INFLUENCE OF FIRE ON CURLLEAF MOUNTAIN-MAHOGANY IN THE INTERMOUNTAIN WEST

G. Gruell, S. Bunting, and L. Neuenschwander

ABSTRACT: Comprehensive sampling of curlleaf mountain-mahogany (*Cercocarpus ledifolius*) on 41 sites in five States allowed an assessment of postfire population dynamics, differences in regeneration patterns, and critical events in stand regeneration. Historical accounts of fire, fire history studies, and early photographs provided historical perspective and contributed to interpretations.

The combined quantitative and historical evidence strongly suggests that before European settlement, fire significantly influenced mahogany in the Northern Rockies by restricting its development. A reduction of fire periodicity and size following Euroamerican settlement apparently allowed mahogany seedlings to regenerate far in excess of former levels. The absence of fire for long periods has resulted in great variation in structure of mahogany stands. Many stands are in a declining condition because the absence of fire has allowed them to reach advanced stages of succession. In some areas, closure of mahogany crowns, excessive litter accumulation, and competition from other vegetation are inhibiting regeneration. In other areas, young vigorous mahogany predominate. These wide differences in stand conditions suggest different management strategies. Many mahogany communities would respond positively to fire, whereas others would not. Management implications are given.

INTRODUCTION

Curlleaf mountain-mahogany, hereafter referred to as mahogany, is an important forage and cover plant on many game ranges in the Northern Rocky Mountains. Various questions about proper management of mahogany ecosystems have surfaced in recent years because of incomplete knowledge of regeneration potential. A primary question involves the role of fire. Mahogany grows in regions where fire has been a common ecological disturbance; however, there has been little research on the effects of fire on long-term mahogany production. To determine whether prescribed fire has a place in future management strategies, it is important to understand the past role of fire in representative mahogany types.

To understand the role of fire in managing mahogany, we conducted comprehensive sampling of mahogany stands on a wide range of sites in Idaho, Montana, and adjacent portions of Nevada, Utah, and Wyoming that were representative of stands in the Intermountain West. In this region mahogany is present in over 20 forested or nonforested habitat types (Henderson and others unpubl.; Hironaka and others 1983; Mueggler and Stewart 1980; Pfister and others 1977; Steele and others 1981). In the forested communities, mahogany may be potential climax or seral, but in the nonforested communities where it occurs, mahogany is potential climax. We assessed the postfire population dynamics, differences in regeneration patterns, and critical events in mahogany regeneration.

Quantitative data gathered at 41 locations (fig. 1) were complemented by fire history studies, fire occurrence records, historical literature, and comparison of historical photographs with recent photographs taken in mahogany types. Study findings allowed us to make implications for fire management, including use of prescribed fire in mahogany types.

PAST RESEARCH

Mahogany is widely distributed throughout semiarid regions of the Intermountain West from eastern California to southwestern Montana and north-entral Wyoming (Little 1976). Growth forms vary rom low shrubs to plants that may reach 30 ft 9 m) in height on productive sites. Older plants ıy exceed 300 years in age.

hogany is a highly palatable forage for mule aeer (*Odocoileus hemionus*) (Smith 1952), and it is a preferred browse (Kufeld and others 1973). Stands in many regions have grown above the reach of big game and are no longer a source of forage. These stands are, however, a valuable seed source and important hiding cover (Dealy 1971). Heavy winter utilization has been widely reported (Deitz

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G. Gruell is a research wildlife biologist with the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Missoula, Mont.

S. Bunting and L. Neuenschwander are associate professor of Range Resources and associate professor of Forest Resources, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow, Idaho.

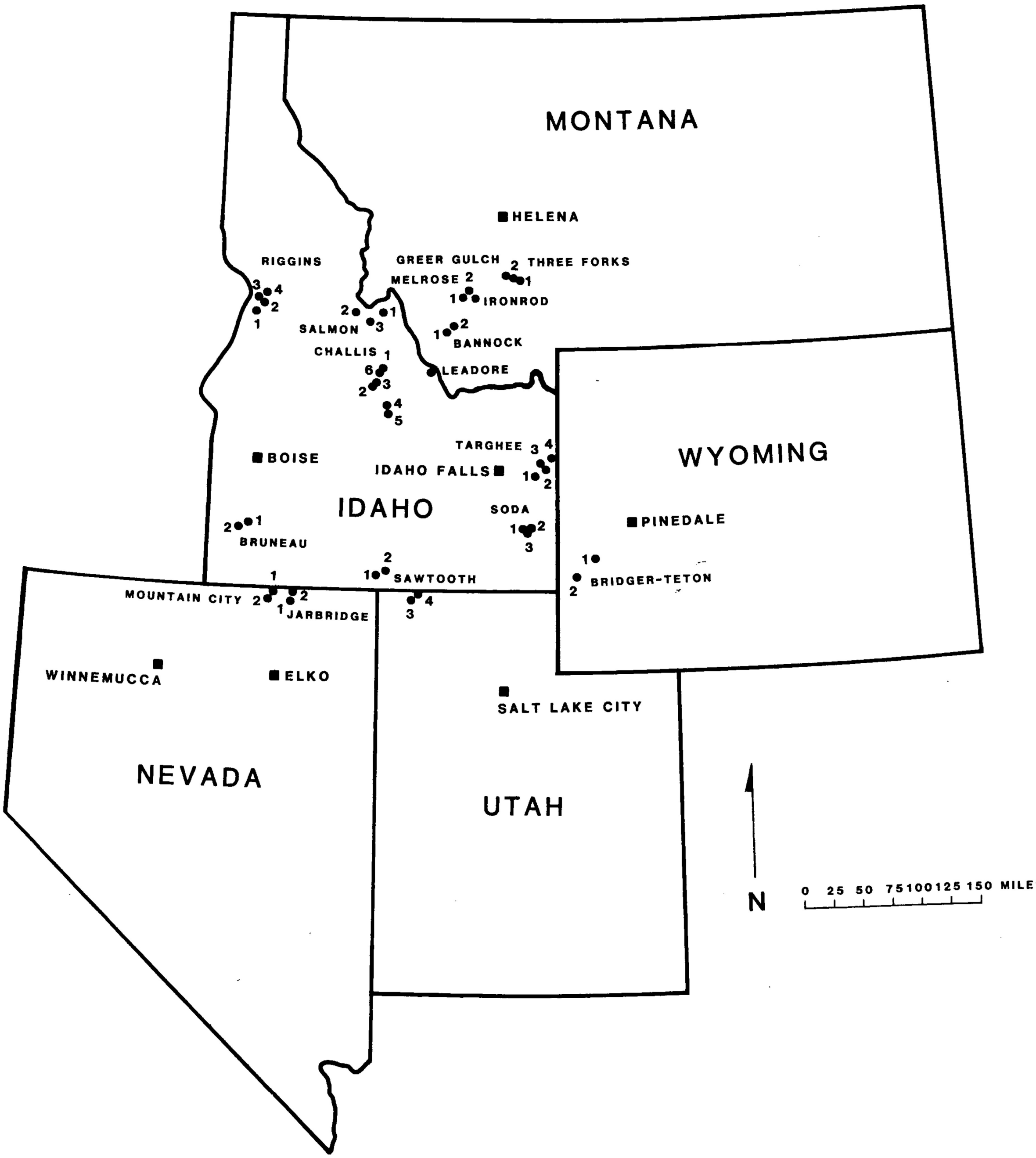

Figure 1.--Location of the 41 mahogany sampling sites. See table 1 for description of site characteristics.

and Nagy 1976; Claar 1973; Richens 1967). In southwestern Montana heavy utilization by ungulates was believed to have been responsible for a deterioration of mahogany stands (South 1957). In contrast, Claar (1973) concluded that decades of heavy browsing by big game in central Idaho had not caused mahogany to deteriorate. Plant losses were compensated by establishment of seedlings. Mackie (1973) concluded that high-level ungulate use over a 5- to 23-year period on two Montana winter ranges had not been responsible for decreased plant populations, browse production, or both.

Researchers working on the ecology of mahogany have postulated fire effects. Dealy (1975) in eastern Oregon and Scheldt (1969) in Idaho reported that the existence of mahogany was related to the fire protection afforded by rocky sites. They also concluded that most mahogany stands on deep soils were less than 100 years old and that tree age seemed to correlate closely to the advent of fire control and use of forage by livestock that otherwise would have fueled fires.

Montana studies that included age determination of mahogany implicitly showed the relationship of age to absence of fire. Duncan (1975) found an average age of 22 years (range 5 to 85 years) for 210 randomly chosen plants in 21 southwestern Montana stands. Lonner (1972) reports the average age of 62 mahogany plants collected on Montana big game winter ranges was 37 years (range 2 to 130 years).

The beneficial influence of fire has also been reported. Claar (1973) concluded that fire seemed to be essential to set succession back and maintain seral mahogany on drier sites associated with adjacent Douglas-fir/ninebark habitat types.

Mahogany, a weak sprouter (Wright and others 1979), is highly susceptible to fire, which results in heavy mortality. It sprouts from undamaged auxiliary buds on the stems or from adventitious buds beneath the bark. Unlike many shrubs, it has a thick bark that allows it to survive light fires when mature and does not sprout from a basal caudex or rhizomes. Sprouting may occur after light burning, but reproduction almost entirely depends on seedling establishment.

Mahogany has successfully regenerated from seed after stands were cut. Dealy (1975) reported that young stands in two Oregon localities developed following intensive cutting for firewood during the late 1800's and early 1900's. Experimental cutting and bulldozing of mahogany on the Targhee and Cache National Forests during the 1960's resulted in germination of many seedlings (Phillips 1970). Seedling germination was heavy on mineral soil that was bared of litter and plant competition. High seedling mortality may occur, however, apparently the result of summer drought.

Marked reductions in mahogany forage availability have led to attempts to increase productivity by top pruning (Austin and Urness 1980; Ormiston 1978; Phillips 1970; Thompson 1970). These experiments indicated that production can be temporarily increased in the browsing zone by pruning plants above a point where there are numerous live twigs. Where large treelike mahogany predominates, however, the scarcity of twigs within the browsing zone precludes pruning as a practical treatment measure. No sprouting from adventitious buds below the cut was reported. Attempts to improve forage availability by pushing over younger mahoganies with a bulldozer have succeeded (Phillips 1970); however, older mahogany usually die when pushed over (Dealy 1971).

HISTORICAL PERSPECTIVE

Examination of historical accounts showed that wildfire was a major perturbation in semiarid regions of the Interior West from at least 1776 to 1900 (Gruell in press). Many of these fires were set by Indians (Gruell in press). Some of these accounts described the beneficial effects of fire in stimulating grasses and suppressing woody plants.

Study of the scars on trees indicates that before Euroamerican settlement fire intervals averaged from 5 to 20 years in ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) forests in the Bitterroot Valley of western Montana (Arno and Peterson 1983). Scar data from higher and cooler Douglas-fir/sagebrush (*Artemisia tridentata* subsp. *vaseyana*) ecotones in Yellowstone Park and southwestern Montana indicated that fire intervals were 20 to 40 years (Houston 1973; Arno and Gruell 1983). Fire-scar evidence in Ephraim Canyon, Utah, indicated an average fire interval of from 7 to 10 years in aspen (*Populus tremuloides*) during the period 1770 to 1875 (Baker 1925). Working in southwestern Idaho, Burkhardt and Tisdale (1976) reported that presettlement fire intervals were about 11 years in sagebrush-grass/western juniper (*Juniperus occidentalis*) ecotones.

An examination of early photographs provided insights about the historical appearance of mahogany stands (Gruell 1983). Figures 2 and 3 are some of the earliest scenes found within the study area. These 1868 and circa 1871 scenes show mahogany confined to protected rocky sites or thin soils where fire was infrequent. Recent field inspection revealed evidence of pre-1868 fire within the scene at figure 2. On other sites (fig. 3) some mahogany plants had apparently resisted light surface fires but were killed by a more severe fire before 1871. Figure 4 shows an example of mahogany regeneration following cutting.

METHODS

Mahogany density varied greatly among communities. To provide consistent sampling among study sites, stands had to meet the following criteria to be selected:

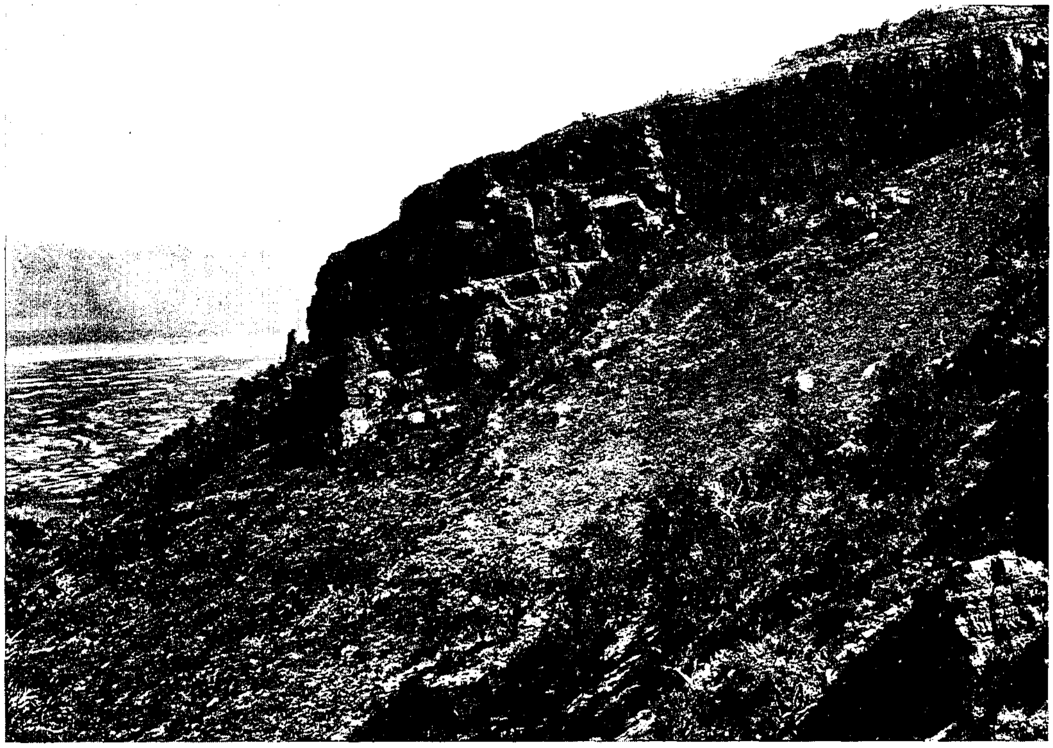

Figure 2a.--Looking east-southeast down canyon toward Ruby Marsh from a point about 1.5 miles above Flyn and Hager Spring (elevation 7,500 ft)(1868). Note the scattered distribution of living and dead fire-killed mountain-mahogany in lower left quarter of photo.

Photograph by Timothy O'Sullivan. Courtesy of U.S. Geological Survey, Denver, Colo.

Figure 2b.--Photo taken July 31, 1982. The absence of fire since the 1840's or earlier has allowed mountain-mahogany and other woody vegetation to increase. Charred material in mahoganies verified loss of mahogany to fire before 1868.

Photograph by G. E. Gruell.

Figure 3a.--Looking north from a point adjacent to county road in southeast quarter of City of Rocks, Idaho (elevation 6,400 ft). Woody plants include singleleaf pinyon pine (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), and mountain-mahogany. Note the dead branches in foreground and absence of large woody plants in the smaller openings between rocks.

Photograph by Timothy O'Sullivan. Courtesy of U.S. Geological Survey, Denver, Colo.

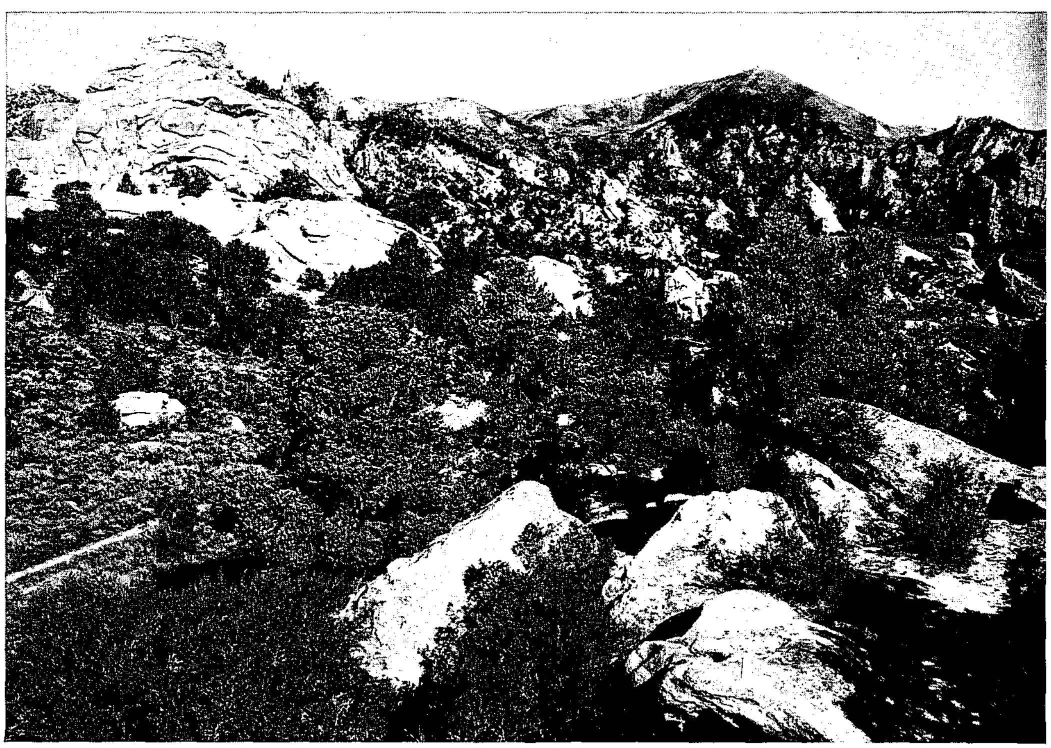

Figure 3b.--Photo taken August 20, 1983. Absence of fire over 100 years has allowed woody plants to proliferate. Sagebrush has increased in opening at left and on flats at right. Mountain-mahogany mixed with pinyon pine and juniper have invaded the deeper soils in openings. Sometime after 1872, a fire swept the upper slopes on distant mountain on right.

Photograph by G. E. Gruell.

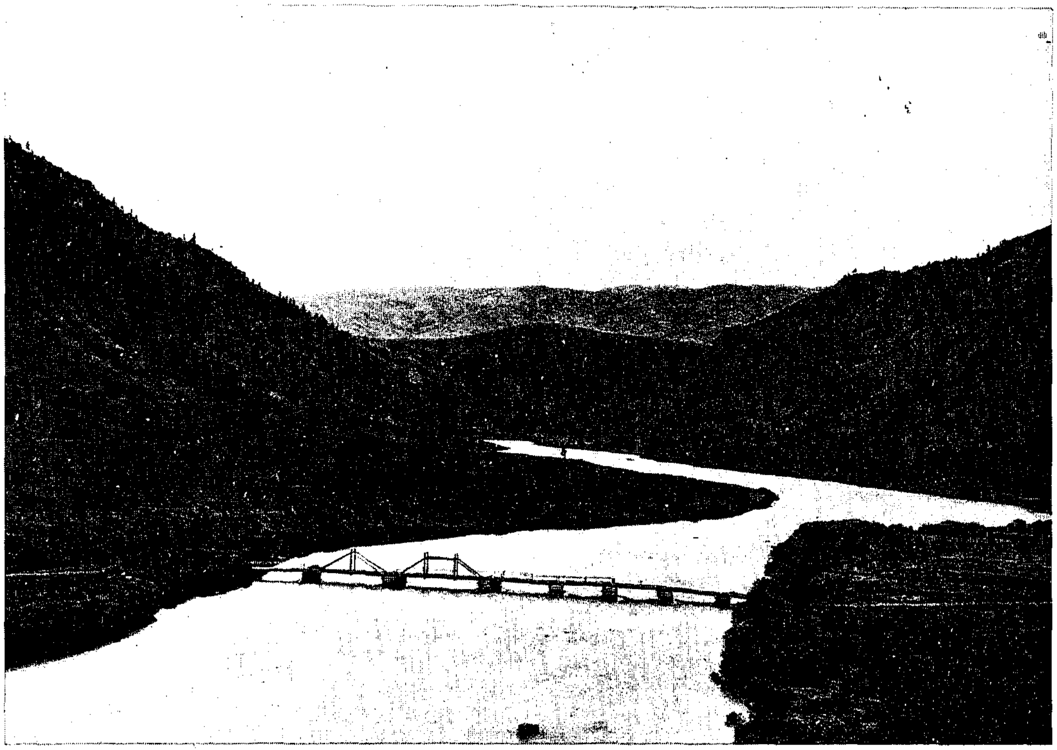

Figure 4a.--Photo taken in 1871. Camera faces south-southeast from position on west bank of Madison River near present day Highway 84 crossing at Beartrap Recreation area (elevation 8,500 ft). Distant slopes support Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), Rocky Mountain juniper (*Juniperus scopulorum*), and mountain-mahogany.

Photograph by W. H. Jackson. Courtesy of U.S. Geological Survey, Denver, Colo.

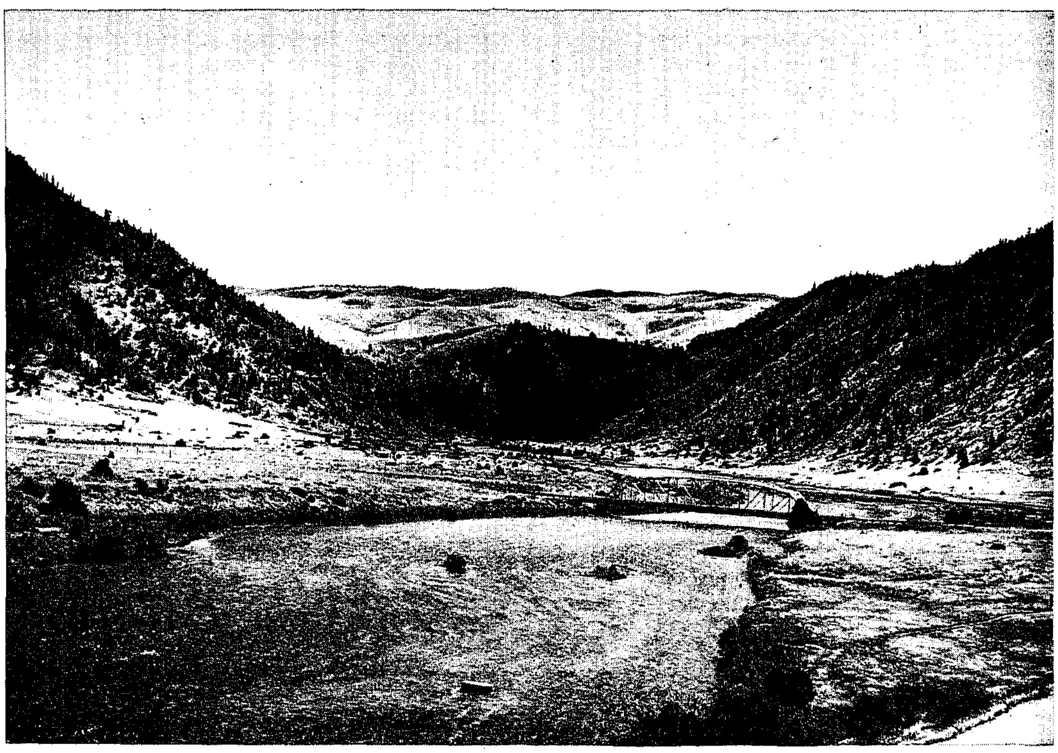

Figure 4b.--Photo taken August 31, 1982. Douglas-fir was cut after original photo was taken. Fire-scarred stumps indicate fires had occurred every few decades before settlement. Removal of conifers and absence of fire allowed great increase in mahogany. Note distant slopes above bridge.

Photograph by G. E. Gruell.

1. Minimum density of 10 mature mahogany per acre (25 per hectare) (in the case of recently burned stands the preburn density had to exceed 10 plants per acre).

2. A minimum stand diameter of 164 ft (50 m).

3. Reasonable accessibility.

Stands meeting these criteria were identified during a prestudy reconnaissance. A random sample of these stands was then selected using a random number table.

Fire-scarred cross sections were collected from all stands in which scarred mahogany occurred. These data aided in interpreting the role of fire in sampled communities. Stands burned on a known date or with a known history of other types of disturbance such as logging were chosen for sampling.

In each stand, the center points for four azimuths were randomly determined. Along each azimuth, a 13- by 66-ft (4- by 20-m) belt transect was used to measure the density of mahogany. The stem diameter near ground level was recorded. Where stands were dense, the belt transect was reduced to a width of 3.28 ft (1 m).

The age-diameter relationship for each stand was determined by randomly selecting 8 to 15 mahogany plants representing the size classes present. Height, maximum crown spread, and basal diameter of the plant were recorded, and a cross-section at the base was then collected. In the laboratory, cross-sections were sanded and annual growth rings counted with the use of a 10- to 50-power dissecting microscope. Ring counts were not considered precise because of the likelihood of false or missing rings. Data from 307 cross-sections were used in regression analysis to develop a model to estimate the age of mahogany.

Litter depth and seedling density were measured within a 3.28- by 66-ft (1- by 20-m) belt transect along each of the azimuths.

Cover of trees, mahogany, shrubs, perennial grasses, perennial forbs, annuals, and bare ground were estimated on circular plots with a radius of 3.28 ft (1 m). Five plots were located along each of the random azimuths at 16 ft (5 m) intervals. Mahogany canopy cover was also estimated by line intercept along the transect lines.

Additional site data collected on each stand included elevation, aspect, slope, vegetational competition, habitat type, surface soil texture, parent material, and time since last fire if known.

RESULTS

Age Determination

Results of the regression analysis indicated that basal diameter was the best single variable to estimate mahogany age.

The regression equation is as follows:

$$Y = 11.66 + 5.90X$$

where:

Y = age (number of growth rings) of mahogany (years).

X = basal diameter (centimeters).

The coefficient of determination (r^2) for this equation was 0.75. Additional variables were included, and the sample was partitioned by such factors as habitat type and aspect in further regression analysis; however, the r^2 improved only slightly. Consequently, the simpler regression equation was used to predict age.

Stand Age And Structure

Forty-one mahogany stands in 13 habitat types were sampled (table 1). Stands were grouped into five categories by potential climax association and stand structure as follows:

Category 1. Mahogany is the potential climax. Stands are comprised of all age classes dating from pre-1830.

Category 2. Mahogany is the potential climax. Stands are almost entirely comprised of post-1900 age classes.

Category 3. Mahogany is seral. Conifers are present but scattered and not yet competitive.

Category 4. Mahogany is seral and is being replaced by conifers.

Category 5. Mahogany communities arising after post-1900 disturbances.

Analysis of stand age (categories 1 to 4) showed a great increase in mahogany density during the past 150 years (table 2). After 1940, the rate of increase accelerated (fig. 5). This rate is inflated because 11 of the 36 stands sampled were almost entirely comprised of young plants. The most noteworthy aspect of the data in figure 5 is that only 1 percent of the mahoganies in 1970 stands was present before 1830. We concluded that the 1980's sampling provided a reasonably accurate picture of the pre-1830 stand because there was little evidence of plant losses after 1830.

Separate analysis of the five categories revealed differences in stand development. Stand data were graphed to display changes in density over time.

Category 1 (All Aged Potential Climax Mahogany)

Historically, category 1 stands were protected from fire by rock outcrops or by discontinuous fuels. In 1855, some stands were lightly stocked (13 stems/acre; 31/ha), and a few stands were well stocked (203 to 329 stems/acre; 501 to 813/ha). Most stands regenerated after 1855. The rate of regeneration seems to have been strongly influenced by canopy coverage and competition from other plants. Closed canopy stands, such as Mountain City 2 (fig. 6), which

Table 1.--Characteristics of potential climax and seral mahogany stands in the five State study area

Stand	Habitat type	Parent material[1]	Aspect	Elevation	Slope	Average Cele cover	Evidence of past fires[2]
				---Feet---	-----Percent-----		
Category 1 (all aged potential climax mahogany)							
Riggins 1	Cele/Agsp	L	SSE	3,100	70	20	P
Riggins 2	Cele/Agsp	L	W	2,300	55	14	C
Riggins 4	Cele/Agsp	B	SW	2,200	32	31	C
Challis 3	Cele/Agsp	L	SSW	7,000	33	18	P
Bruneau 1	Artrva/Syor/Feid	B	SE	6,000	5	50	P
Bruneau 2	Artrva/Syor/Feid	B	N	6,100	8	15	P
Mountain City 2	Artva/Syor/Feid	B	WNW	6,500	7	49	N
Jarbridge 2[3]	Cele/Syor/Feid	R	W	7,600	46	69	P
Sawtooth 1	Artva/Syor/Feid	B	N	7,200	8	50	N
Bridger-Teton 1	Cele/Artva/Feid	S	W	7,800	35	29	P
Bridger-Teton 2	Cele/Artva/Feid	S	W	7,500	33	18	P
Ironrod 1	Cele/Agsp	G	W	6,200	26	38	N
Category 2 (young stands; mahogany potential climax)							
Riggins 3	Cele/Agsp	L	S	3,200	33	1	P
Challis 4	Artrva/Syor/Feid	L	ENE	7,500	47	55	P
Soda 2	Juos/Cele/Agsp	L	E	6,200	63	4	P
Bannock 1	Cele/Agsp	G	SW	6,200	47	23	N
Bannock 2	Pifl/Cele/Agsp	G	WSW	7,000	43	30	C
Melrose 1	Cele/Agsp	L	SW	6,300	32	11	N
Melrose 2	Cele/Agsp	L	WSW	6,300	18	16	N
Threeforks 1	Pifl/Cele/Agsp	L	NW	4,800	23	45	N
Threeforks 2	Pifl/Cele/Agsp	L	NW	4,800	25	25	N
Category 3 (seral mahogany with scattered conifers)							
Salmon 1	Pipo/Feid	G	SW	4,500	62	18	P
Salmon 3	Psme/Cele	G/L	S	4,600	62	21	P
Leadore	Pifl/Cele	L	W	7,500	42	24	P
Challis 5	Psme/Cele	L	NE	7,500	50	57	P
Jarbridge 1	Abla[5]	G	W	8,200	58	12	P
Sawtooth 2	Abla[5]	B	NW	7,100	14	59	N
Sawtooth 3	Pimo/Artrva/Agsp[5]	L	SE	8,000	26	31	N
Soda 1	Juos/Cele/Agsp[5]	L	S	6,200	39	40	N
Targhee 3	Psme/Syor	L	SW	6,300	51	19	P
Targhee 4	Pifl/Syor	L	SSE	7,200	52	57	P

See footnote at end of table.

continued

Table 1.--(continued)

Stand	Habitat type	Parent material[1]	Aspect	Elevation	Slope	Average Cele cover	Evidence of past fires[2]
				---Feet---	-----Percent-----		
Category 4 (seral mahogany with competitive conifers)							
Sawtooth 4	Pimo/Artrva/Agsp[5]	L	S	7,500	35	8	N
Challis 1	Psme/Cele	L	N	8,000	5	34	N
Targhee 2	Psme/Syor	L	S	6,500	50	20	P
Greer Gulch	Psme/Cele	G	WSW	5,000	38	28	N
Category 5 (disturbed mahogany stands)							
Mtn. City 1	Artrva/Syor/Feid	B	SW	6,500	20	6	Burned October 1975
Targhee 1	Psme/Syor	L	W	6,300	64	1	Burned 1966. Seeded to grass after fire
Challis 2	Cele/Agsp	L	SSW	7,000	35	1	Burned 1934. Very slow regeneration.
Salmon 2	Psme/Cele	G	W	4,800	64	37	Last burned in 1919.
Challis 6	Psme/Cele	L	NE	8,000	5	2	Timber harvested. Slash was piled and burned.
Soda 3[4]	Juos/Cele/Agsp[5]	L	SE	6,200	46	20	Juniper had been cut for posts.

[1]B = basaltic; G = granitic; L = limestone; R = ryolite; S = sandstone.
[2]P = fire evidence present; C = circumstantial evidence present; N = no evidence of past fires.
[3]Sapling sized Abla establishing in former Cele stand.
[4]Post-cutting estimated to have occurred 30 to 50 years ago.
[5]This vegetation has not been adequately habitat typed in this region, consequently this designation has been tentatively applied by the authors.

Table 2.--Summary of number mahogany stems per acre (stand density) by period of establishment for all stands except disturbance stands in category 5

	Period of establishment							
	Before 1830	1831-1855	1856-1900	1901-1920	1901-1940	1921-1950	1941-1960	1961 1970
Statistic[1]								
Median	0	26	26	51	76	51	51	51
High	89	253	177	405	759	2277	3138	4200
Low	0	0	0	0	0	0	0	0

[1]Median data were used in place of mean because extraordinary high values reflective of young stands in category 2 tended to skew the mean unreastically high as an (average).

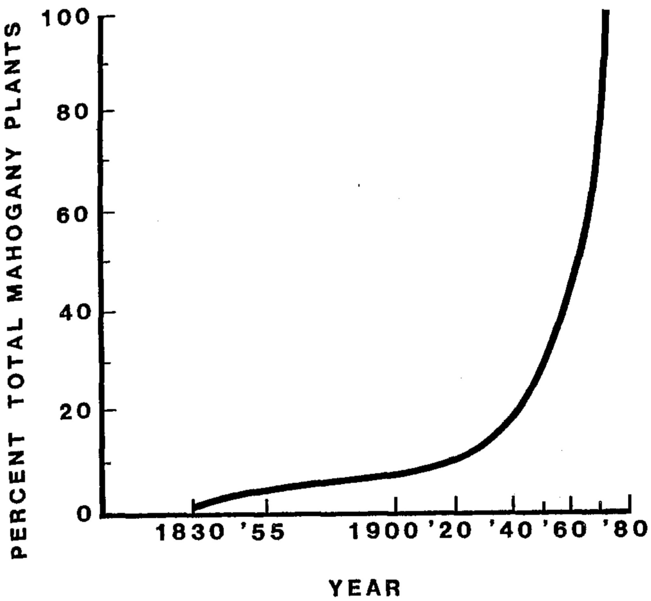

Figure 5.--Mountain mahogany densities in category 1-4 stands from 1830 to 1970. Percentage values for dates of record were calculated by dividing the number of stems per record date by the total number of stems in 1970. After 1830 percentage values are accumulative.

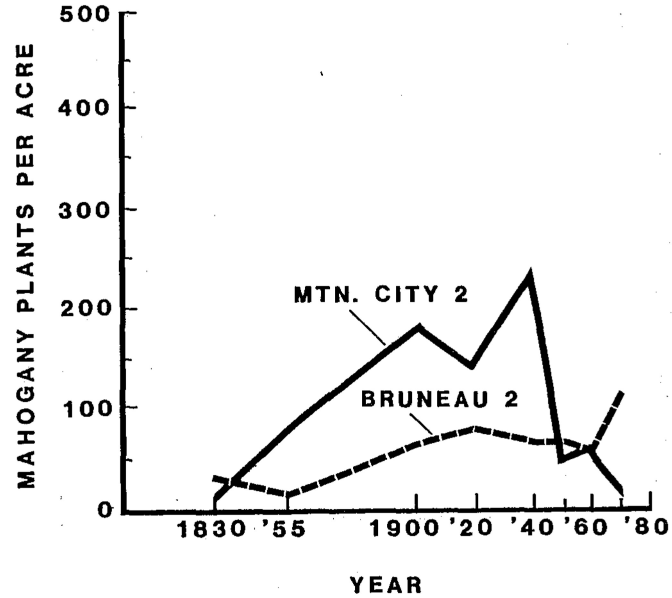

Figure 6.--Potential climax stands showing contrasts in reproduction. Mountain City 2 regenerated at an accelerated rate through about 1940 and then declined sharply. Bruneau 2 shows a lower rate of regeneration with an upturn since 1960.

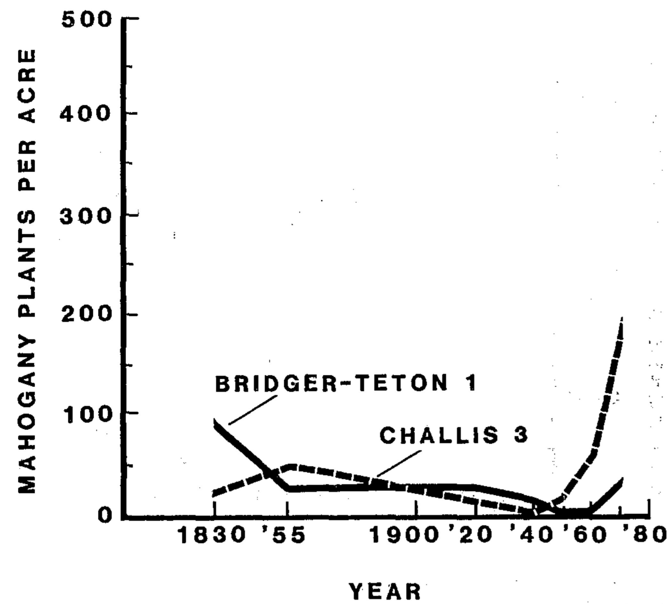

Figure 7.--Examples of potential climax stands that show differences in rates of regneration. Bridger-Teton 1 is an old stand that continues to regenerate at a low level. In contrast, Challis 3 shows accelerated regeneration during the past 30 years.

regenerated mostly after 1900, show a significant decline in regeneration since 1940. Shading, litter accumulation, and lack of bare soil apparently reduced the opportunity for seedling establishment. Foraging on seedlings by domestic livestock, deer, rabbits, and rodents may also be inhibiting regeneration. Stands with more open canopies and exposed bare soil such as Bruneau 2 have been regenerating at a sustained rate (fig. 6). Less open stands (B-T-1) continued to regenerate but at a slower rate; whereas others (Challis 3) have had a substantial increase in regeneration during the past 30 years (fig. 7). Accelerated rates of regeneration in recent decades seem to be strongly influenced by stands reaching a critical reproductive age. When this point is reached, seed is dropped and regeneration establishment takes place on suitable microsites.

Category 2 (Young Stands; Mahogany Potential Climax)

These stands occur typically on deep soils that historically have had grass cover. Except for Bannock 2 (table 1), past fires were not evident. We believe that surface fires were once frequent and completely consumed the light fuels, thus preventing the establishment of mahogany.

Some stands became established between 1900 and 1920, and regeneration accelerated after 1940 (fig. 8). Since about 1960, however, the rate of regeneration has sharply declined. Other stands, such as Threeforks 1 (fig. 9), did not become established until about 1940. This stand has been regenerating rapidly in recent decades.

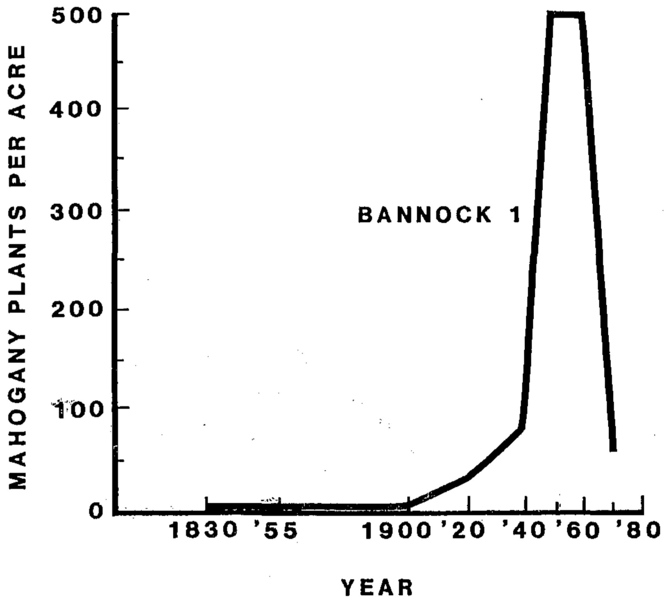

Figure 8.--Example of a potential climax stand in category 2 that regenerated on a site that was not occupied by mahogany prior to about 1920. Sharp decline in regeneration seems to be result of the site becoming fully stocked.

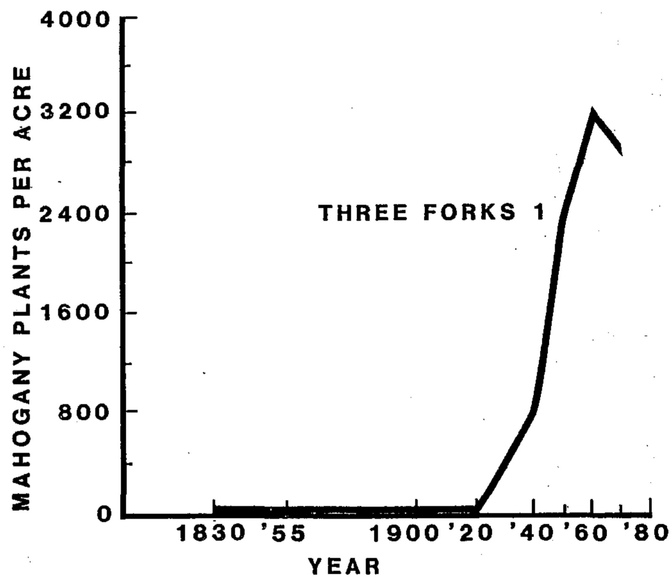

Figure 9.--Example of a potential climax stand that did not become established until about 1940.

Category 3 (Seral Mahogany With Scattered Conifers)

These stands are structurally similar to category 1 except that mahogany is seral. In regions of short fire intervals (mean intervals less than 30 years), fire suppressed conifers and kept the mahogany confined to rock outcrops or sites where sparse fuels did not allow fire to carry. Visual evidence suggests that when woody fuels had accumulated and burning conditions were extreme, fires killed portions of mahogany stands (fig. 2). In more moist communities, such as the Targhee 3 and 4 stands (table 1), infrequent severe fires killed conifers and mahogany over large areas.

Sawtooth 2 (fig. 10) is indicative of many stands having had a sustained increase in regeneration over the past 150 years. Most of the regeneration occurred after 1940. In contrast, other stands have had a marked reduction in regeneration. Regeneration on Targhee 3 (fig. 10) has declined markedly since 1920. Failure of some stands to regenerate seems to be influenced by closure of mahogany canopies and a marked reduction in conditions favorable for seedling establishment.

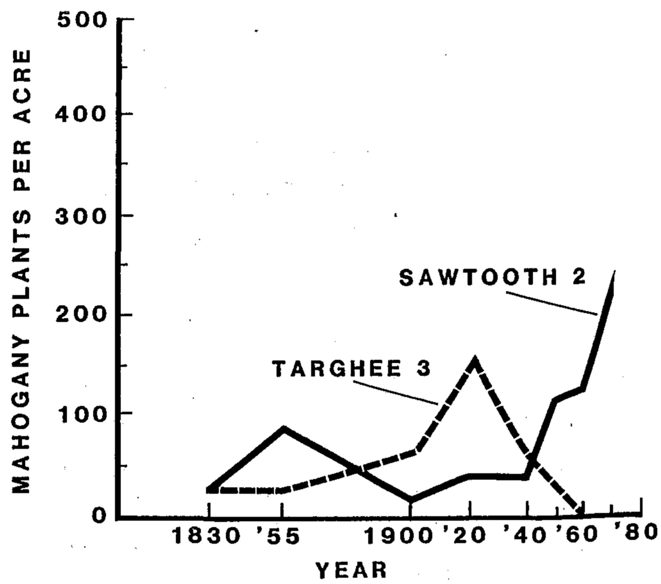

Figure 10.--Examples of seral mahogany stands in category 3 where conifers are not competitive. Sawtooth 2 shows accelerated regeneration after 1940, while regeneration on Targhee 3 has been on the decline or absent since 1920.

The trend in these stands has been a long-term increase in numbers of plants. During the past several decades, some stands have had increased regeneration; in others regeneration has subsided. Stands that contain old plants will become increasingly susceptible to fatal attacks by insects such as those described by Furniss and Barr (1975). Losses to insects and closure of conifer canopies will conceivably result in large-scale loss of mahogany.

Category 4 (Seral Mahogany With Competitive Conifers)

Many mahogany stands fall in this category; however, few met our criteria because the density of mahogany was too low to be included in the sampling. These stands vary most in age and stand structure. They frequently exhibit wide differences in the success of regeneration. For example, Targhee 2 had not regenerated successfully (except the 1970 age group) since about 1900 (fig. 11). In contrast, Greer Gulch (fig. 11) is almost entirely comprised of plants that regenerated post-1900. This stand is comparable to category 2 stands except for the presence of many conifers.

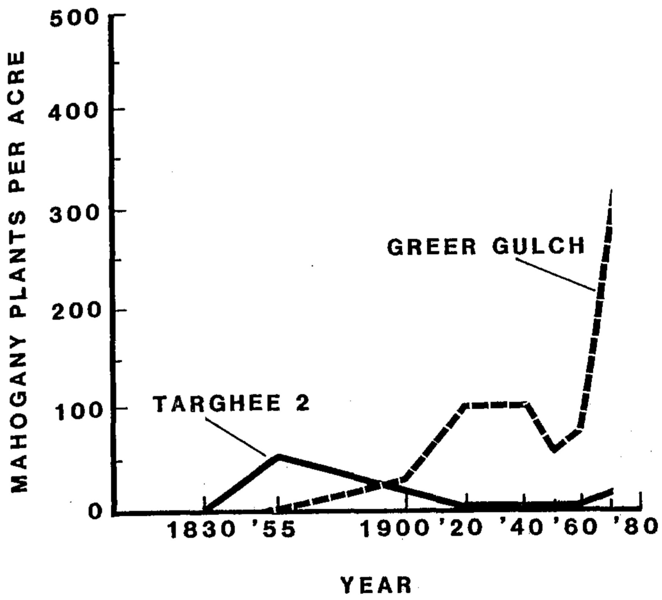

Figure 11.--Examples of differences in regeneration in mahogany stands in category 4 where conifers are competitive. Targhee 2 shows virtually no regeneration in an established stand of conifers since about 1900. In contrast, the Greer Gulch stand essentially regenerated since 1900 and at a much higher level in a developing conifer stand.

Mahogany in category 4 stands is being displaced by conifers. The level of competition varies from scattered conifers, beneath which are mahoganies in low vigor, to closure of conifer crowns and whole-scale loss of mahogany. Without disturbance, the long-term prognosis for category 4 stands is replacement of mahogany by conifers.

Category 5 (Disturbed Mahogany Stands)

Stands in this category were selected to determine the success of mahogany regeneration after disturbance. The time required for seedling establishment varied considerably. The Mountain City 1 stand (table 1) regenerated from seed following an October 21, 1975, fire that completely destroyed the parent stand. Over 4,000 seedlings per acre older than 3 years were tallied in 1982. Initial germination was from seeds of the 1975 crop that apparently had fallen to the ground or from seed banks stored in the litter. The likelihood of this quantity of seed having been transported from off-site sources is remote. Immediate seedling establishment following fire was also measured at the Targhee 2 site (table 1). Other examples of successful seedling establishment following fire were noted. Only 2 percent of the Mountain City 1 and 4 percent of the Targhee 1 stands regenerated from sprouting, which was confined to plants between 20 and 30 years old.

Measurement of the Challis 2 site revealed delayed regeneration within the 1934 Pats Creek burn. The preburn stand was of low density, and the stand did not regenerate until about 30 years after the fire. All parent trees except those on outlying ridges and in rock outcrops were killed by a severe summer wildfire that apparently destroyed the on-site seed source. Subsequent failure of seedling establishment may have resulted from limited seed dispersal and the warm south-southwest aspect, where temperatures were excessively hot for seedling survival. Shading from sagebrush and other ground cover in later years may have provided suitable microsites for seedling germination. Initially, seed dispersal from off-site locations was apparently inadequate; however, scattered mahogany seedlings eventually established themselves. As on-site mahogany regeneration reached seed-bearing age, the rate of regeneration increased dramatically.

Immediate establishment of mahogany following cutting was recorded on two sites. A selection cut in dense Douglas-fir (Salmon 2, table 1) that contained scattered old-growth mahogany resulted in establishment of many mahogany seedlings. Vigorous seedlings were observed growing where the slash had been piled and burned. Before the timber harvest, mahogany had not regenerated successfully since 1900. Sampling at the Soda 3 site (table 1) also documented accelerated mahogany regeneration following the cutting of juniper for posts and poles.

Sampling in disturbed stands that were logged or burned indicated that a reduction in competition and an increase in exposed mineral soil enhanced successful seedling establishment. Observations of other logged and burned mahogany stands that were not sampled suggested comparable relationships. Quantitative data from this study showed that successful seedling establishment was closely linked to condition of the soil surface. Most seedlings were found on exposed mineral soil. No seedlings over 2 years old were found where litter exceeded 0.25 inches (6 mm) in depth.

Regeneration following disturbance can vary greatly depending on intensity of treatment and availability of seed crop. Fires in very small stands kill most mahogany, thus removing the seed source. In large stands, however, many plants survive because of discontinuous fuels. This "fire mosaic" treatment allows seeds to disperse from surviving plants into openings, thus increasing the probability of successful seedling regeneration.

MANAGEMENT IMPLICATIONS

Our data and observations show the desirability of excluding fire from many communities, especially sites where mahogany is the potential climax and where stands are 50 years of age or less. Burning would cause marked retrogression in these communities. There are, however, many low-vigor mahogany communities that would respond positively to fire.

Following are some considerations that may prove helpful in determining where it would be desirable to exclude fire and where there is a solid ecological rationale for using prescribed fire.

Potential Climax Mahogany Stands.--Vigorous stands are not candidates for prescribed fire. Many of these stands are young, having regenerated since 1920. Prescribed fire is also not recommended in stands with woody fuels such as sagebrush where mahogany is scattered or in stands of 0.5 acre (0.20 ha) or less.

Prescribed fire can benefit old mahogany stands that support sufficient fuels to carry fire. The best opportunities include localities where rocky outcrops and sparse fuels allow mahogany to survive as scattered individuals and in clumps. The chances of mahogany surviving and serving as cover and a seed source for immediate mahogany regeneration are enhanced as the burn becomes larger. A fall prescription including several thousand acres of burned and unburned areas would be ideal, especially where mahogany is associated with woody, crown-sprouting shrubs and trees.

Seral Mahogany Stands.--Prescribed fire is most likely to improve mahogany productivity in seral mahogany stands. The higher priorities are in category 4 stands, where conifers are competitive and mahoganies have not been reproducing for many decades. The objective of burning would be to kill competing conifers, remove other plant competition, and promote conditions conducive to seedling establishment.

The size of the burn would depend upon type of terrain, fuels, and the abundance of mahogany. In most instances a burn of several hundred acres would be advisable to avoid excessive browsing of seedlings by wild ungulates and livestock. In remote regions where wildlife values and livestock grazing are primary considerations, there are opportunities to use fall burning prescriptions and natural features of the terrain to execute prescribed burns of several thousand acres. These burns would result in differential burning by removing groups of mahogany where woody fuels were plentiful and leaving mahogany unharmed where woody fuels were sparse. Our observations suggest that mahogany stands will not carry fire unless there are sufficient surface fuels. Large treelike stands supporting grassy fuels and minimal litter usually survive the fire.

In some areas, old-growth mahogany is associated with patches of commercial-sized saw timber. In this circumstance, there is an opportunity to encourage new mahogany plants by making small block cuts of 0.50 to 2 acres (1.23 to 1.94 ha). Opening of the conifer canopy, mechanical disturbance, and prescribed fire used in slash cleanup can provide conditions that permit seeds to disseminate on exposed mineral soil and thus establish seedlings. Leaving several seed-producing mahoganies in openings increases the probability of successful regeneration provided grazing impacts are not excessive.

Fire management plans that include unscheduled (lightning or human) ignitions can be a useful tool in future management of mahogany. It is particularly apparent that there is little or no rationale for suppressing wildfires in localities where mahogany is being outcompeted by conifers. Prolonged fire suppression will continue to reduce the numbers of seed- producing plants and thus will markedly reduce recovery potential following a hot wildfire.

Prescribed fire to enhance the condition of mahogany should be considered on a case-by-case basis. Applying prescribed fire through planned or unscheduled ignitions has a place in mahogany management. We suggest that managers responsible for ecosystems that include mahogany strongly consider the consequences of continually protecting declining stands. The future viability of this important plant will depend on whether we take the short-term approach of protection or the long-term view that recognizes disturbance as essential in promoting productive mahogany stands.

SUMMARY AND CONCLUSIONS

The combined quantitative and historical evidence strongly suggests that before European settlement fire significantly influenced mahogany in the Northern Rockies by restricting stand development. A reduction of fire periodicity and size following Euroamerican settlement apparently allowed mahogany seedlings to regenerate far in excess of former levels. The absence of fire for long periods has resulted in great variation in structure of mahogany stands. Many stands are declining because of losses to insects and conifer competition. In other areas, vigorous young mahogany predominate. These wide differences in stand conditions suggest different management strategies are needed at the local level. Fire management strategies may be used to manage mahogany stands.

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