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Vegetation Management Across Colorado Plateau BLM Lands: 1950–2003

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Abstract

Large tracts of land across the western United States have been managed over the last century in an effort to increase forage production, reduce the risk of wildland fires, and/or restore ecosystem structure and function. Yet documentation of this land-treatment history is lacking. With the use of data collected from Bureau of Land Management (BLM) field offices across the Colorado Plateau, we quantified the number, spatial extent, and implementation cost of tree-reduction and seeding treatments done in piñon (*Pinus edulis*)–juniper (*Juniperus osteosperma, Juniperus monophylla, Juniperus scopulorum*) woodlands between 1950 and 2003. Over 247 000 hectares of land were treated, corresponding to 6.6% of the piñon–juniper vegetation type within BLM-owned lands. Tree-reduction treatments involving chaining, bulldozing, or cabling were most prevalent between the 1950s and 1970s, with over 163 000 ha of land treated with these methods. Prescribed burning became increasingly prevalent in the 1980s, with over 43 000 ha burned. In more recent years, hydroaxe treatments have become common (4 400 ha treated), but to a much lesser extent than prescribed burns. Over 60% of these tree-reduction treatments were done in conjunction with revegetation or seeding treatments. Implementation costs of these tree-reduction treatments were over $26.7 million, with the hydroaxe treatment having nearly three times the cost of implementation than all other tree-reduction treatments. The spatial extent of these tree-reduction treatments and associated implementation costs highlight the importance of research examining the efficacy of these treatments and the potential legacy effects. The land-use history reported in this study and the accompanying freely accessible on-line database is a useful tool to guide research and management objectives and methodology.

Key Words: fuel reduction, piñon–juniper, mastication, prescribed burn, seed application, tree reduction

INTRODUCTION

Over the past century, large tracts of land across the western United States have been managed in an effort to increase forage production, reduce the risk of wildland fires, and/or restore ecosystem structure and function. Yet clear documentation of the spatial extent, implementation cost, and types of management actions is lacking. Here, we focus on the management history of woodlands dominated by piñon (*Pinus edulis*) and juniper (*Juniperus monosperma*, *Juniperus osteosperma*, *Juniperus scopulorum*) (hereafter piñon–juniper), a spatially extensive vegetation type in the western United States and one of the predominant vegetation types administered by land management agencies in the continental United States (Romme et al. 2009).

Beginning in the late 19th century, piñon–juniper woodlands increased in tree density and expanded into adjacent grasslands and shrublands in certain areas (Tausch et al. 1981; Weisberg et al. 2007; Miller et al. 2008; Jacobs et al. 2008). This expansion was coupled with a decline in understory plant cover (Miller et al. 2000; Reiner 2004; Van Auken 2009) that reduced forage production and habitat quality for some wildlife species (Miller et al. 2000; Noson et al. 2006). Historical (1950s–1970s) treatment objectives were to restore understory plant cover and increase forage production. In addition to increasing forage production for livestock, more recent (1990s–current) treatment objectives aim to reduce the risk of catastrophic fire and to restore ecosystem structure and function (National Fire Plan [NFP] 2000; Bureau of Land Management [BLM] 2008). This shift in objectives, combined with new technology, has likely shifted the predominant treatment methods being applied (BLM 2008).

Although it is clear that large tracts of piñon–juniper woodlands have been managed over the past 70 yr, treatment data relevant to resource planning and ecosystem studies have not been widely available for use. In this study, our objectives were to quantify the number, spatial extent, and implementation cost of all tree-reduction and seeding treatments done in piñon–juniper woodlands on BLM-owned land on the Colorado Plateau from 1950 to 2003.

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METHODS

Data Collection

We focused our study on treatment history of piñon–juniper woodlands on BLM-owned land of the Colorado Plateau (for environmental characteristics associated with the treatment locations see Table S1, available online at http://dx.doi.org/10.

Table 1. The number (treatment count), spatial extent (treatment area), and minimum total implementation cost (minimum cost) for each type of tree-reduction treatment done between 1950 and 2003 by the Bureau of Land Management in the Colorado Plateau. Revegetation is the percentage of treatments that included a seeding treatment, based on treatment area.

Time period	Treatment type	Treatment count (no. yr[1])	Treatment area (ha yr^{-1})	Minimum cost[1] (USD $year^{-1}$)	Revegetation[2] (%)
1950s	Burn	0.2	52	$2 932	100
	Chain	4.4	2 939	$226 068	58
1960s	Burn	1.4	381	$54 202	99
	Chain	27.7	13 413	$1 520 681	80
	Wood cut	0.1	20	$2 013	0
1970s	Burn	1.0	271	$22 048	57
	Chain	4.0	2 156	$230 447	64
	Woodcut	0.1	42	$15 861	100
1980s	Burn	6.7	1 301	$95 532	51
	Chain	3.9	803	$154 739	87
	Hydroaxe	0.1	1	–[3]	100
	Wood cut	2.2	66	$1 585	42
1990s	Burn	3.6	958	$57 373	23
	Chain	0.7	63	$15 742	67
	Hydroaxe	0.2	23	$5 838	70
	Wood cut	1.7	183	$21 371	28
2000–2003	Burn	5.7	3 550	$218 942	26
	Chain	0.3	37	$8 040	100
	Hydroaxe	4.3	1 058	$331 218	15
	Wood cut	1.3	63	$36 415	61
Unknown	Unknown	0.2	30	$419	60
Total[4]		636	247 153	$26 665 415	67

[1]This is the minimum total implementation cost per year (after accounting for inflation; see Methods) because treatment-cost data were missing from 21% of the treatments.
[2]This is the minimum percentage of revegetation treatments, because some revegetation treatments may have not been documented.
[3]Data unavailable.
[4]The total row shows the total number, extent, and cost of all tree-reduction treatments done between 1950 and 2003 (rather than per year).

2111/REM-D-13-00171.s1). Treatment-history data were retrieved from each BLM field office within the Colorado Plateau and digitally archived. This required visiting each field office, scanning paper records, and entering these records into a database. Data collected about each treatment application included treatment methods, location, implementation cost, purpose, and spatial extent. All of the information collected can be found in the accompanying on-line database through the Merriam Powel Center for Environmental Research at Northern Arizona University (http://perceval.bio.nau.edu/MPCER_OLD/pj/pjwood). Only management actions involving piñon and juniper tree-reduction treatments were included in this study.

Data Analyses

Tree-reduction methods included bulldozing, cabling, railing, chaining, prescribed burning, hydroaxing and wood cutting (Table S2; available online at http://dx.doi.org/10.2111/REM-D-13-00171.s1). For analyses, we grouped the bulldozing, cabling, railing, and chaining treatments (hereafter collectively referred to as chaining), because these four treatments result in similar soil and vegetation disturbances. When prescribed burning was applied in conjunction with other tree-reduction methods, such as chaining, we classified these treatments as prescribed burning. All tree-reduction treatments that involved seeding were also classified as revegetation treatments.

We quantified total implementation cost of each tree-reduction method (hydroaxe, prescribed fire, chaining, and wood cut) within each decade and adjusted for inflation. We used the inflation calculator provided by the US Department of Labor, which is based on the average Consumer Price Index for a given calendar year (http://www.bls.gov/data/inflation_calculator.htm), to quantify implementation cost of each treatment as if it were in the year 2010. Cost values were missing for 21% of the treatments, and thus, total cost is the minimum total cost of all tree-reduction treatments. To compare the implementation costs associated with the different tree-reduction methods and how this cost varied with time, we excluded all treatments that had also been seeded or had multiple tree-reduction methods applied. Using these criteria, we calculated implementation cost per hectare of each treatment after accounting for inflation (using the same methodology described above). To understand how treatment implementation cost varied with time, we performed a linear regression for each tree-reduction method with implementation cost per hectare (after accounting for inflation) as the response variable and year as the predictor variable. To compare the implementation costs associated with the different tree-reduction methods, we performed a one-way analysis of variance (ANOVA) with tree-reduction treatment as the fixed effect and implementation cost per hectare as the response variable. When significant, post hoc analyses were performed using Tukey's Honestly Significant Difference (HSD). Because the implementation cost of chaining increased with time (Fig. S1; available online at http://dx.doi.org/10.2111/REM-D-13-00171.s1), and because this treatment method was common in the 1950s and 1960s, we performed a similar ANOVA as above but excluded all treatments that were done prior to 1970. All analyses were performed in R (R Development Core Team 2011), with $\alpha=0.05$.

RESULTS

From 1950 to 2003, over 240,000 hectares of piñon–juniper woodlands were treated by the BLM across the Colorado Plateau (Table 1 and Fig. 1). Tree-reduction treatment methods varied throughout this time, with chaining common earlier in the 20th century and prescribed burning and hydroaxing common later in the 20th century (Table 1). In addition, treatment methods varied by field office—certain field offices used prescribed burning as a predominant treatment method, whereas others predominantly used chaining (Fig. 1).

Seed applications were applied to at least 61% of tree-reduction treatments. These seed applications predominantly consisted of perennial grasses, such as *Agropryron cristatum* (L.) Gaertn. (crested wheatgrass) and *Pascopyrum smithii* (Rydb.) A. Love (western wheatgrass), but some also contained perennial forbs and shrubs such as *Melilotus officinalis* (L.) Lam. (sweetclover) and *Atriplex canescens* (Pursh) Nutt. (fourwing saltbrush). Seed applications included aerial broad-

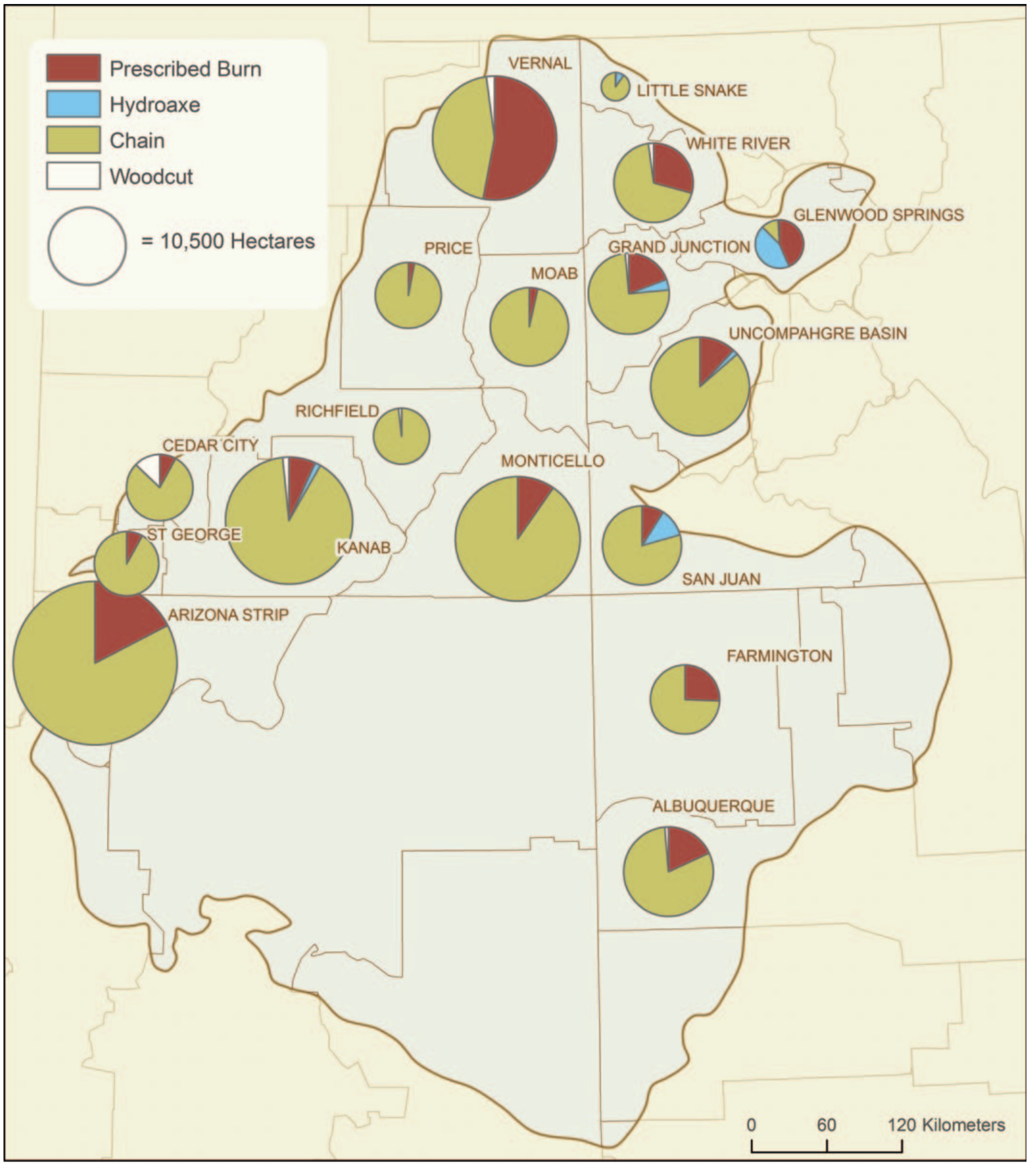

Figure 1. Map of the different tree-reduction treatments implemented within each Bureau of Land Management (BLM) field office in the Colorado Plateau between 1950 and 2003. The size of each pie chart indicates the spatial extent of the total area treated within each BLM field office.

casting, hand seeding, seed drilling, or a using a dribbler (Table S3; available online at http://dx.doi.org/10.2111/REM-D-13-00171.s1). Prior to seeding, a roller chopper, plow, or harrow was often used to prepare the seed bed (Table S3; available online at http://dx.doi.org/10.2111/REM-D-13-00171.s1).

A total of $26.7 million was spent on the 500 tree-reduction treatments on the Colorado Plateau (out of 636 total treatments) for which the implementation cost was recorded (Table 1). There was no strong relationship between treatment implementation cost and year of treatment among the hydroaxe, wood cut, and prescribed-burn tree-reduction treatments, after accounting for inflation and excluding all tree-reduction treatments that had also been seeded ($P > 0.10$). However, there was a significant positive relationship between treatment implementation cost and year of treatment among the chaining treatments ($R^2 = 0.26$; $P < 0.0001$; Fig. S1, available on-line at http://dx.doi.org/10.2111/REM-D-13-00171.s1). There was also a significant effect of treatment method on implementation cost ($F = 21$, $P < 0.0001$), with hydroaxing having threefold higher implementation costs than all other treatments ($P < 0.0001$; Fig. 2). Wood cutting had higher implementation costs than prescribed burning ($P = 0.02$; Fig. 2). When examining only tree-reduction methods that occurred since 1970, hydroaxing was still significantly higher in cost than all other treatments ($P < 0.02$). Chaining also had significantly higher implementation costs than prescribed burning ($P = 0.009$), whereas there was no difference between wood cutting and prescribed burning ($P = 0.09$).

DISCUSSION

On the Colorado Plateau, over 247,000 hectares of piñon–juniper woodlands were treated with tree-reduction treatments between 1950 and 2003, representing 6.6% of woodlands managed by the BLM. These tree-reduction treatments may

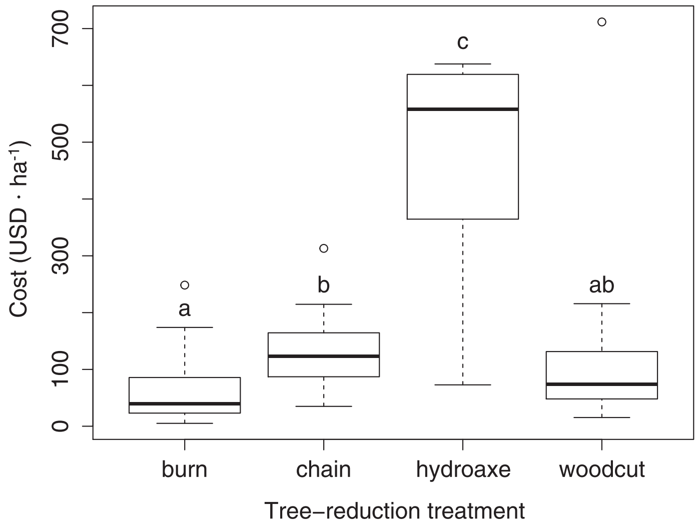

Figure 2. The implementation cost associated with each tree-reduction treatment in piñon–juniper woodlands across the Colorado Plateau. Treatments that occurred prior to 1970 were not included. Different letters denote significant differences among treatments, with $\alpha = 0.05$. The box indicates the 25th and 75th percentile (interquartile range) of the data, the bolded line inside the box indicates the median, the whiskers indicate the range, and the points outside of the whiskers indicate potential outliers.

alter herbaceous communities (Owen et al. 2009; Huffman et al. 2013; Redmond et al. 2013), tree composition (Redmond et al. 2013), and soil erosional processes (Gifford 1973; Farmer et al. 1999; Pierson et al. 2007; Cline et al. 2010). Further, the array of treatment methods may differentially affect vegetation cover and soil erosion (Owen et al. 2009; Huffman et al. 2013; Redmond et al. 2014).

Chaining was the predominant treatment method between 1950 and 1979 (Table 1). Beginning in the 1980s, prescribed burning became a more prevalent management technique. This shift in methodology may be partially explained by the increased recognition that chaining may adversely affect archeological sites or cultural resources (Debloois et al. 1974; Haase 1983) and may result in faster woodland recovery following treatment (Tausch and Tueller 1977; Skousen et al. 1989; Bristow 2010). By the early 2000s, the predominant tree-reduction treatments were hydroaxing and prescribed burning; chaining was rare. At this time, treatment objectives were aimed to reduce the risk of catastrophic fire and to restore ecosystem structure and function (NFP 2000; BLM 2008).

Over 60% of tree-reduction treatments also involved seeding treatments (Table 1). Seeding treatments have the potential to increase herbaceous cover following tree-reduction treatments (Redmond et al. 2014), particularly because the seed bank may have become depleted (Koniak and Everett 1982; Poulsen et al. 1999). Seeding treatments may also reduce the abundance of invasive species (Thompson et al. 2006, Sheley and Bates 2008), especially following fire. Many of the seeding treatments involved reseeding with drought-tolerant, highly productive, nonnative perennial grasses, such as crested wheatgrass. These nonnative perennial grasses are still abundant 40 yr later on some treated areas (Redmond et al. 2013).

A minimum of $26.7 million was spent implementing these tree-reduction treatments, with the hydroaxe treatment having the highest implementation cost per hectare treated (Fig. 2). Although implementation costs are one consideration when developing management plans, it is highly important to also consider the effectiveness of different treatments at accomplishing restoration and/or fuel-reduction goals, over both the short- and long-term time scales.

IMPLICATIONS

The spatial extent and cost of past tree-reduction treatments is rarely readily available for science and management purposes. Yet digitally archived information on treatment history is an important tool for researchers and land managers. For example, the information reported in this study and accompanying freely accessible on-line database (http://perceval.bio.nau.edu/MPCER_OLD/pj/pjwood/) can help guide research objectives and methodology to understand the legacy effects of past treatments. We found that over 65% of past tree-reduction treatments involved chaining, highlighting the need for studies to document the long-term effects of chaining on ecosystem structure and function. The on-line database contains information for each individual tree-reduction treatment, such as location, treatment type, and revegetation methods if applicable (note that this resource does not contain data on vegetation or soil responses to treatments). The on-line database can therefore be used to locate areas that have had past treatments. This unique data set is useful for tree-reduction studies and future management, as well as a range of other studies that require land-use history.

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