Effects of Livestock Grazing on Pre-Settlement Fire Regimes in New Mexico

Ramzi Touchan
Thomas W. Swetnam
Henri D. Grissino-Mayer

In this study we investigate the effects of livestock grazing on fire regimes in northern New Mexico. We accomplish this by reconstructing and comparing multi-century fire histories of ponderosa pine forests in areas with different grazing histories. Contrasting fire histories in these areas reveal the importance of land use history in the interpretation of pre-settlement fire regimes. The current structure and functioning of these ecosystems are intimately linked to past fire regimes. Consequently, knowledge of grazing practices and their potential effects on past fire regimes is important for interpreting, understanding and managing modern forests.

DESCRIPTION OF STUDY

Study Areas

Fire-scarred trees were sampled in north-central New Mexico in the Monument Canyon Natural Area. Grazing did not begin in this central area of the Jemez Mountains until the late 1800's (Allen 1989). Elevation is about 2,600 meters, with variable aspects. Large ponderosa pine dominate in the overstory. Scattered dense clumps of small diameter pines (dog-hair thickets) occur throughout the stand. These dense stands are an indirect result of fire suppression, since continuation of frequent low-intensity surface fires would have thinned the stand.

Fire-scarred trees were also sampled in north-central New Mexico at a site we call Continental Divide located on the western slope of the Jemez Mountains. This area has a long history of livestock grazing by Navajo and Hispanic populations, beginning in the early 1700's (Bailey 1980). The sampled area encompasses three adjacent sites: Laguna Gurule; Laguna Jaquez; and Continental Divide. The average elevation is 2,300 meters with south- to southwest-facing aspects. The area is characterized by low ridges covered by ponderosa pine (*Pinus ponderosa*), and scattered Rocky Mountain juniper (*Juniperus scopulorum*). The drainages are broad and shallow with sagebrush (*Artemisia tridentada*) and grasses interposed among the ridges.

A third area was sampled in west-central New Mexico in El Malpais National Monument. This area encompasses two isolated sites, Mesita Blanca and Hidden Kipuka. These sites are "kipukas," or islands of older substrate completely surrounded by more recent lava flows. The kipukas are inaccessible to domestic livestock because of the very rugged and broken terrain of the lava, and therefore have not been intensively grazed (Grissino-Mayer 1993). The average elevation is 2,100 meters. This area supports two vegetation types—an open ponderosa pine forest and a pinyon-juniper forest. Trees are widely spaced in these stands with grasses as ground cover.

Methods

We collected fire-scarred samples from 30 trees distributed over 259 hectares in the Monument Canyon Natural Area site, 27 trees distrubuted over 27 hectares in the Continental Divide site, and 39 trees distributed over 56 hectares in the El Malpais National Monument site. Full or partial cross-sections were cut with a chainsaw from fire-scarred boles of downed logs, snags, and stumps. In the laboratory, samples were fine-sanded and crossdated using dendrochronological techniques (Stokes and Smiley 1968).

All fire-scar dates from individual trees within each site were compiled into master fire chronology charts so that both temporal and spatial patterns of past fire occurrence could be examined. Descriptive statistics were also computed, including fire frequency (number of fires per time period), percentage of trees scarred, mean fire interval, maximum and minimum fire interval, and standard deviations of fire intervals. These statistics were computed for all fire dates and for fire dates recorded by more than 10% of the fire-scarred trees. The latter computations generally emphasize the larger, more widespread fires within the sites.

Changes in fire frequency through time were examined by computing and plotting moving-period fire frequencies. The moving periods were overlapping time periods of different length (51 and 21 years) during which the total number of recorded fires were summed. Each sequential value was the summation of fire events in the time period lagged one year forward from the previous period. The fire frequencies in these moving periods were plotted on the central-year of the period.

The computation of mean fire interval, maximum and minimum fire interval, and standard deviations were based on a time period when the number of fire-scar samples was deemed sufficient to reliably estimate fire regime characteristics. Generally this was at least four samples recording the fire events.

In: Brown, James K.; Mutch, Robert W.; Spoon, Charles W.; Wakimoto, Ronald H., tech. coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. Gen. Tech. Rep. INT-GTR-320. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Ramzi Touchan is Research Specialist, Thomas W. Swetnam is Associate Professor of Dendrochronology, and Henri D. Grissino-Mayer is Graduate Research Associate, Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721.

RESULTS

The fire-scar samples contained abundant and well-preserved records of past fire. We crossdated specimens from trees and downed logs that established more than 400 years before the present. Individual fire-scarred samples typically contained five or more fire scar dates. Collectively the samples from the Monument Canyon Natural Area extended from A.D. 1408 to 1972, with 57 fire scar dates between 1493 and 1909. Samples from the Continental Divide site spanned a 592-year period between 1387 and 1979, with 54 fire scar dates between 1601 and 1899. Samples from the El Malpais National Monument extended from A.D. 1407 to 1991 with 66 fire scar dates between 1447 and 1989.

The mean fire intervals for fires recorded by more than 10% of trees were not greatly different among the three sites when only the periods of reliability were considered (see Table 1). However, the data in Table 2, for the time period of 1750 to 1899 show a different result. The mean fire interval for the Continental Divide site, where more than 10% of trees are scarred, is much larger than for the other two sites. The maximum and minimum fire intervals are also larger.

DISCUSSION

A sharp decline in fire frequency after about 1880 was observed in virtually all southwestern fire history studies (Weaver 1951; Dieterich 1980; Allen 1989; Swetnam 1990). The fire frequency decline coincided with the beginning of intensive livestock grazing (especially by sheep) in each study area and preceded organized fire suppression by one to three decades. This pattern is exemplified by the Monument Canyon Natural Area fire chronology where we observed an abrupt cessation of fires around 1899 (Figures 1, 2, and 3). The last major fire occurred in 1887. Allen (1989) and Rothman (1992) reported that the number of livestock in the Jemez Mountains was very high by 1880 because of the development of local railroad links to external markets. The Roman Vigil Grant on the Pajarito Plateau in the Jemez Mountains was leased to a Texas stockman who grazed 3,000 cattle on 13,000 hectares from 1885 to 1887, about ten times the modern carrying capacity (Foxx and Tierney 1984; Allen 1989). Wooton (1908) reported that the number of sheep in 1880 in New Mexico was 2,088,831; by 1906 the number had increased to 4,558,365. The magnitude and impact of this intense grazing is vividly illustrated by a quote from Rixon (1905), an early surveyor

Table 1—Summary of fire interval statistics for two sites in Northern New Mexico. Mean fire intervals (MFI), standard deviations (STD), and maximum and minimum fire intervals (Max. and Min. F.I.) for all fires and for fires that scarred at least 10% of trees for the period of reliability (1648 to 1892 for the Monument Canyon Natural Area, 1654 to 1880 for the Continental Divide site, 1625 to 1976 for the El Malpais National Monument. All values are expressed in years

		MFI		STD		Max. F.I.		Min. F.I.	
Site Name	Site Code	All Fires	≥10% Trees Scarred	All Trees	≥10% Trees Scarred	All Fires	≥10% Trees Scarred	All Fires	≥10% Trees Scarred
Monument Canyon Natural Area (Late Grazed Area)	MCN	5.5	6.6	2.6	2.9	12	16	1	2
Continental Divide (Early Grazed Area)	CON	6.5	9.8	6.8	12.7	28	48	1	2
El Malpais (Ungrazed Area)	ELMA	6.6	10.6	4.8	8.2	22	41	1	1

Table 2—Summary of fire interval statistics for three sites in Northern New Mexico. Mean fire intervals (MFI), standard deviations (STD), and maximum and minimum fire intervals (Max. and Min. F.I.) for all fires and for fires that scarred at least 10% of trees from 1750-1899. All values are expressed in years

		MFI		STD		Max. F.I.		Min. F.I.	
Site Name	Site Code	All Fires	≥10% Trees Scarred	All Trees	≥10% Trees Scarred	All Fires	≥10% Trees Scarred	All Fires	≥10% Trees Scarred
Monument Canyon Natural Area (Late Grazed Area)	MCN	5.7	6.7	2.8	2.8	12	12	1	2
Continental Divide (Early Grazed Area)	CON	12.0	30.0	10.4	19.8	28	48	1	10
El Malpais (Ungrazed Area)	ELMA	7.5	11.6	5.1	8.0	22	24	2	2

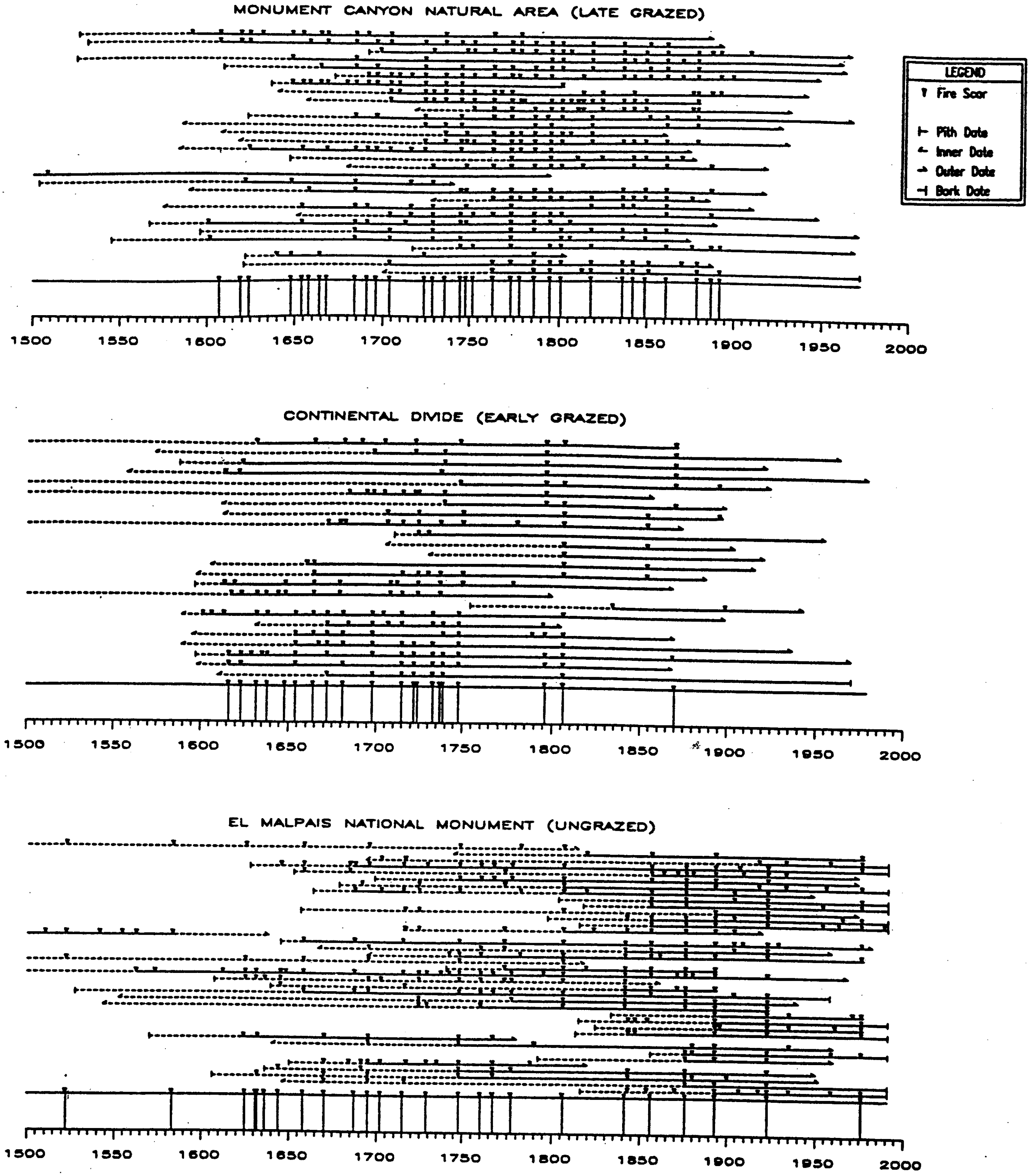

Figure 1—Master fire chronologies for three sites in northern New Mexico. Horizontal lines are life spans of sampled individual trees and arrowheads are fire-scar dates. Fire dates recorded by 25% of the sampled trees are shown on the lowermost line, with vertical lines extending to the time scale.

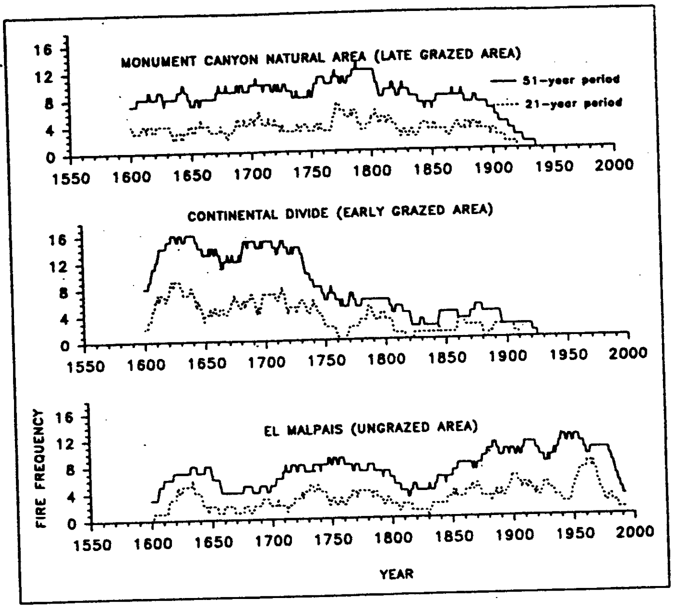

Figure 2—Fire frequency (number of fires per period, based on all fire dates) for the three study sites in northern New Mexico. Moving periods of 51 and 21 years were used for computing the fire frequencies. The frequencies are plotted on the central year of the moving period.

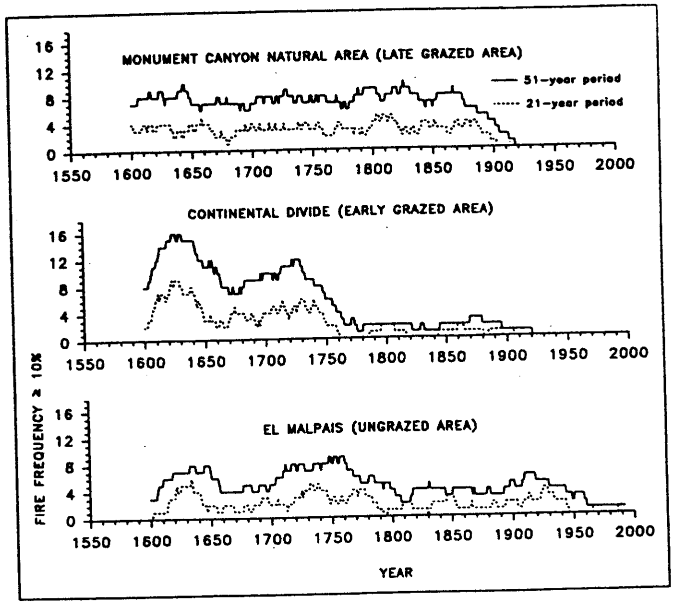

Figure 3—Fire frequency (number of fires per period, based on dates of fires that scarred at least 10% for sampled trees for the three study sites in northern New Mexico. Moving periods of 51 and 21 years were used for computing the fire frequencies. The frequencies are plotted on the central year of the moving period.

(around 1904) of the Gila River Forest Reserve of southwestern New Mexico, in an area that is now ponderosa pine savanna:

> A large area which was entirely given up to sheep, has been overstocked, with the result that about half the township is a barren desert, not a blade of grass being seen and even the roots being entirely destroyed. When the wind blows, the sand and soil rise in vast clouds. I have been informed that this district, previous to the advent of sheep, was a fine grazing area covered with the most succulent grasses.

Hence, it is likely that wherever such intensive grazing occurred, the previous high-frequency fire regimes, depending at least partly on grass fuels, would have been affected.

A similar abrupt and persistent decline in fire frequency also occurred at the Continental Divide site, but much earlier than at Monument Canyon. The Continental Divide master fire chronology shows a sudden decrease in the fire frequency between 1750 and 1796. Scattered fires occurred around the turn of the 19th century, then another gap is evident between 1806 and 1854 or 1870, depending on the portion of the site represented (Figures 1, 2, and 3). These gaps could be due to early grazing by sheep as this area was subjected to early use by both Navajo and Hispanic herdsmen (Bailey 1980).

There is clear evidence that livestock were present in this area during the 16th and 17th century. The Spanish introduced livestock in northern New Mexico in 1598 (Baydo 1970; Bailey 1980). Baydo (1970) reported that during the late 16th and 17th centuries the Indians of the northern Mexico frontier traded livestock into the Southwest, and by 1680 all of the tribes of the border area had livestock in relative abundance. Bailey (1980) estimated the number of sheep that Navajo owned in northern New Mexico to be 8,000 by 1721, 32,000 by 1735, and 64,000 by 1742. The total probably reached a half-million by the mid-19th century (Bailey 1980).

A fire history study in ponderosa pine forests of the Chuska Mountains on the Najavo Indian Reservation (west of the Jemez Mountains) showed an early fire decline beginning around the mid-1800's that may have corresponded with the rise of intensive sheep herding by the Navajo in this area (Savage and Swetnam 1991). Savage (1991) reported that at least 500,000 sheep grazed the Navajo Reservation in the Chuska Mountains during most of the 19th and 20th centuries.

Fire frequency in the relatively ungrazed El Malpais National Monument remained approximately the same in the 19th and 20th centuries (Figures 1, 2, and 3). The more-or-less continuous fire regime into the 20th century is a very rare phenomenon in the southwestern U.S., where more than 30 other fire history studies show a sharp decline in fire frequency after about 1880 (Swetnam 1990, unpublished data). We have observed such an uninterrupted fire regime in only one other remote southwestern mountain range located in northern Sonora, Mexico (Baisan and others, this proceedings). We believe the continuation of frequent surface fire regimes during the 20th century in these areas is due to a combination of lack of intensive grazing and lack of fire suppression by firefighting agencies.

In summary, we observed a decline in fire frequency starting at the end of the 19th century in the Monument Canyon Natural Area. At another site (Continental Divide) which had a long history of sheep grazing by Navajo and Hispanic herdsmen, we observed an early decrease in fire occurrence in the late 18th and early 19th centuries. In contrast, the El Malpais National Monument, which was isolated from grazing impacts, shows a relatively uninterrupted history of spreading surface fires.

Based on these observations and other related work (Savage and Swetnam 1991), we conclude that intensive sheep grazing was the initial and primary reason for the decline in frequent large surface fires in many southwestern forests. The intensive grazing reduced fine fuel (such as grasses) necessary to carry fire from one tree to the other. Also, trampling of fuels, and trails made by livestock and herdsmen, probably limited fire spread in these forests. Frequent large fires were effectively eliminated by subsequent fire suppression by land management agencies.

CONCLUSIONS

Intensive sheep grazing reduced fine fuels necessary for fire spread in the high-frequency fire regimes of the southwestern United States. Intensive livestock grazing, followed by reduced grazing, favorable climate, and fire suppression resulted in increased forest density in the 20th century. Reduced competition from grass for moisture and light and subsequent favorable germination and establishment conditions enabled many thousands of tree seedlings to develop into dense dog-hair thickets (Madany and West 1983; Weaver 1951). Declines in fire frequency may also have favored tree regeneration during the long fire-free intervals of the 18th and 19th centuries at the Continental Divide. This would be especially likely if intensive sheep grazing by Navajo and Hispanic Peoples was intermittent, allowing pine seedlings to establish.

If this is the case, then it is likely that the structure (age distributions and species composition) of ponderosa pine forests that sustained early livestock grazing and early declines in fire occurrence differ from forests that did not sustain altered fire regimes until the late 19th century (most of the Southwest forests), or the very rare forest islands that did not sustain intensive grazing and the consequent decline in fire occurrence (the kipukas at El Malpais). Study of contrasting fire regimes, and the canopy and understory structures of such areas, may provide new insights into ecosystem trajectories of natural and human-disturbed forests. Better understanding of these dynamics is needed for predicting the outcome of 20th-century grazing and fire-suppression related changes in ponderosa pine forests. This understanding may provide some guidance for restoring structures and processes that will impart greater stability and health to southwestern forests.

ACKNOWLEDGMENTS

Funding was provided by the USDI National Park Service and USDA Forest Service. We thank Dr. Craig Allen for arranging funding and providing assistance in many other ways. We thank Tony Caprio, Peter Brown, Rex Adams, and Wolfgang Ortloff for their valuable field assistance, and Christopher Baisan for assistance in checking the dating and for offering advice and suggestions.

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