ARTICLE IN PRESS
FORPOL-01218; No of Pages 7
Forest Policy and Economics xxx (2015) xxx–xxx
Contents lists available at ScienceDirect
Forest Policy and Economics
journal homepage: www.elsevier.com/locate/forpol

Ecological and social implications of employing diameter caps at a collaborative forest restoration project near Flagstaff, Arizona, USA

Dave Egan [a,*], Michael Stoddard [b], Alicia Formanack [c]

[a] Ecological Restoration Institute, P.O. Box 15017, Flagstaff, AZ, USA
[b] Ecological Restoration Institute, P.O. Box 15017, Flagstaff, AZ86011, USA
[c] Scottsdale, AZ85254, USA

ARTICLE INFO

Article history:
Received 7 February 2014
Received in revised form 13 November 2014
Accepted 30 November 2014
Available online xxxx

Keywords:
Ecological restoration
Forest policy
Forest restoration
Collaboration
Diameter cap
Fort Valley Experimental Forest

ABSTRACT

The issue of implementing diameter caps as a means of preserving old-growth trees on forest restoration projects continues to permeate collaborative land management discussions and treatment decisions on public lands in the Southwest and, indeed, throughout the western United States. We examine the ecological and social results of the collaborative Fort Valley Ecosystem Restoration Project on U.S. Forest Service lands near Flagstaff, Arizona. Since this experiment had areas treated with and without a diameter cap, we sought to determine: 1) the ecological consequences of implementing a 16-inch diameter cap, 2) whether the fears and concerns of the environmental groups who proposed the diameter cap were, in fact, warranted, and 3) how the local collaborative responded to implementing the diameter cap. The ecological data revealed that a site's management history played a major role in how a diameter cap would affect the restoration of stand structure in terms of tree density and tree size. The data suggest that, if implemented, diameter caps are best applied in a manner that takes into account both site conditions and stand management history. In general, we found the concerns about the loss of old-growth trees due to thinning treatments were not realized at Fort Valley. Finally, stakeholder surveys indicate that while the discussion of diameter caps caused tension within the collaborative group, the overall goal of forest restoration was not compromised.

1. Introduction

In 1931, the U.S. Forest Service (USFS) created the Fort Valley Experimental Forest (FVEF) from Forest Service lands surrounding and adjacent to the historic Fort Valley Experimental Forest Station, northwest of Flagstaff, Arizona. This action initially protected some 2420 acres of forest research study area from logging, homesteading, fuelwood cutting, and hunting (Olberding, 2000) with more acreage added in the following decades. Almost 70 years later, Unit 1 of the FVEF became the site of one of the first collaborative forest restoration efforts in the western United States and received national recognition from former Vice President Al Gore as a National Reinvention Laboratory. Most importantly, this community-wide effort marked a significant change in how American society would begin to manage its national forests and their vast resources through ecological restoration rather than commodity extraction.

This Flagstaff-based collaboration emerged when a small, diverse set of constituencies began meeting in 1996 with the idea of identifying approaches to forest management that could reduce the hazard of stand-replacing wildfire and restore forest vitality and resiliency. In 1998, an alliance of more than 20 local government, academic, environmental, and business organizations established a collaborative effort with the Forest Service in response to unprecedented, stand-replacing fires in southwestern ponderosa pine forests, in particular the Horseshoe and Hochderffer wildfires that scorched tens of thousands of forested acres near Flagstaff. Initially known as the Grand Canyon Forest Partnership (GCFP) and later (2002) as the Greater Flagstaff Forest Partnership (GFFP), the collaborative's main goals are:

1. Restore the natural ecosystem functions and structure—within the range of natural variability—of the ponderosa pine forests in Flagstaff's urban/wildland interface (i.e., Flagstaff and the Kachina Peaks Wilderness Area).
2. Manage forest fuels within the urban/wildland interface to reduce the risk of catastrophic fire.
3. Research, test, develop, and demonstrate key ecological, economic, and social dimensions of restoration efforts.

The collaborative has been successful both in terms of staying active as an organization and moving forward to meet their goals through project design and implementation, public education and involvement, utilization and economic development, monitoring and research, and

* Corresponding author. Tel.: +1 928 863 4668.
E-mail addresses: dave.egan@nau.edu (D. Egan), Michael.stoddard@nau.edu (M. Stoddard), Amf258@nau.edu (A. Formanack).

http://dx.doi.org/10.1016/j.forpol.2014.11.013
1389-9341/

Please cite this article as: Egan, D., et al., Ecological and social implications of employing diameter caps at a collaborative forest restoration project near Flagstaff, Arizona, USA, Forest Policy and Economics (2015), http://dx.doi.org/10.1016/j.forpol.2014.11.013

management and administration (Gatewood, 2010). The real-life performance of the collaborative has also been instructive and invaluable in terms of understanding the various aspects of leadership, decision-making, trust, and partnership within a collaborative forest restoration setting.

However, the GCFP/GFFP's initial project, known as the Fort Valley Ecosystem Restoration Project (or the Fort Valley Wildland-Urban Interface), sparked a controversial public debate between restoration proponents and several environmental groups about the validity and appropriateness of restoration efforts and proposed restoration treatments (Velush and Tolan, 1999; Hoffman et al., 2000; Ghioto, 2001; Friederici, 2003). It featured many of the fears about clearcutting and commodity-driven logging raised by environmental groups during previous national debates about forestry on public lands as well as the threat of litigation to prevent or delay management efforts (Shapiro, 1995; Keele et al., 2006). This viewpoint was in contrast to the hopeful, science-based rationale of the then newly emerging practice of ecological forest restoration (Friederici, 2003).

This clash of perspectives was somewhat predictable and, perhaps, unavoidable. Within the context of previous USFS forest management decisions, the new idea of restoring forests on public lands was perceived by the environmental community not only as a "cover-up" for business-as-usual logging (Ghioto, 2000b), but a threat to their preservationist core values and preference for "hands-off" land management (Baldwin et al., 1993). Thus, their insistence on size-restricted tree thinning prescriptions, known as diameter caps, was seen by them as a reasonable compromise and recognition that Southwestern forests in their present condition were extremely vulnerable to the vagaries of wildfire. The GCFP/GFFP restoration community, on the other hand, was eager to move forward quickly to find a solution to the devastating ecological and social effects of wildfires while simultaneously restoring the forest's ecological structure and functions. Moreover, they felt that many of the environmental groups were "outsiders" (i.e., not members of the collaborative) trying to score another legal victory in their ongoing confrontations with the USFS over the management of national forests.

Since the issue of diameter caps permeates land management discussions and treatment decisions in the Southwest and, indeed, throughout the West, we sought to understand 1) the ecological consequences of the 16-inch diameter cap proposed by some environmental groups and 2) whether the fears and concerns of these groups about the loss of large trees were, in fact, warranted in the case of the GCFP/GFFP project at Fort Valley.

2. The ecological and sociological implications of a 16-inch diameter cap: a case study of the Fort Valley Ecosystem Restoration Project and the GCFP/GFFP

The idea of implementing a diameter cap (i.e., a limit on the size of tree that can be removed or thinned) often arises at some point during the collaborative forest restoration process. In the southwestern United States, this typically means not cutting ponderosa pine trees 16 inches or greater in diameter at breast height (dbh) in order to protect "old-growth" trees. There are, however, different views about the metrics that define "old growth" trees in the American Southwest (Kaufmann et al., 2007). Disagreement about "old growth" seems to arise when size (diameter at breast height), which in and of itself does not necessarily indicate a tree is old, is the only metric. Such a divergence in perspectives about "old growth" and "large" trees occurred during the implementation of the Fort Valley Ecosystem Restoration Project.

Proponents of diameter caps believe that they are ecologically and socially necessary to protect large trees from being harvested during restoration thinning operations (Center for Biological Diversity, 2001, see also 4FRI 2011 for an overview of the diameter cap concept and its implementation) and to provide habitat for forest species that prefer closed canopies, such as Abert's squirrel and northern goshawk, as a part of their habitat matrix.

Opponents typically view diameter caps as arbitrary and, at times, restrictive in terms of reaching forest restoration goals, including emulating natural or historic forest structural and functional patterns (Abella et al., 2006; Triepke et al., 2011). Diameter caps are also seen as problematic when used at a landscape-scale because forest stands differ in their history and site conditions. Thus, a diameter cap that may be justifiable scientifically in one stand does not necessarily translate well throughout a landscape (Noss et al., 2006). Instances where science-based, forest restoration proponents do not support a diameter cap include projects: 1) that aim to restore historically open stands, 2) where the goal is to support understory diversity and microorganism productivity, and 3) where reducing current tree density to presettlement levels is needed to reduce crown-fire potential (Abella et al., 2006). In addition, opponents sometimes point to research (e.g., Larson and Mirth, 2001) that indicates diameter caps make the economics of thinning trees difficult for small-scale logging operators. Indeed, some members of the Flagstaff collaborative felt that an increase from a 16-inch to 18-inch diameter cap would significantly improve the economic value of a thinning operation at Fort Valley (Coughlan, 2003).

From a social perspective, employing diameter caps as part of the restoration prescription may be viewed as a political tool meant to placate potential appellants and litigants from either inside or outside of the collaborative (Friederici, 2003; Abrams and Burns, 2007). By implementing a diameter cap, some suggest that the collaborative effort can avoid litigation that might halt or delay a forest restoration project. It must also be acknowledged, however, that the threat of litigation, often from entities outside the collaborative (Wynsma, 2013), may create factions within the collaborative group (i.e., it raises issues of trust), and, therefore, may change the dynamics of how stakeholders interact.

2.1. Fort Valley as a study site

Fort Valley is located about nine miles northwest of Flagstaff on the southern base of the San Francisco Peaks at an elevation of 7400–7600 feet. This area has a gentle topography with a cool, sub-humid climate. Half of the mean annual precipitation—22.4 inches—is comprised of snowfall while the other half comes from summer monsoonal rains. These rains follow the late spring/early summer drought typical for this region (Covington et al., 1997). Until the restoration treatments at Fort Valley, fire had been excluded since 1876. Before that time, it is estimated that low-severity surface fires occurred at a frequency of every two to ten years (Covington et al., 1997). Fort Valley has long been an area for USFS research, including pioneering work by noted researchers G.A. Pearson, T.S. Woolsey, C.K. Cooperrider, G.H. Schubert, and many others (Olberding, 2000).

The Ecological Restoration Institute (ERI), led by forest ecologist and Northern Arizona University professor, W. Wallace Covington, established successful, small-scale forest restoration experiments in the G.A. Pearson Natural Area of the FVEF during the early 1990s. This pioneering work provided much of the scientific foundation, including the experimental design, for the larger, collaborative effort envisioned for the Fort Valley Project (Moore et al., 2008). Over the years, the ERI continued to monitor the effects of the Fort Valley Project, amassing data about various aspects of the work including: the effects of diameter caps, the response of exotic and native understory plant species, the effects on wildlife, and the human response to working in collaborative efforts and confronting differing values and perspectives.

2.2. The Fort Valley Ecosystem Restoration Project

Restoring forest structure (i.e., number of trees per acre, size of trees, amount of canopy, understory cover) is a central goal in the ecological restoration of ponderosa pine forests because of the role forest structure plays in regulating above and belowground competition, nutrient cycling, animal nesting and foraging areas, and forest responses to disturbances, such as wildfire (Fulé et al., 1997). Key structural variables, such as tree density (trees per acre) and basal area (a measure of tree size), are practical metrics used by forest ecologists to quantify forest stand structure. These measures form the basis for management decisions about how much intervention is needed to meet restoration or other management goals (Moore et al., 1999). In some cases, employing diameter caps may make it more difficult to accomplish some management goals or require managers to modify their goals.

The Fort Valley Ecosystem Restoration Project is an ideal case to study the effects of a diameter cap because the project had two different approaches to the diameter cap issue. The Phase I restoration treatments, which were carried out following ERI prescriptions, did not include a diameter cap (Covington et al., 1998). However, because there was a negative reaction to those prescriptions from some environmental groups (e.g., see Hoffman et al., 2000), a diameter cap was incorporated into more expansive Phase II part of the project (Ghioto, 2000a) in order to avoid possible litigation and move the project ahead. A review of the Environmental Assessment (EA) for the project indicates that saving old-growth trees was one of the significant issues of concern raised by EA respondents (USFS, 2000).

2.3. Fort Valley Experimental Design

There are three different ponderosa pine stands that comprise the Phase 1 experimental design in the Fort Valley Ecosystem Restoration Project (Fig. 1). Experimental Block 1 (EB 1) is a predominately yellow pine area with more than five yellow pine per acre; Experimental Block 2 (EB 2) is an area of yellow pine and blackjack pine with less than two yellow pine per acre; and Experimental Block 3 (EB 3), a blackjack pine area, contains little to no yellow pine (Larson and Mirth, 2001) and is located in "a key wildlife corridor and portions of a goshawk post fledgling area" (United States Fish and Wildlife Service, 1999). Yellow ponderosa pines are generally larger in size, older than 150 years, and have a distinctive yellow, plated bark. Blackjack ponderosa pines tend to be younger, smaller trees with a black, furrowed bark (Larson and Mirth, 2001). The yellow pine areas (EB1) and the blackjack/yellow pine areas (EB 2) were located within the FVEF and had not been logged. As a result of this protection and a lack of prescribed fire, these two areas, while having numerous old-growth ponderosa pine, also contained large numbers of small-diameter pines. The blackjack areas (EB 3) were in the Coconino National Forest and had been logged once for larger trees and later thinned from below, which removed most of the smaller-diameter ponderosa pines (Covington et al., 2001; Larson and Mirth, 2001).

For the sake of replication, each EB contained three treated units and a control unit (12 total units; see Fig. 1). Each unit was approximately 40 acres and contained 20, 0.1-acre circular sampling plots (240 total plots). The blocks were thinned in 1998–1999 and prescribed burned in 2000 or 2001 (see http://www.gffp.org/fort_valley/frameset.htm for more details).

The experiment implemented three different ecological restoration treatment prescriptions that were designed to produce low, medium, and high tree density stands after thinning treatments. These levels reflect the different numbers of post-settlement trees selected to replace dead pre-settlement trees (as determined by pre-settlement tree evidence, such as stumps, down logs, snags, and/or stump holes; Friederici, 2003). The low-retention (i.e., full restoration) treatment produces the least dense stand and is designated "full restoration" because it comes closest to replicating the tree density found in this area prior to Euro-American settlement as determined by pre-settlement evidences. It replaces 1 pre-settlement tree with 1.5 post-settlement trees, if those trees are greater than 16″ dbh, and with 3 post-settlement trees, if the replacements are smaller than 16″ dbh. The medium level of retention (i.e., modified restoration) leaves 2 existing trees greater than 16″ dbh for each evidence of a pre-settlement tree or 4 post-settlement trees for every evidence if the

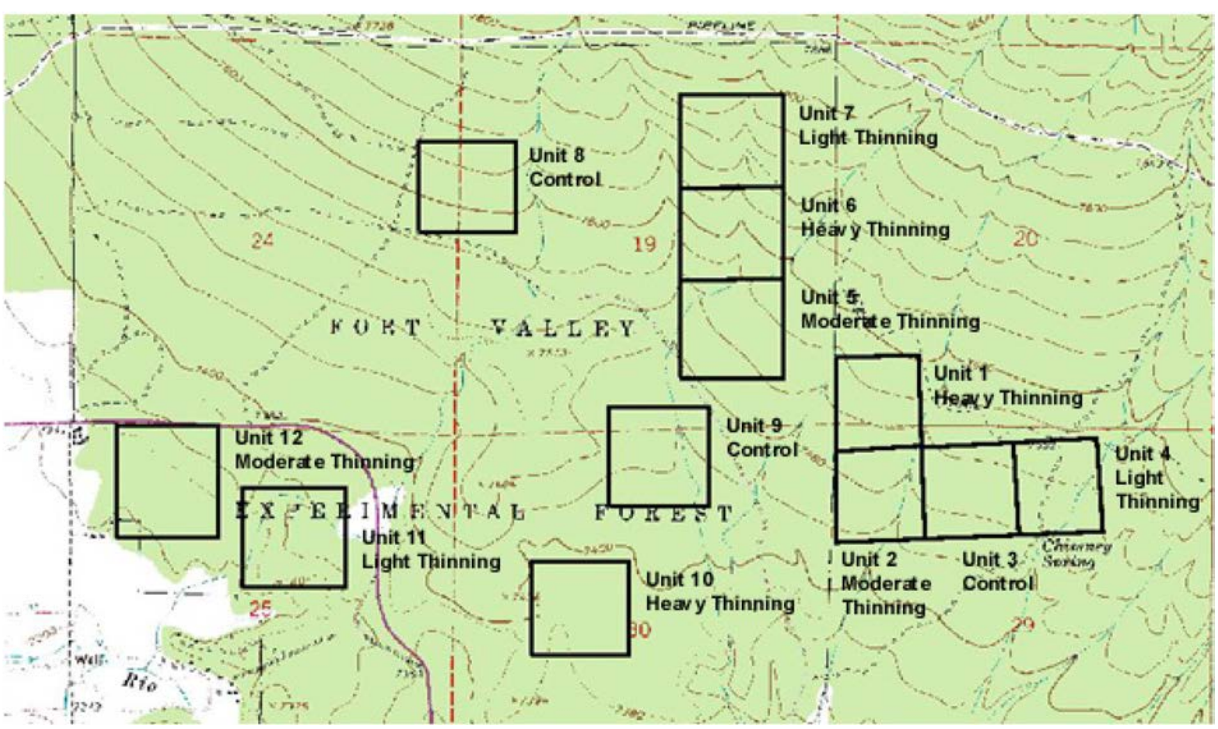


Fig. 1. Map of the various units in Phase 1 of the Fort Valley Restoration Project. Units 1, 2, and 4 (EB 3) contained blackjack pine only. Units 5, 6, and 7 (EB 2) contained a mix of blackjack and yellow pine. Units 10, 11, 12 (EB 1) contained yellow pine only (Larson and Mirth, 2001). Light thinning = high retention/minimal restoration, moderate thinning = medium retention/modified restoration, and heavy thinning = low retention/full restoration.

Please cite this article as: Egan, D., et al., Ecological and social implications of employing diameter caps at a collaborative forest restoration project near Flagstaff, Arizona, USA, Forest Policy and Economics (2015), http://dx.doi.org/10.1016/j.forpol.2014.11.013

existing trees are less than 16″ dbh. The high level of retention (i.e., minimal restoration) produces the densest stand of the three levels. It calls for leaving 3 post-settlement trees for every pre-settlement evidence if the existing trees are greater than 16″ dbh and 6 post-settlement trees for every evidence if the existing trees are less than 16″ dbh. Replacement/retained trees are chosen from trees existing within 60 feet of the pre-settlement tree evidence (Friederici and Sanchez-Meador, 2005) in order to emulate the natural clumpy, groupy structure that naturally occurred in the forest prior to anthropogenic-induced changes.

3. Analysis of the ecological and social effects of a diameter cap at the Fort Valley Ecosystem Restoration Project

In order to understand the ecological implications of a 16-inch diameter cap, we set out to assess the difference in tree density and stand basal area between capped and non-capped treatments at the Fort Valley Ecosystem Restoration Project. We hypothesized that there would be little difference in tree density or basal area within different thinning intensities due to the implementation of the diameter cap. Formanack also conducted and analyzed semi-structured interviews with eight people involved in the process (five stakeholders in the GCFP/GFFP collaborative, two Coconino National Forest employees, and one representative of a local environmental organization) in order to identify their beliefs and obtain their recollections of how the collaborative dealt with the diameter cap issue.

3.1. Ecological data analysis

In 2006, ERI ecologists collected overstory data to assess treatment effects on forest density and tree size following Phase I of the Ft. Valley Ecosystem Restoration Project. Trees per acre and basal area or BA (i.e., the cross-sectional area of all stems of a tree species or all tree stems in a stand measured at breast height, and expressed in terms of per unit of area) were determined for pre- (1998) and post- (2006) restoration treatments. A 16-inch diameter cap was then superimposed on the 2006 data set to provide values for tree density and basal area per acre for a capped restoration scenario. Those trees that were 16-inch dbh or greater and thinned during Phase 1 were added back and their observed growth increases were added to calculate basal area per acre for the capped restoration scenarios. The capped and non-capped data sets were then compared within each experimental block and treatment using a 1-tailed, paired *t*-test with the *p*-value set at 0.05 (Table 1).

3.2. Ecological data analysis results

The comparisons between capped and non-capped showed significant differences in four out of the nine treated units, especially in EB 3 (Table 1). All treated units in EB 3, an area that had been previously logged, indicated significantly higher tree density and basal area when a diameter cap was superimposed than did a cap-free prescription. The EB 2 moderate retention unit also showed significant differences between a capped and non-capped prescription. The EB 3 had an increase of 5 trees/acre and a 10 ft^2/acre increase in BA across all treatment units following a capped-constrained prescription. Meanwhile, EB 1 had increases of 1 tree/acre (1 ft^2/acre BA), and EB2 had increase of 3 trees/acre (5 ft^2/acre BA).

Interestingly, 60% of the large, but post-European settlement, trees (≥16 inches) cut following Phase I of the Ft. Valley Ecosystem Restoration Project were in EB 3, whereas 9% and 31% were cut in EB 1 and EB 2, respectively. These results appear to be due to the variation in the pre-treatment tree densities in the three EBs. Pretreatment tree densities were significantly greater in EB 1 and EB 2 (both in the experimental forest and never subject to logging) than in EB 3 (Coconino National Forest and subject to past logging) (Figs. 2–4). On average, treatment units inside the experimental forest had twice as many trees than units found outside the experimental forest (EB 3) due to the cessation of fire. The majority of trees in EB 1 and EB 2 were small in diameter (in the 0 to 4-inch size class) and when their diameter distribution is plotted on a graph, they produce a reverse J-shaped curve (Figs. 2–3). Meanwhile, the same type of data from EB 3 creates a bell-shaped curve that reaches its highest abundance of trees per acre at the 12-inch size class (Fig. 4). Across all thin-and-burn treatment units, two of the 111 (1.8%) presettlement trees (i.e., those established before 1877) were cut as part of the treatment. Both of trees were in EB3.

Differences between treatment intensity (i.e., low-, medium-, high-retention) in a capped and non-capped scenarios were indistinguishable in terms of in terms of tree density and basal area.

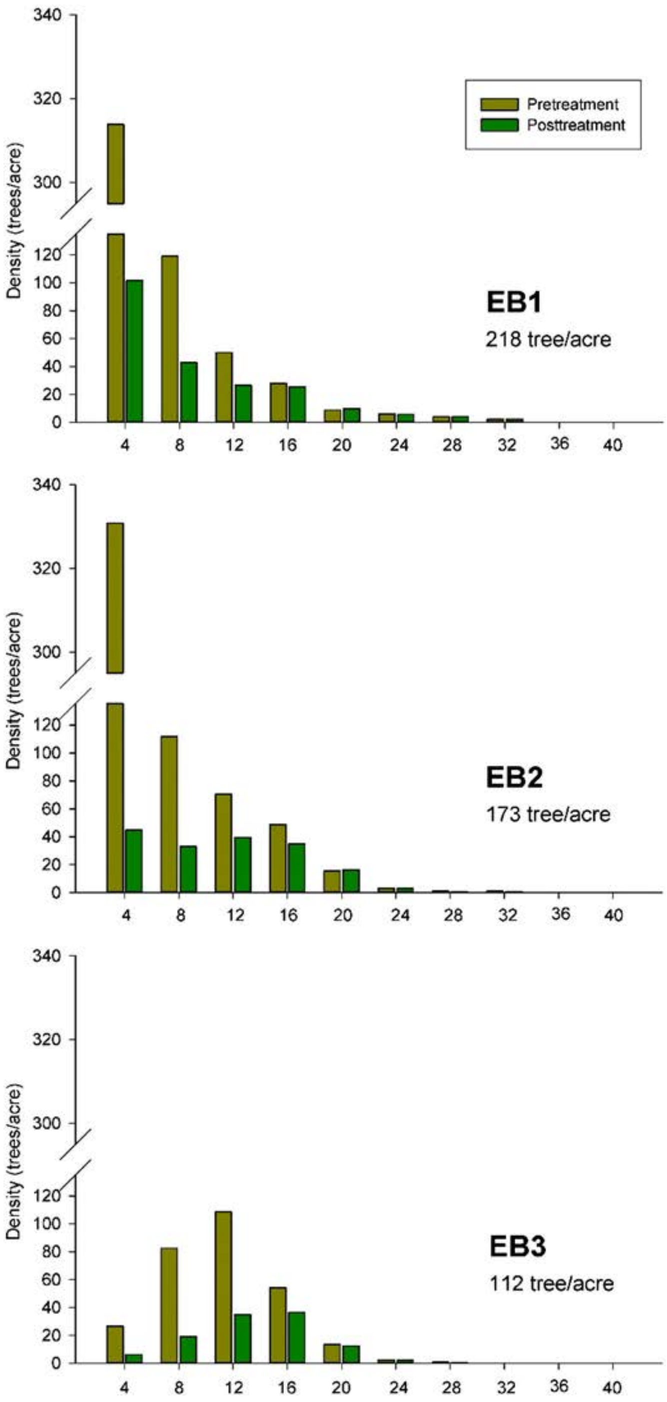
3.3. Discussion of ecological effects

The hypothesis that there would be little difference between capped and non-capped restoration was not supported by the results, especially those from EB 3. At Fort Valley, the data revealed that it was not the intensity of the treatment that dictated a significant difference between capped and non-capped restoration treatments, but rather the site history and the resulting tree size, which, in this case, was the difference between protected areas (EB1 and EB2) and those that were logged (EB3). This issue of available tree size plays a key role in terms of the number of existing trees that are marked to save as replacement trees. For example, if there are only few small trees and a 16-inch diameter cap (and relatively more trees per acre in that size class), as was the case in EB 3, then the result will be an area with higher tree densities and greater basal area than is desirable in terms of obtaining protection from crown fires, increasing the growth of a grassy understory, and, ultimately, producing a number of large, but not necessarily older, trees.

Treatment intensity showed no significant difference between capped and non-capped scenarios when all three experimental blocks are examined together. It was only when individual units were analyzed that significant differences can be seen. Trees that fell within the 8.1–16.0 inch range dominated EB 3 (Covington et al., 2001), while trees that were less than 4 inches in diameter dominated EB 1 and EB 2.

Table 1
Mean (SE) of both tree density and stand basal area following restoration treatment with and without a 16 inch-diameter cap. For each EB block and treatment, bold text and different lowercase letters indicate significantly different means at $P < 0.05$.

	Control		Low retention		Moderate retention		High retention	
EB block	Cap	No cap	Cap	No cap	Cap	No cap	Cap	No cap
Tree per acre								
EB1	651.0 (98.4)	651.0 (98.4)	73.5 (8.8)	73.5 (8.8)	79.0 (10.0)	77.5 (10.2)	73.0 (5.6)	72.5 (5.8)
EB2	406.5 (59.2)	406.5 (59.2)	70.5 (10.2)	69.5 (10.3)	**81.0 (7.0)a**	**75.0 (7.5)b**	140.5 (19.7)	140.0 (19.7)
EB3	269.5 (13.9)	269.5 (13.9)	**41.0 (6.6)a**	**38.0 (6.7)b**	**59.5 (8.5)a**	**54.0 (9.0)b**	**92.0 (11.8)a**	**86.5 (11.9)b**
BA (ft^2/acre)								
EB1	152.5 (10.9)	152.5 (10.9)	91.1 (7.4)	91.1 (7.4)	106.9 (9.4)	113.7 (8.5)	102.1 (9.8)	101.2 (10.1)
EB2	173.6 (14.5)	173.6 (14.5)	79.4 (9.5)	77.0 (9.5)	**100.3 (8.2)a**	**88.8 (7.8)b**	100.5 (7.2)	99.4 (7.3)
EB3	178.2 (8.6)	178.2 (8.6)	**50.0 (7.5)a**	**43.9 (7.2)b**	**62.6 (7.7)a**	**50.6 (7.1)b**	**108.0 (9.4)a**	**96.4 (10.7)b**



Figs. 2–4. Diameter distribution of trees per acre before and after restoration treatments (not influenced by a diameter cap). Diameter size classes are in 4-inch increments. Tress per acre are post-treatment.

This difference is related to the difference in historical context of these blocks—EB 3 had been logged for large trees and later had thinned from below (Larson and Mirth, 2001), whereas EB 1 and EB 2 have been protected from logging and burning. Because of the differing distribution in size classes before treatment, EB 3 has a higher probability of tree removal within the 16-inch range. There are also significantly fewer trees per acre in EB 3, which leaves fewer trees to choose from when marking and thinning take place. In the case of Fort Valley, it appears that site history played a major role in how a diameter cap would affect the restoration of stand structure in terms of tree density and tree size.

3.4. Effects of a diameter cap on the GCFP/GFFP collaborative process

We used criteria sampling (Henry, 1990) to select participants to interview about their thoughts regarding diameter caps and how employing a diameter cap affected the collaborative process. Her interviewees included members of the collaborative from the ERI, Grand Canyon Trust, NAU College of Engineering, NAU School of Forestry, and the Flagstaff Fire Department. She also interviewed USFS liaisons to the collaborative and an individual from the Southwest Forest Alliance. She developed and used a semi-structured guide for the interviews to obtain relevant and comparable information.

We conducted semi-structured interviews (either face-to-face or telephone) with eight individuals during a one-month period. The interviews were digitally recorded and transcribed. All data was imported into QSR Nvivo 9 software, organized into principal themes with graduated levels of detail (Miles and Huberman, 1994), and analyzed for trends. Snowball sampling was applied (Goodman, 1961) to thoroughly capture all perspectives within the partnership.

There were three themes to the questions: 1) What motivates people/groups to implement a diameter cap? 2) What type of "atmosphere" did discussions of implementing a diameter cap create within and outside the collaborative? 3) How did interviewees think a diameter cap would affect the outcome of restoration treatments at Fort Valley?

3.5. Interview results

The interviews revealed that there was general agreement that old-growth trees were valuable components of the Southwest forest ecosystem. Sixty-two percent of interviewees agreed that the implementation of a diameter cap helped avoid litigation (Fig. 5), while 75% believed that the idea of implementing a diameter cap created factions within the collaborative (Fig. 6). Also, 71% of the interviewees thought that, due to the stand structure present at Fort Valley, there would be little structural difference between the capped and non-capped areas (Fig. 7).

3.6. Discussion of effects on the collaborative process

Plans for Phase 2 of the Fort Valley Restoration Project were appealed by environmental groups three times during 1999 and 2000. The U.S. Forest Service denied each of these appeals, which were based on a variety of ecological, social, and legal concerns. While these appeals were rendered as insignificant by the agency, according to the members interviewed they had a deep effect on the collaborative process and, ultimately, pushed the collaborative to accept the implementation of a diameter cap in order to move the project forward without delays. Indeed, a majority of the collaborative's stakeholders were in

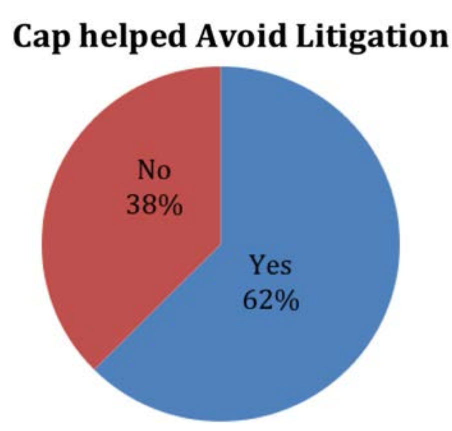


Fig. 5. A majority of the respondents agreed that implementation of a 16-inch diameter cap helped avoid litigation.

Please cite this article as: Egan, D., et al., Ecological and social implications of employing diameter caps at a collaborative forest restoration project near Flagstaff, Arizona, USA, Forest Policy and Economics (2015), http://dx.doi.org/10.1016/j.forpol.2014.11.013

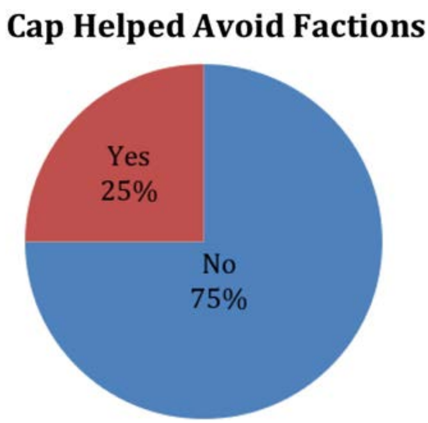


Fig. 6. Three-quarters of the respondents agreed that implementation of a diameter cap created or revealed factions within the collaborative group.

general agreement that the implementation of a diameter cap was important to increase the likelihood that restoration treatments would not be halted by litigation.

While a diameter cap did help the collaborative avoid litigation, according to those interviewed, it also created and/or reinforced factions within the group by causing stakeholders to become engaged in an issue that was ultimately defined by someone winning and someone losing a debate. That said, the success of the GCFP/GFFP and the Fort Valley project overall is due to in many ways to the stakeholders' ability to see that controversy was normal and that continuing to work together through various problems would ultimately result in successfully implementing treatments on the ground. Thus, members were able to keep the eyes on the greater mission of achieving the collaborative's stated goals of 1) restoring the natural ecosystem functions and structure of ponderosa pine forests in Flagstaff's urban/wildland interface, 2) managing forest fuels to reduce the risk of catastrophic fire, and 3) researching and demonstrating the key ecological, economic, and social dimensions of restoration efforts.

4. Conclusion

The results of this study indicate that at Fort Valley:

- A 16-inch diameter cap was not necessary to protect old-growth trees in ponderosa pine stands where there were sufficient numbers of small-diameter growing in a matrix of old-growth, like the conditions found in EB 1 and EB 2. In both of these EBs, although especially in EB 1, the tree density per acre and the BA were roughly similar regardless of whether a diameter cap was in place or not.

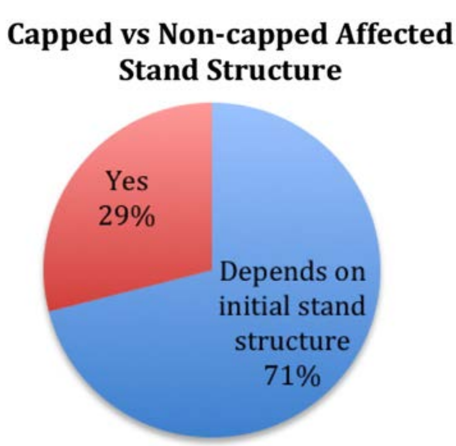


Fig. 7. Seventy-one percent of the respondents agreed that a 16-inch diameter cap would not affect the restoration of stand structure at Fort Valley.

- In formerly logged ponderosa pine stands with large, but not necessarily old, trees, like those found in EB 3, the 16-inch diameter cap only served to increase both the tree density and basal area by limiting the number of trees available for thinning.
- In all EBs, both capped and non-capped scenarios significantly reduced the tree density and basal area from what was recorded in the control units.
- Differences between treatment intensity (i.e., low-, medium-, high-retention) in a capped and non-capped scenarios were indistinguishable in terms of forest density and tree size in all EBs.

These first two results reflect similar findings by other researchers (e.g., Abella et al., 2006; Triepke et al., 2011). Moreover, the outcome of this study strongly suggests that even if a decision is made for socio-political reasons to implement diameter caps, this approach should not be used as a "one-size-fits-all" solution, but should be applied in a manner that takes into account both site conditions and stand management history. Finally, while decisions to implement diameter caps are ultimately derived from the values and attitudes of stakeholders, these results indicate that the fears and concerns of environmental groups and other concerned citizens were not realized at Fort Valley in terms of how the forest responded.

The Four Forests Restoration Initiative (4FRI) now underway in Arizona, has taken a different and more nuanced approach to large tree retention. The stakeholder group produced a "Large Tree Retention Strategy" that urges protecting trees greater than 16 inches while allowing the removal of larger diameter trees in situations where their removal is deemed necessary and acceptable to a review committee (Four Forests Restoration Initiative, 4FRI, 2012) to achieve ecological goals and reduce the risk of unnatural fire. And while Region 3 of the Forest Service ultimately rejected this stakeholder proposal, it remains a viable concept because it has the potential to provide environmental groups with assurances that restoration treatments will primarily focus on small trees while giving the agency the flexibility it needs to achieve outcomes that are both practical and ecologically sound. As was the case with the Fort Valley Restoration Project, the success of any forestry-related collaboration is partially due to addressing existing fears and concerns, and, ultimately, finding a workable balance between social and ecological perspectives.

Acknowledgments

This paper was adapted and revised from an earlier, unpublished report for the ERI written by Alicia Formanack. We would also like to acknowledge Dr. Wally Covington and Diane Vosick of the ERI for their advice and help with this article. Two anonymous reviewers also provided useful comments during the preparation of the manuscript for this journal. This research was funded by a grant (Award # 10-DG-11031600-050) from the USDA Forest Service. Northern Arizona University is an equal opportunity employer.

References

Abella, S.R., Fule, P.Z., Covington, W.W., 2006. Diameter caps for thinning southwestern ponderosa pine forests: viewpoints, effects, and tradeoffs. J. For. 104, 407–414.
Abrams, J., Burns, S., 2007. Case Study of a Community Stewardship Success: The White Mountain Stewardship Contract. Ecological Restoration Institute- Issues in Forest Restoration, Flagstaff, AZ.
Baldwin Jr., A.D., De Luce, J., Pletsch, C. (Eds.), 1993. Beyond Preservation: Restoring and Inventing Landscapes. University of Minnesota Press, St. Paul.
Center for Biological Diversity, 2001. Grand Canyon Forest Partnership abandons cap on logging large trees. https://www.biologicaldiversity.org/news/press_releases/LOGGINGCAP.HTML.
Coughlan, M.R., 2003. Large diameter trees and the political culture of "restoration:" a case study with the Grand Canyon Forest Partnership, Flagstaff, Arizona. Ariz. Anthropol. 15, 48–71.
Covington, W.W., Fulé, P.Z., Moore, M.M., Hart, S.C., Kolb, T.E., Mast, J.N., Sackett, S.S., Wagner, M.R., 1997. Restoration of ecosystem health in southwestern ponderosa pine forests. J. For. 95 (4), 23–29.

Covington, W.W., Smith, H.B., Moore, M.M., Fulé, P.Z., 1998. Comments on Fort Valley Urban/Wildland Restoration Issues. Ecological Restoration Program, School of Forestry, Northern Arizona University, Flagstaff, AZ (www.for.nau.edu/forestry/ecorest/1998).

Covington, W.W., Smith, H.R., Fulé, P.Z., Moore, M.M., 2001. Report on the Experimental Forest Treatments in the Flagstaff Wildland/Urban Interface. Ecological Restoration Program, School of Forestry, Northern Arizona University, Flagstaff, AZ (Submitted to the USDA Forest Service, Rocky Mountain Research Station).

Four Forests Restoration Initiative (4FRI), 2012. Old Growth Protection and Large Tree Retention Strategy. http://www.4fri.org/pdfs/documents/collaboration/old_growth_protection-revised080812.pdf.

Friederici, P., 2003. The Flagstaff Model. In: Friederici, P. (Ed.), Ecological Restoration of Southwestern Ponderosa Pine Forests. Island Press, Washington, D.C., pp. 1–25.

Friederici, P., Sanchez-Meador, A., 2005. Restoration of Ponderosa Pine Forests to Presettlement Conditions. Ecological Restoration Institute Working Paper 9. Ecological Restoration Institute, Flagstaff, AZ.

Fulé, P.Z., Moore, M.M., Covington, W.W., 1997. Determining reference conditions for ecosystem management in southwestern ponderosa pine forests. Ecol. Appl. 7 (3), 895–908.

Gatewood, S., 2010. Forest Restoration and Community Wildfire Protection: Ten Years of Lessons Learned From the Greater Flagstaff Forest Partnership. Greater Flagstaff Forest Partnership, Flagstaff, AZ.

Ghioto, G., 2000a. Forest Service Offers New Thinning Plan. Arizona Daily Sun (September 22).

Ghioto, G., 2000b. Appeal Denied. Arizona Daily Sun (December 22).

Ghioto, G., 2001. Activists Insist on Limited Thinning. Arizona Daily Sun (April 25).

Goodman, L.A., 1961. Snowball sampling. Annual of Mathematical Statistics 32, 148–170.

Henry, G.T., Sampling, Practical, 1990. SAGE Publications; Newbury Park. CA: v. 21.

Hoffman, M., Schulke, T., Crumbo, K., 2000. Why the Flagstaff Restoration Model Should not be Applied to Public Forest Lands. Southwest Forest Alliance, Flagstaff, AZ.

Kaufmann, M.R., Binkley, D., Fulé, P.Z., Johnson, M., Stephens, S.L., Swetnam, T.W., 2007. Defining old growth for fire-adapted forests of the western United States. Ecol. Soc. 12 (2), 15 (http://www.ecologyandsociety.org/vol12/iss2/art15/).

Keele, D.M., Malmsheimer, R.W., Floyd, D.W., Perez, J.E., 2006. Forest Service land management litigation, 1989–2002. J. For. 104, 196–202.

Larson, D., Mirth, R., 2001. Projected economic impacts of a 16-inch tree cutting cap for ponderosa pine forests within the Greater Flagstaff Urban-Wildlands. USDA Forest Service Proceedings RMRS-P-22.

Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis: An Expanded Sourcebook. SAGE Publications, Thousand Oaks, CA.

Moore, M.M., Covington, W.W., Fulé, P.Z., 1999. Evolutionary environment, reference conditions, and ecological restoration: a southwestern ponderosa pine perspective. Ecol. Appl. 9 (4), 1266–1277.

Moore, M.M., W.W. Covington, P.Z. Fule, S.C. Hart, T.E. Kolb, S.S. Sackett, and M.R. Wagner. 2008. Ecological restoration experiments (1992-2007) at the G.A. Pearson Natural Area, Fort Valley Experimental Forest. Pages 290-304 in S.D. Olberding and M.M. Moore (tech. cooords.), Proceedings of Fort Valley Experimental Forest—A century of research 1908-2008. Conference Proceedings; August 7-9, 2008; Flagstaff, AZ. Proc. RMRS-P-53CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Noss, R.F., Beier, P., Covington, W.W., Grumbine, R.E., Lindenmayer, D.B., Prather, J.W., Schmiegelow, F., Sisk, T.D., Vosick, D.J., 2006. Recommendations for integrating restoration ecology and conservation biology in ponderosa pine forests of the southwestern United States. Restor. Ecol. 14, 4–10.

Olberding, S.D., 2000. Fort Valley: The Beginnings of Forest Research. Forest History Today, pp. 9–15 (Spring).

Shapiro, M., 1995. The United States. In: Tate, C., Vallinder, T. (Eds.), The Global Expansion of Judicial Power. New York University Press, New York, pp. 43–66.

Triepke, F.J., Higgins, B.J., Weisz, R.N., Youtz, J.A., Nicolet, T., 2011. Diameter Caps and Forest Restoration: Evaluation of a 16-inch Cut Limit on Achieving Desired Conditions. USDA Forest Service Forestry Report FR-R3-16-3. U.S. Forest Service, Southwestern Region, Regional Office, Albuquerque, NM.

United States Fish and Wildlife Service, 1999. Biological Opinion Summary, Fort Valley 10 K. Response from US Fish and Wildlife Service to Fort Valley 10K proposal. http://www.fws.gov/southwest/es/Arizona/Documents/Biol_Opin/99145_Ft_Valley_10K.pdf.

United States Forest Service, 2000. Environmental Assessment for Fort Valley Ecosystem Restoration Project. Coconino National Forest. http://www.fs.fed.us/r3/coconino/nepa/ft_valley_01.html.

Velush, L., Tolan, M., 1999. Appeal delays Fort Valley Road Fire Reduction Project. Arizona Daily Sun (June 18).

Wynsma, B., 2013. U.S. Forest Service collaboration process: solution or sham? Evergreen Magazine (March 19. Online: http://evergreenmagazine.com/web/U_S_Forest_Service_Collaboration_Process_Solution_or_Sham_-v3.html).