feet as establishment height.

To reduce tree damage, the timing of grazing with attention to forage abundance needs to be considered. Cattle should not be turned out to pasture on an exact date year after year. The growth of the forage should determine how early a pasture is opened up to grazing. If it is a late spring, then the cows should be held off the pasture while the forage has a chance to grow to a sufficient height enabling it to better withstand early summer grazing.

It seems seedlings have a better chance of survival if cattle are kept off for one to several years. The productivity of the site has much to do with the length of time needed to keep the cattle off. On the drier habitat types, such as are typical of the GRA, where tree growth is slow, it may be more than one to three years before the trees are able to withstand grazing.

If we are to manage for both timber production and livestock grazing, there need to be more stringent restraints on livestock grazing. If cattle could be kept off young plantations for five to ten years in the GRA, I believe the chances of survival and increase in the growth of trees would be enhanced. It is not practical to fence out the cows every time a new unit is harvested. Currently, the BLM is installing electric fences around those units most severely grazed; these fences will be maintained for the first three years after planting. Economically, the increased timber production does not pay for fencing materials and labor to install, monitor, and take down these fences every year.

Forest managers need to consider the far-reaching results of this study. After eight years there was a significant reduction in height growth. How long will this last over the life of the stand?

By definition multiple-use is not driven by the combination of uses that will give the greatest dollar return or the greatest unit output. All the various renewable surface resources are to be utilized in the combination that will best meet the needs of the American people with consideration being given to the relative values of the various resources. As managers we are making choices now that affect the value of our resources in the future. Are we really taking into consideration the relative values of these resources in the future and are the potential future outcomes of our management decisions the best for the American people?

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APPENDIX 1. Plant species found on the plot.

Agropyron caninum
Calamagrostis rubescens
Carex geyeri
Fragaria virginiana
Poa pratensis

Other forbs included:

Achillea millefolium
Antennaria rosea
Carduus nutans
Epilobium angustifolium
Lupinus spp.
Penstemon cyaneus
Rosea woodsii
Taraxacum officinale

APPENDIX 2. Example of a prognosis run for the grazed plot.

Year	Age	No of trees	Top Ht.Ft.	QMD	Merch Bd.Ft.	MAI Merch Cu. Ft.
1988	10	489	6	.2	0	.0
1998	20	445	24	2.1	0	.0
2008	30	438	38	4.1	146	1.8
2018	40	420	42	5.0	828	7.4
2028	50	392	47	5.8	2183	15.2
2038	60	363	51	6.6	4009	22.4
2048	70	336	56	7.3	6466	28.5
2058	80	312	61	8.0	8878	32.0
2068	90	289	65	8.7	11421	34.5
2078	100	267	69	9.3	13837	35.8
2088	110	246	72	9.9	16057	36.2
2098	120	226	76	10.5	17985	36.0
2108	130	206	79	11.0	19618	35.4
2118	140	189	81	11.6	21111	34.7
2128	150	172	84	12.1	22356	33.8

APPENDIX 3. Example of a prognosis run for the nongrazed plot.

Year	Age	No of trees	Top Ht.Ft.	QMD	Merch Bd. Ft.	MAI Merch Cu. Ft.
1988	10	588	7	.2	0	.0
1998	20	560	25	2.2	0	.0
2008	30	553	38	4.5	166	1.9
2018	40	543	43	5.3	1298	11.8
2028	50	498	47	6.0	3301	23.3
2038	60	458	52	6.8	5740	32.1
2048	70	421	56	7.5	8444	37.8
2058	80	387	61	8.1	11266	40.9
2068	90	355	65	8.7	14182	42.9
2078	100	325	68	9.3	16757	43.5
2088	110	297	72	9.9	19128	43.3
2098	120	270	75	10.4	21288	42.7
2108	130	246	78	11.0	23159	41.8
2118	140	223	82	11.5	24697	40.7
2128	150	202	85	12.1	26015	39.4