Surface Runoff and Erosion from Pine Grasslands of the Colorado Front Range[1]

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In the Colorado Front Range, intensity of land use must be gaged with special care to maintain acceptable watershed conditions. Sparse cover, unstable soils, and intense summer rains compound the difficulties characterizing multiple-use management. Water from the Front Range is acutely needed in the adjacent Great Plains, but its quality and regularity of flow have long since been impaired by heavy grazing and unrestricted timber cutting. While such activities can very likely be continued at a reduced scale, it is important to establish the limits dictated by good watershed management. A measure of these limits is being obtained from two small studies, described herein, which concern the influence of cattle grazing and timberland disturbance on runoff and erosion.

Characteristics of the Front Range

The Colorado Front Range is formed by the lower mountains and foothills between 6,000 and 9,000 feet elevation on the east flank of the Continental Divide. The area receives an average of 10 to 20 inches of precipitation annually, the bulk of which results from summer convectional storms. In general, the soil is relatively permeable, but it erodes easily under abuse. Recovery of protective vegetation is very slow, particularly on south slopes.

Vegetative cover consists largely of timber and grass. In a considerable portion of the area, bunchgrass is found in mixture with ponderosa pine and in open valleys, parks, and meadows. Grass cover varies in density, depending on the site, from relatively lush meadow lands to extremely thin and patchy cover on steep, unstable south slopes. The latter condition is common in the Front Range, especially on soil developed from Pikes Peak granite. Best grazing sites are the small, bunchgrass openings dotted through open-growing pine and in broader parklike areas, swales, and lower alluvial benches. Some grazing is provided throughout, except on north-facing slopes where denser mixtures of Douglas-fir and pine prevail.

Timber cutting for lumber, ties, mine props, poles, and posts has been going on for more than 75 years. Commercially valuable tree species are ponderosa and lodgepole pine, Douglas-fir, and some Engelmann spruce. Today, much of the forest cover is a residual of old growth passed over in earlier cuttings, mixed with patchy stands of second growth. Aspen is an important component in many young stands, particularly where fire has occurred.

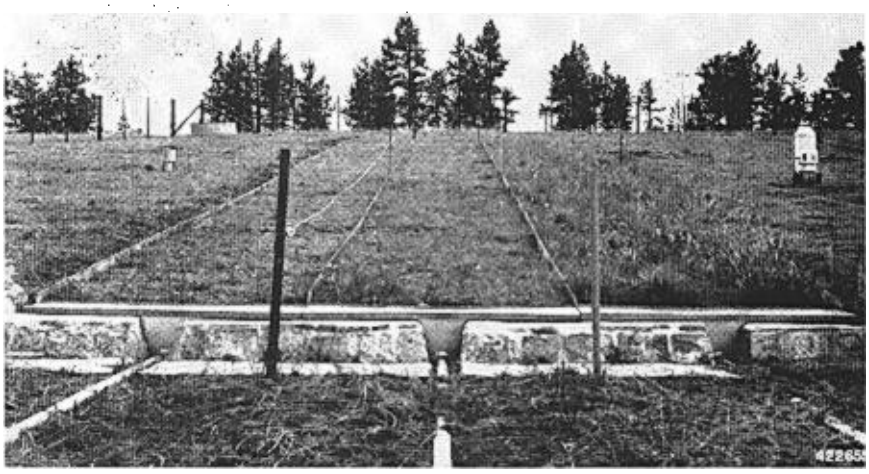

Fig. 1.—Bunchgrass plots (block A) after grazing by cattle. Grazing intensities from left to right (plots 1 to 3) are: heavy, moderate, and none. August 1942.
Photo U.S. Forest Service

The Experiment

The study is being conducted at Manitou Experimental Forest in the Pikes Peak region near Colorado Springs. Runoff and erosion have been measured from six 1/100-acre plots in the bunchgrass type since 1937. The object is to determine how two different degrees of grazing use affect amounts of surface water flow and the quantity of soil moved by erosion. Similar measurements were begun a year later in young ponderosa pine. In this case the object is to determine the runoff and erosion resulting from removal of the protective forest floor, as in a ground fire, and later from complete elimination of the tree cover.

The two study sites were chosen to avoid major differences other than cover. They are located about a half mile apart on an alluvial bench characterized by a relatively permeable soil. Both are on 17.5 percent slopes with north exposures, and at practically identical elevation—7,600 feet. A tension zone between trees and grass appears to exist locally at this elevation, characterized by fingers of

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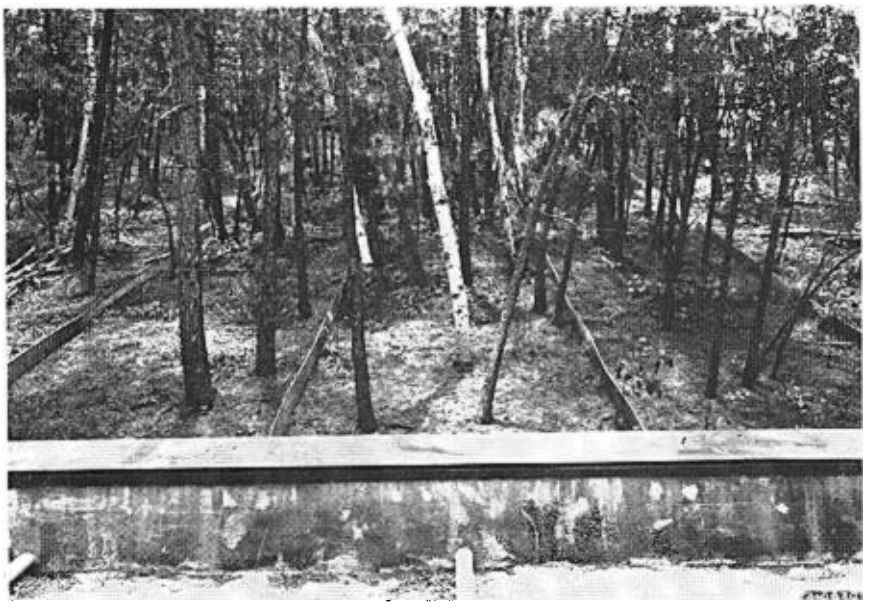

FIG. 2.—Ponderosa pine plots in block B after removal of litter. June 1941. *Photo U.S. Forest Service*

open grassland extending into the lower limits of tree growth and intermixing with the more open-grown timber stands. On the bunchgrass site, the principal species are Arizona fescue, mountain muhly, sedge, and associated miscellaneous grasses and weeds. The timbered site is covered with a dense stand of sapling ponderosa pine with a scattered mixture of aspen but virtually no grass.

At both installations, surface runoff and eroded material are measured from six plots numbered consecutively from east to west and divided into two blocks of three each. A distance of approximately 15 feet separates block A (plots 1, 2, and 3) from block B (plots 4, 5, and 6). Plot boundaries are sheet metal baffles measuring 6.6 x 69 feet, and enclosing a projected horizontal area of 1/100 acre. A catchment trough is fitted at the bottom of each plot from which the surface runoff and eroded material drain into a silt tank. Baffles are provided in the silt tank to help settle out the fine soil particles, and any overflow water thus cleared of sediment drains off into collector tanks.

Three basic types of data are recorded: precipitation and surface runoff in inches and eroded material in pounds per acre. Precipitation is measured in standard 8-inch-diameter cans and also in recording gages, which give additional information regarding time of occurrence and intensity of storms. Runoff is measured in both the silt tanks and collector tanks after each storm of sufficient size to produce overland flow and converted to inches depth over the plot delivering it. Eroded material is collected, air-dried, weighed, and expressed as pounds air-dry weight per acre. Both runoff and erosion have been used in this study to gage the effect of treatment.

Precipitation, measured at the bunchgrass site since 1937, has been somewhat variable, ranging in yearly totals from 7.6 inches in 1939 to 24.0 inches in 1947. The average for the period has been 15.6 inches. Approximately 10 inches, or about two-thirds of the yearly total, is in the form of rain. Winter precipitation is very light but comes entirely as snow. That which arrives in April, May, September, and October can be either snow or rain. July and August are the peak months. High-intensity storms producing runoff and erosion occur most frequently during this 2-month period, but also have been recorded during all months from May to September, inclusive. It is common for intensities to reach 3 inches per hour for 5-minute periods, but storms exceeding 4 inches per hour are a rare occurrence.

Supplementary records taken at the ponderosa pine plots substantiate the general trends found at the bunchgrass plots. Slightly more precipitation was received; an average yearly gross catch of 17.0 inches was recorded for the years 1939 through 1952. Net rainfall under the trees, measured by stationary gages at the four corners of the installation, showed an average catch of 13.8 inches or 81 percent of gross.

Both experimental areas were fenced and protected from livestock disturbance between time of installation and the application of the first treatments in 1941. A period of nonuse was necessary to detect inherent plot differences which might obscure the effects of applied treatments.

Bunchgrass Study.— Prior to installation of the bunchgrass plots in 1937, cattle had grazed the area during winter and spring months. Density studies, made on the plots from 1937 to 1941 while they were ungrazed, showed an average plant cover of 14.5 percent. Densities for individual years ranged from 8 percent to 23.6 percent, varying with annual precipitation.

During this calibration period, precipitation, runoff, and erosion were also measured and following the 1940 rainfall season, the data were analyzed to determine readiness for treatment. Statistical analysis indicated no real difference in runoff from individual plots within blocks, but real differences between the two blocks appeared to exist. Accordingly, identical sets of treatments were assigned to both blocks and randomized among plots within them.

The treatments, first applied in July and August of 1941, consisted of hand-clipping all the vegetation on four of the plots, leaving two unclipped as checks. Heavy grazing (2½ acres per cow-month) was simulated by hand-clipping and removing all vegetation down to an inch above the root crown on plot 1 (block A) and plot 6 (block B). Plots 2 and 4 were clipped leaving 2 inches to represent moderate grazing (4 acres per cow-month),

and no clipping was done on plots 3 and 5. Weight of the grass and weeds removed from the heavily clipped plots averaged 863 pounds per acre while moderate clipping produced 536 pounds per acre on an air-dry basis.

Following the 1941 season, it became apparent that the absence of trampling was a serious drawback in hand-clipping and that more usable and reliable results would be gained from actual grazing by cattle. Difficulties in obtaining the desired grazing intensities were foreseen, but very satisfactory control was achieved by using movable electric fence (Fig. 1). Grazing has been continued annually by using cattle for a duration of 3 to 5 days, once during each summer season.

Grazing intensity is judged by eye, based on standards derived from experience with controlled grazing in associated management studies.[3] Moderate grazing in the bunchgrass type results in the utilization of 30 to 40 percent of the herbage, whereas for heavy grazing, utilization is 60 to 75 percent. Stubble height of the key species—Arizona fescue and mountain muhly—provides a reliable indicator of utilization.

Ponderosa Pine Study.—After a calibration period ending in 1940, data from the ponderosa pine installation were subjected to an analysis similar to that in the bunchgrass study. Differences in the average runoff between the two blocks proved to be nonsignificant, indicating that a treatment could be assigned at random to either. This was done in June 1941; needle litter was removed from the ground surface of all three plots in block B, simulating the effects of a ground fire (Fig. 2). Material removed included all organic material not incorporated into the A_1 horizon. The treatment was not varied among the three plots because results would likely have been partially obscured by border influence, particularly as the result of interlacing tree crowns. In contrast to the bunchgrass study, where plots were the sampling unit, the evaluation of the ponderosa pine treatments is based on the differences between blocks A and B.

A second treatment was applied to block B in July 1952. This time the overstory of trees, as well as the litter which had accumulated since 1941, was removed. A border strip approximately 6 feet in width around the edges of the block was also cleared.

[3]Johnson, W. M. Effect of grazing intensity upon vegetation and cattle gains on ponderosa pine-bunch grass ranges of the Front Range of Colorado. U. S. Dept Agric Circ 929. 1953.

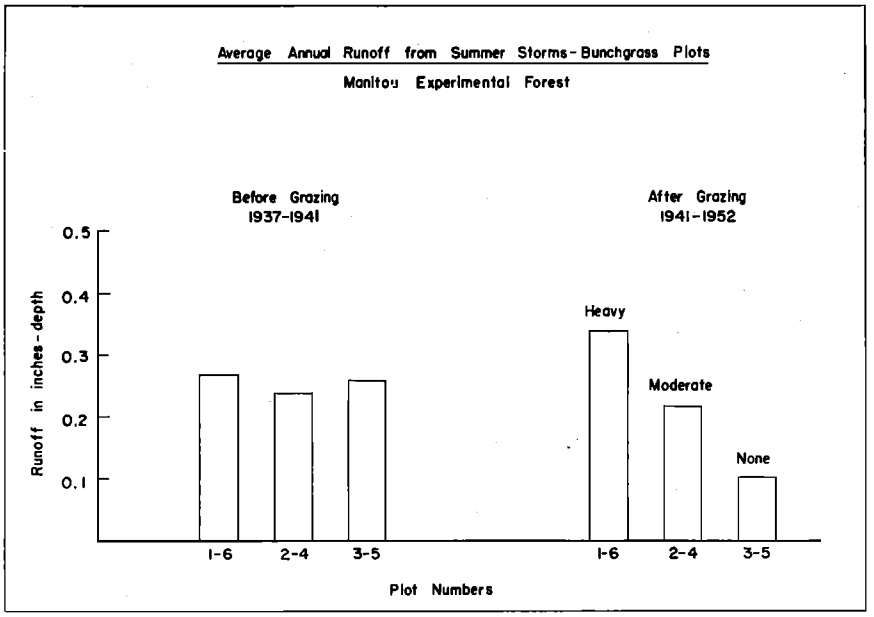

FIG. 3.—Average seasonal runoff in inches depth from summer storms before and after grazing treatment.

Results from the Bunchgrass Plots

An analysis of runoff on the untreated check plots for the entire 16 years shows that individual summer storms producing measurable surface runoff occur on the average of four to five times per year. In addition, a portion of the annual runoff is credited to spring snowmelt. Runoff from snowmelt is not strongly influenced by relative amounts of cover on the plots because drifting of the snow pack

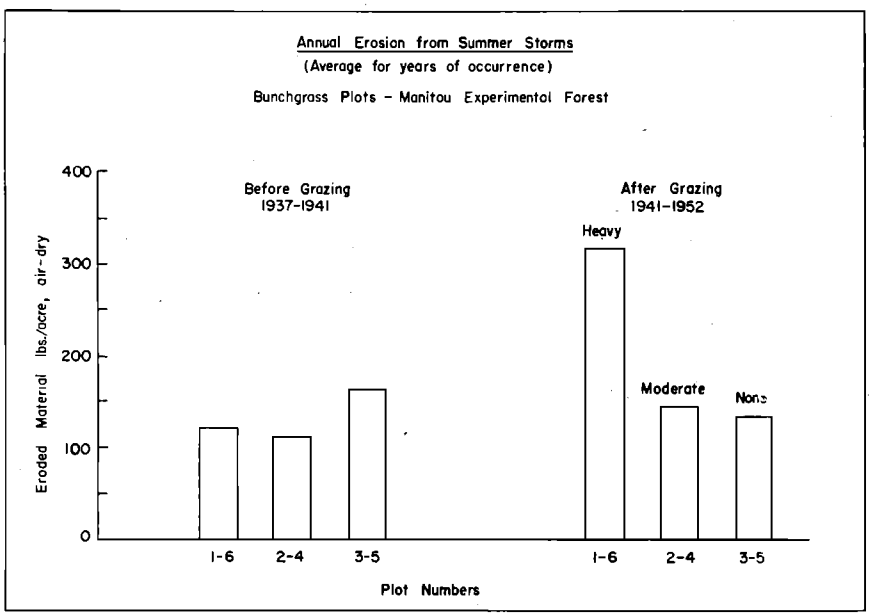

FIG. 4.—Erosion from summer rainfall, averaged for seasons of occurrence, before and after grazing treatment.

TABLE 1.—AVERAGE SURFACE RUNOFF PER SEASON IN INCHES DEPTH FROM PONDEROSA PINE PLOTS RESULTING FROM REMOVAL OF LITTER IN 1941 AND TREES AND LITTER IN 1952

Year and treatment	No.of storms causing runoff	Av. seasonal runoff in inches		Ratio Blocks B/A
		Block A	Block B	
Before treatment:		Untreated	Untreated	
1938	13	0.17	0.10	0.6
1939	13	0.05	0.04	0.8
1940	3	0.06	0.05	0.8
After removal of litter:		Untreated	Treated	
1941	14	0.17	1.17	6.9
1942	9	0.12	0.43	3.6
1943	6	0.06	0.20	3.3
1944	8	0.31	0.65	2.1
1945	12	0.59	1.05	1.8
1946	6	0.10	0.11	1.1
1947	13	0.23	0.36	1.6
1948	6	0.07	0.06	0.9
1949	10	0.10	0.07	0.7
1950	3	0.02	0.02	1.0
1951	1	Trace	Trace	----
After removal of trees & litter:		Untreated	Treated	
1952	3	0.03	0.49	16.3

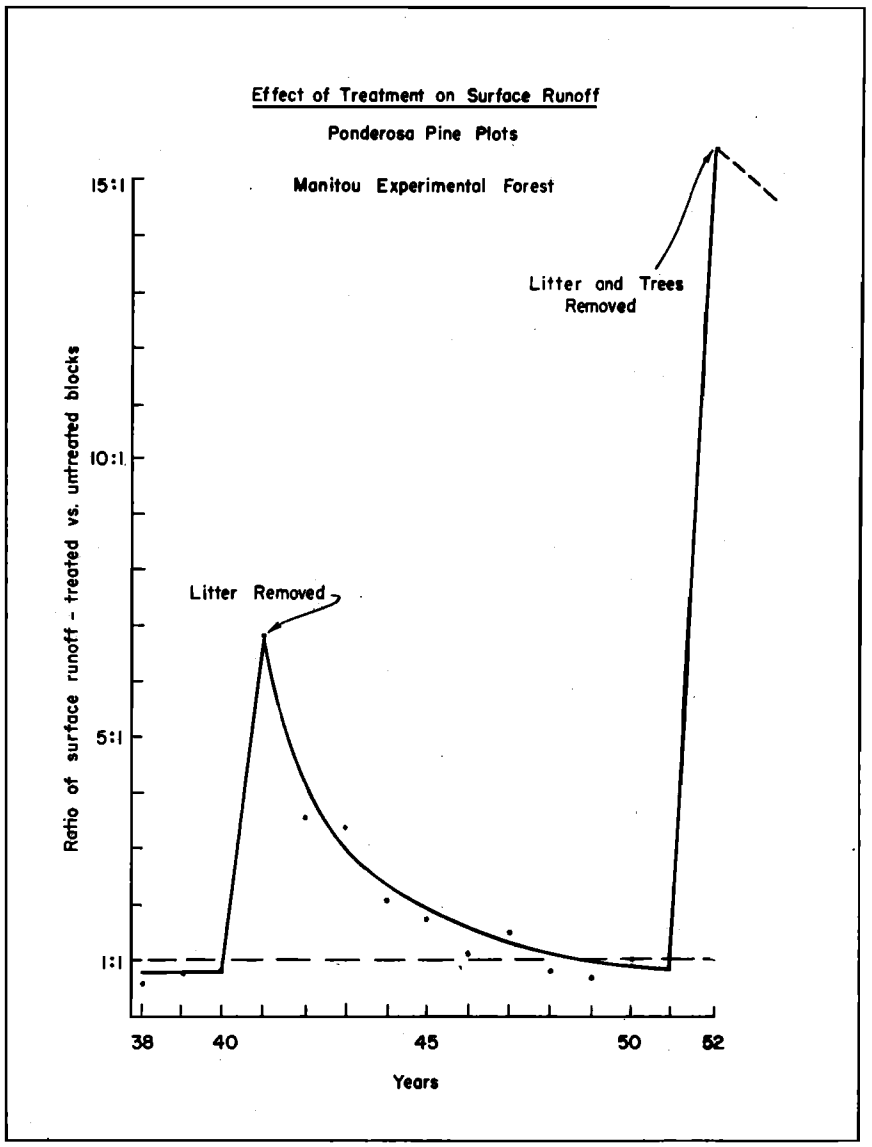

FIG. 5—Plotted ratios showing relation of surface runoff from treated and untreated blocks.

tends to obscure the results. On the other hand, runoff occurring during the months of June through September results from individual rain storms and responds to variations in cover treatment.

The influence of grazing on runoff during these four summer months is shown graphically in Figure 3. In the period before grazing, the average runoff varied from .24 to .27 inch. These plot differences were not statistically significant but soon became so following treatment as average amounts of runoff began to reflect variations in grazing intensity. In twelve years, the heavily grazed plots have yielded an average of .34 inch of runoff per season; moderately grazed, .22 inch; and nongrazed, .11 inch per season.

Grazing has also caused an increase in erosion, but not in direct proportion to intensity of use. During the calibration period, while there was no grazing by livestock, erosion occurred as the result of four separate storms occurring in three summer seasons. Average annual erosion for seasons of occurrence, as shown in Figure 4, ranged from 111 pounds per acre to 163 pounds per acre. Following the initiation of grazing treatment, 13 storms were of sufficient size to produce erosion. Average annual depositions for seasons of occurrence were 134, 145, and 316 pounds per acre, respectively, for none, moderate, and heavy grazing A significant increase in erosion has resulted from heavy grazing while erosion from moderately grazed plots remains near normal In 8 of the 16 years of study, there has been no measurable erosion Months of greatest soil movement, as might be expected, were July and August. It was noted, particularly in 1938, 1944, and 1945, that erosion tended to occur during periods when large storms follow one another at short intervals.

Results from Ponderosa Pine Plots

Both treatments in the ponderosa pine plots produced striking increases in runoff and erosion Prior

to disturbance, no erosion occurred through three summer seasons. In the summer of 1941 following removal of needle litter in June, three storms were of sufficient size to cause soil movement. The three plots in the treated block yielded an average of 76.1 pounds of air-dry eroded material, almost 4 tons per acre, while the untreated block yielded none. During the period June through September, in the years 1941 to 1945 inclusive, erosion resulted from 14 storms, but at a steadily decreasing rate. In these five years, the amount of air-dry eroded material derived from the treated plots decreased from 25.4 to 1.0 pounds per storm. No erosion occurred from 1946 through 1952, and it was concluded that the effect of litter removal in 1941 had been virtually eliminated by the gradual return of a ground cover.

The second treatment—removal of trees as well as the litter cover—was applied to the same block in July 1952. Again, erosion resulted from the next heavy rains while the undisturbed block produced none. Three storms during the remainder of the summer season produced an average of 89.5 pounds of air-dry eroded material per plot —more than 4 tons per acre.

The response in surface runoff was equally impressive. Influence of litter and tree removal is depicted by the ratios of runoff from treated and untreated blocks in Table 1 and Figure 5. Prior to disturbance, no significant differences existed. During the 1941 summer period following removal of the litter layer, runoff produced from the treated block was 6.9 times that of the untreated. In subsequent years, runoff from the two blocks returned to an approximate equilibrium. Following the second treatment in July 1952, a differential in runoff between blocks occurred again, with the ratio this time reaching 16.3 to 1. Since tree cover was also removed in this instance, surface runoff is expected to remain at an abnormal level for a considerably longer period.

Discussion

These two studies were designed to examine the results of grazing and forest disturbances on runoff and erosion. The objective has been to establish limits on the intensity of such uses in Front Range watersheds.

From the bunchgrass study, it is possible to develop some standards for management of Front Range grazing lands. Heavy grazing (2½ acres per cow-month) appears to go beyond the limits allowable in good watershed management practice. Erosion has begun to accelerate above a rate which can be regarded as normal. In addition, surface runoff has increased and less water enters the soil reservoir where it could be available for plant growth or subsurface supply for regulated streamflow. Erosion does not appear to be substantially increased as a result of moderate grazing (4 acres per cow-month) in spite of some additions to surface flow. In practice, it appears that moderate grazing on relatively gentle slopes is permissible if the increased loss of runoff water does not cause critical shortages of moisture for plant development.

These observations have been partially substantiated by a large-scale pasture study being conducted in the same general area.[4] Here, similar grass cover has been subjected to three rates of grazing—light, moderate, and heavy—since 1942. Moderate grazing has proved to be the most efficient from the standpoint of economic returns in beef production. Furthermore, moderately grazed pastures are holding their own in annual forage production, plant vigor, and density.

Results of treatment in the ponderosa pine plots show the tenuous protection supplied by forest cover in Front Range watersheds. Complete removal of litter, as may occur from ground fire, brings immediate response in terms of flashier runoff and greatly increased erosion. Clearcutting accompanied by removal of the protective litter simply increases the effect by removing the sheltering overstory. This suggests that timber, even on moderate slopes in the Front Range, should be lightly cut by a single-tree system of selection and harvested with great care. Fire and other forms of widespread ground disturbance should be eliminated entirely.

[4]Op. cit.