USING ARCHIVAL DIGITAL ORTHOPHOTOGRAPHS TO INVESTIGATE THE DOUGLAS-FIR FIRE REGIME: A PRELIMINARY STUDY FROM GRAND TETON NATIONAL PARK AND THE BRIDGER-TETON NAITONAL FOREST, WYOMING

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Abstract

We conducted a pilot study to explore the utility of geo-rectified historic aerial photos in studying the fire ecology of lower montane forests in the Rockies. We sought to gain knowledge on Douglas-fir dominated forests, which are thought to be characterized by a complex mixed-severity fire regime. A set of aerial photographs of Teton County, Wyoming, from 1945 were geo-rectified and projected in a Geographic Information System (GIS), then compared with 2009 digital orthophotography from the National Agricultural Imagery Program (NAIP). Two questions were of particular interest: 1) how well can comparison of historic and new photos reveal expansion of Douglas-fir forest cover into formerly shrub-dominated openings? 2) Can historic photos be used to distinguish "landscape scars" of past stand-replacing fires that are no longer visible on the landscape? We used the photos to identify a set of candidate sites for each of these questions, then collected field data on forest age structure and fire scars in those sites to evaluate whether ground evidence supported the inference suggested by the photos.

We found that it was possible to see substantial changes over the 64-year interval represented by the historic and new photos, where forest has expanded into previously shrub-dominated openings. Age structure of forests in and around these sites proved to be consistent with this dynamic. This analysis suggested a more quantitative and repeatable approach to evaluating these changes in forest cover, relative to the more common oblique-angle black-and-white photos from the settlement era. Secondly, the historic black-and-white photography helped to identify past stand-replacing fires that are not visible on the current landscape, with forest age structures showing clearly younger, relatively even-aged stands compared to surrounding stands. Fire scar data in some cases showed co-incident (similarly timed) surface fires in surrounding stands, and suggested utility of combining the photographic analysis with other field data on tree establishment and fire history.

When combined with field data, we were able to use the historic images to make preliminary conclusions about past fire severity patterns and the timing of post-fire Douglas-fir regeneration. While further study is needed, the use of geo-rectified imagery in a GIS environment holds promise for more measurable, unbiased assessments that can be evaluated over broader landscapes.

Additional follow-up studies are planned that will more fully explore questions about Douglas-fir establishment and propagation into adjacent shrub communities under different site and disturbance conditions (e.g., past bark beetle outbreaks). The use of the 1945 imagery dataset shows promise for this and other ecological studies in Teton County, and elsewhere if similar archival photography can be made available.

Introduction

This pilot study tested the utility of historic aerial photography for an investigation of fire history and ecology in Rocky Mountain Douglas-fir forests in Northwest Wyoming. These lower montane forests, which often compose the wildland-urban interface, are shaped by fire and insect disturbance regimes that are poorly understood. Both frequent surface fires and infrequent stand-replacing crown fires occurred, but their relative frequency and distribution patterns across broad scales are uncertain. Bark beetles preferentially attack older, mature trees; many of which have survived low-severity fires in the past. In the last century, fire exclusion and suppression appears to have decreased surface and crown fires activity in these forests. The ecological impact of this potential reduction in fire is unknown, but two concerns for fuels managers are 1) ladder fuels have increased from increases in stand density, leading to increased potential for severe fire, and 2) Douglas-fir forests have encroached into former shrub-dominated areas, altering the historical forest / non-forest habitat mosaic. The occurrence of these phenomenon and any appropriate management treatments to mitigate or reverse effects are likely variable across space. With limited management resources to implement treatments, studies that build off the methods we describe here can identify where on the landscape treatments are of highest priority.

To examine the fire history and forest regeneration relationships in these areas, we used a set of historic aerial photos of Teton County, Wyoming, from 1945 to evaluate evidence of past disturbances and changes in forest cover over the past several decades (Figure 1). Two sites were chosen that featured apparent expansion of Douglas-fir forest into adjacent open areas that did not show trees in 1945 (Figure 2). Two additional sites were selected where the older photographs showed obvious landscape scars where even-aged Douglas-fir stands had developed adjacent to older stands with large crowns, possibly associated with past stand-replacing fire patches (Figure 3).

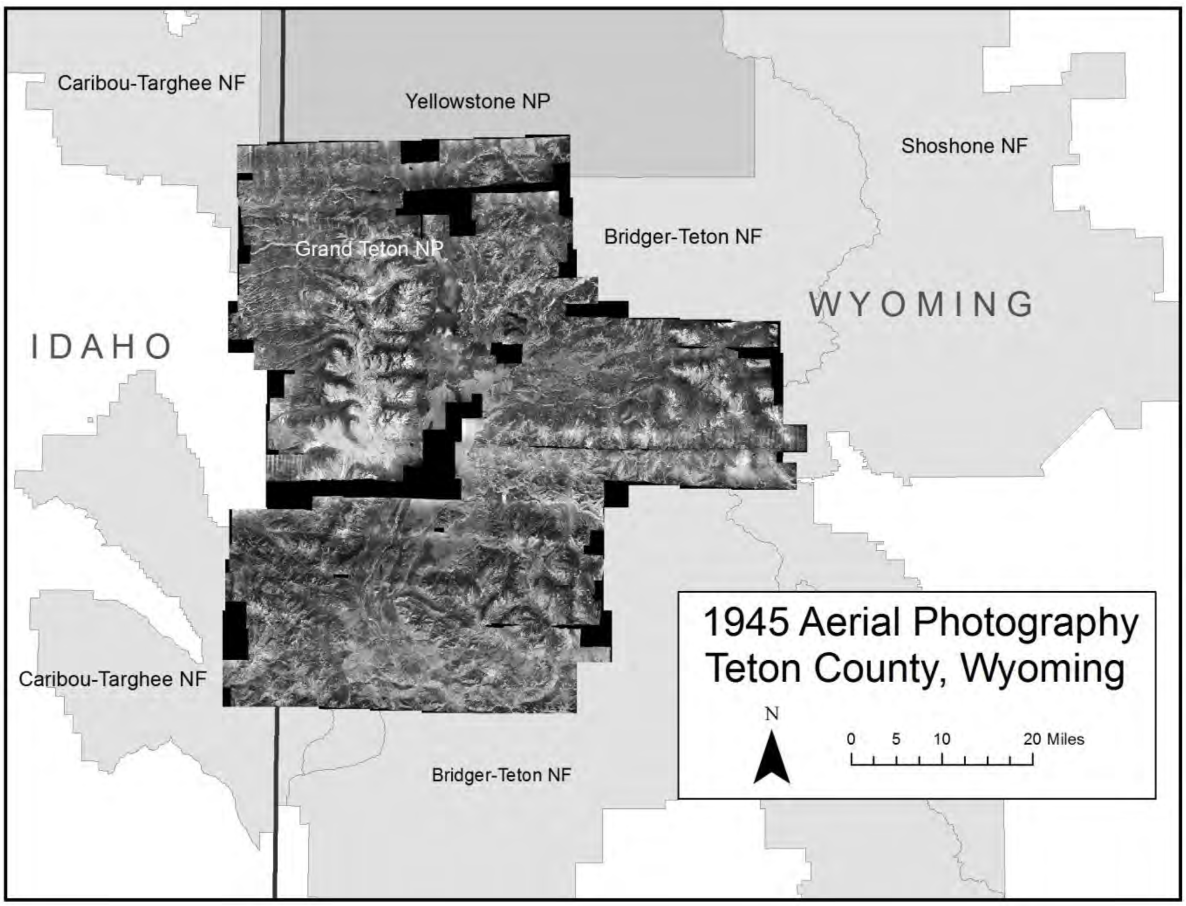


Figure 1. Extent of 1945 aerial photography for the area of Teton County, Wyoming

In areas where Douglas-fir appeared to have expanded into open shrub communities in the past decades, we collected tree age data form randomly-located plots to estimate how long the expansion has taken, and when it began. Preliminary evidence on potential causes of the forest expansion was investigated to determine if fire exclusion, climate, wildlife, or other factors could be involved. Finally, a general comparison of stand characteristics was made between the older and newer stands, to elucidate other potential influences.

Field Plots – Forest Expansion Areas

Older forest seen in 1945 Photographs, Lozier Hill Plot 1

Newer forest not evident on 1945 photographs, Lozier Hill Plot 7

Figure 2. Examples of field plot photographs from the newer and older locations at the Lozier Hill site.

Field Plots – Burn Scar Areas

Older forest adjacent to burn scar area evident in 1945 Photographs (Snow King Mountain Plot 3)

Newer forest in burn scar area seen on 1945 photographs (Snow King Mountain Plot 8)

Figure 3. Examples of field plot photographs from the Snow King site, where the 1945 air photographs showed evidence of a previous stand replacing fire.

Where the historic photos suggested a stand-replacing fire prior to modern record-keeping, we investigated stand age distributions and searched for evidence of past fire effects. We suspected that the older adjacent stands experienced low severity surface fire effects during the same event as the nearby stand replacing crown fire; thus, we collected a set of opportunistic fire scar samples (wedges) from the older stands. A comparison of general site characteristics and stand history between newer forest within the fire scar and adjacent older stands was made to help explain their juxtaposition and interaction.

Study Area

Grand Teton National Park and the Bridger-Teton National Forest surround Jackson Hole Valley, at the headwaters of the Snake River in Northwest Wyoming. Elevations range from 6,200 ft on the valley floor to mountain peaks over 12,000 ft. The climate is generally arid in summer with most precipitation falling in the form of snow in winter. Douglas-fir forests occupy foothills between aspen and sagebrush on and near the valley floor and mixed conifer forests in the higher calcareous mountains (Douglas-fir is replaced by lodgepole pine where nutrient-poor volcanic soils are found). Douglas-fir forest is often found growing on north-facing slopes where sagebrush or other shrub communities occupy sunnier aspects.

Fire history studies and historic journals describe a period of frequent and intense forest fires in Jackson Hole during the 1880's and 1890's. Photo comparisons between the settlement era and modern times show some increases in forest coverage, which has been linked to post-fire succession and possible departure from the historic fire regime. Few large fires burned in Douglas-fir forests until the 21st century. Since the 1945 aerial photos were taken, much of Douglas-fir forests along the public-private land interface has seen residential development and recreational use, which usually mandates immediate fire suppression.

Methods

Geo-rectification

A series of aerial photos taken in 1945 was discovered in the archives of Grand Teton National Park. The collection of 1,020 printed black-and-white photographs covered all of Teton County, with very few missing areas. With financial support from the Teton County Conservation District, the collection was scanned at 12,000 dpi resolution at the Western Archaeological and Conservation Center in Tucson Arizona. The photos were then mosaicked and rectified as MrSID raster layers.

GIS Application

The 1945 Aerial photo imagery was viewed in ArcGIS in combination with 2009 NAIP digital orthophotographs. In addition, vegetation maps of Grand Teton National Park and the Bridger-Teton National Forest were used to create a seamless GIS layer of Douglas-fir forest. By switching the viewer between past and present images, it was possible to select several study sites where Douglas-fir forest appeared to have spread into formerly open meadows (Figure 4), and where areas appearing to consist of younger, even-aged trees indicated old fire scars.

Several of the study sites were later rejected when it was discovered that lodgepole pine rather than Douglas-fir was the dominant forest type. The two forest types can be difficult to distinguish using air photos, and vegetation maps lacked sufficient detail in some areas.

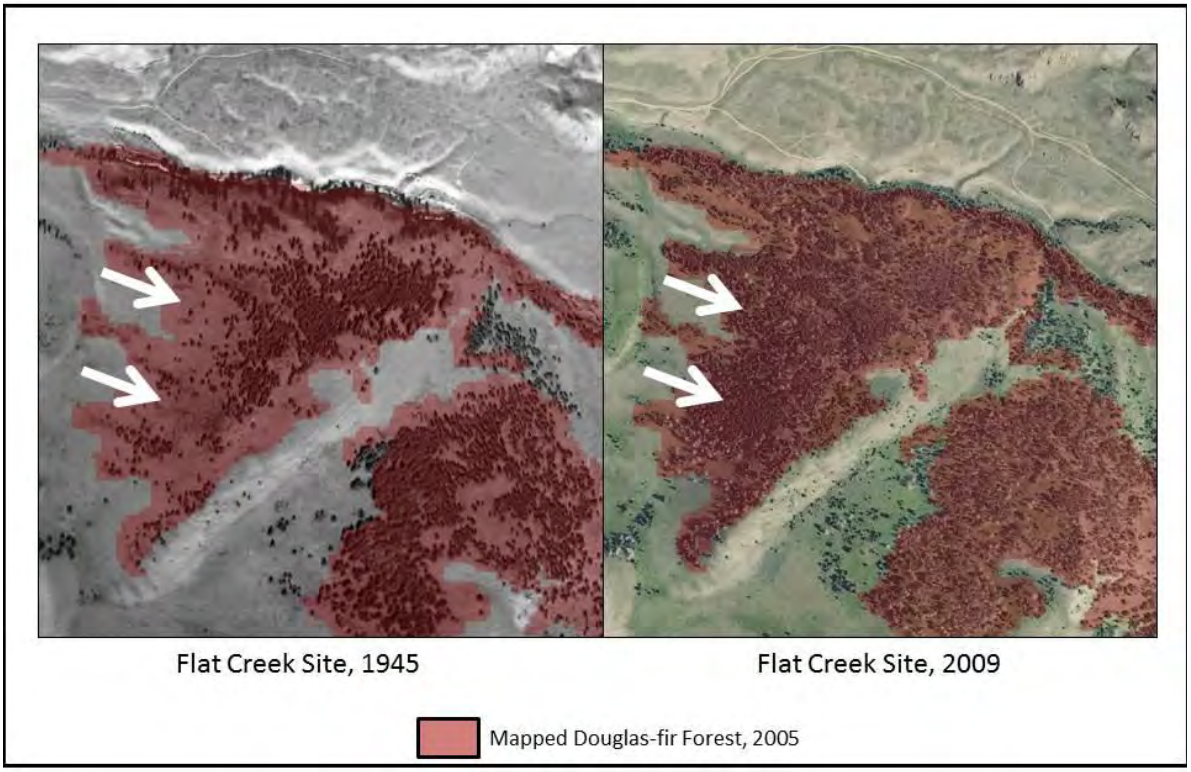


Figure 4. Side-byside comparisons of 1945 and 2009 aerial photographs show the extent of Douglas-fir forest expansion at the Flat Creek site.

Field Data Collection

Each study site (Figure 5) was designated with two polygons, one for the older, pre-existing forest and one for the post-fire regeneration or newly expanded forest.   Four randomly located plot locations were created in each polygon.

In the field, the nearest 16 trees to each plot center were identified by species, cored, and measured for diameter at breast height (dbh). Dead trees, downed logs, and seedlings were also counted. Evidence of fire was noted, and some wedge and cross-section samples were taken from fire scarred trees to facilitate backdating of fire events (Figure 5). Digital photographs were taken of each plot, and the topography, dominant understory plant community, and bark beetle infestation effects were recorded. Tree cores were processed in a dendrology lab at Oregon State University and crossdated using standard techniques.

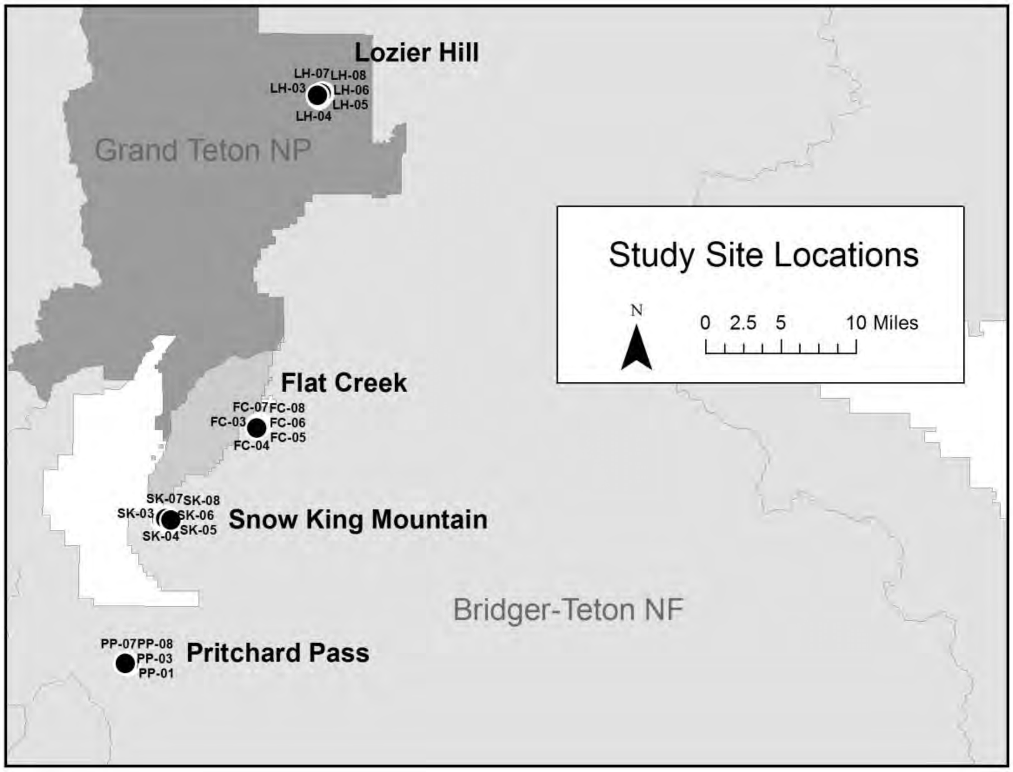


Figure 5. The Lozier Hill and Flat Creek sites featured areas where Douglas-fir forest has expanded into former shrub/meadow areas. The Pritchard Pass and Snow King Mountain sites focused on past burns with young replacement stands that were evident in the 1945 photographs.

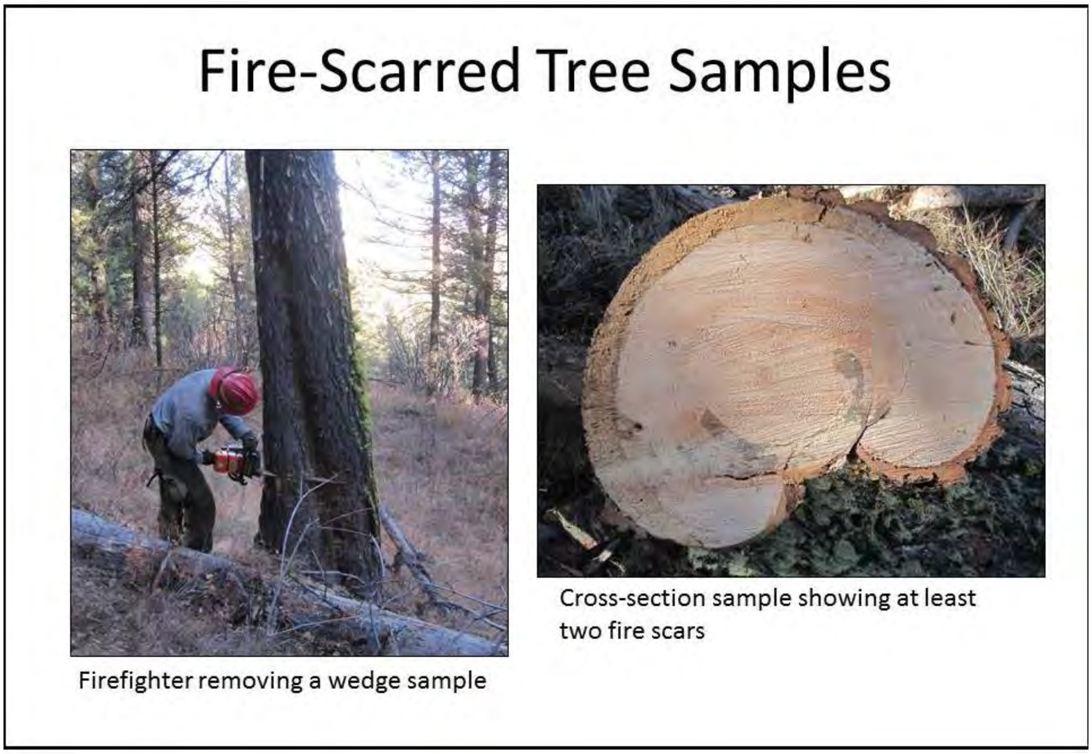
Results and Interpretation

At the study sites where comparisons of 1945 and 2009 imagery suggested that Douglas-fir had expanded into adjacent shrublands or meadows, tree age data indeed showed a younger forest. On one site, the new trees were fairly even-aged, while the other site a more gradual establishment process occurred. The older forest polygons included numerous fire scarred trees. Scar dates were mostly concentrated in the late 1800's and early 1900's. Evidence of past fires (scattered charcoal and charred stumps) was also found at many of the newer forest sites, but the 1945 photos did not show a signature of snags or logs that would occur in a recently burned forest. It is therefore difficult to know if Douglas-fir has encroached into previously unforested areas, or if it is just recovering at a very slow rate in previously-occupied locations. At both expansion sites, the newer forests were located on slightly warmer, drier sites (although greater statistical power is needed from a larger sample size to better evaluate this pattern). Forest regeneration may take much longer under those conditions than on shadier and moister aspects. Given the limited data available, it would be premature to attribute the Douglas-fir expansion to fire exclusion associated with human suppression policies.

As expected, fire scars evident on the 1945 air photos proved to be populated by younger, even-aged Douglas-fir forests. The surrounding older forests appeared to have experienced surface fires, with many fire scars and burned stumps. Based on comparisons between the tree ages in the new stands and adjacent fire-scarred tree dates, it probably takes 30-50 years for a Douglas-fir tree population to establish as 30 cm tall seedlings on a formerly-burned site. This is much longer than previously described for the Douglas-fir fire regime.

Stand-replacing fire patches were found on cooler, more northeast-facing aspects than the adjacent sites where only surface fires appear to have burned. If these fire events were coincident, this may be related to the moister conditions producing greater fuel accumulations which then would tend to burn hotter when the weather is hot and dry. Some stand-replacing fires also occurred on steeper slopes, where surface flames would have had more contact with the bases of trees and would more easily torch the crowns.

Without aerial photography showing the changes in Douglas-fir forest extent and structure over the 64-year interval, it would have been very difficult to recognize and assess these changes in a systematic way. Moreover, the landscape scars evident in the 1945 photos provided insight into stand-replacing fire patches that are otherwise not visible on the current landscape. Thus, the historic photographs highlighted patterns throughout the landscape that were not previously seen, and allowed us to investigate new questions about Douglas-fir disturbance ecology.



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Recommendations

More data from both of the types of Douglas-fir regeneration sites is needed in order to pinpoint the relationships between burn severity, topography, fire frequency, and other disturbance mechanisms. A better understanding of the timing and site factors of Douglas-fir regeneration would greatly inform our knowledge of the fire regime. In turn, land and fire management of these forests would benefit. In particular, prescribed fire could be applied with greater sensitivity to the drivers of mixed severity effects. Desired future conditions for Douglas-fir at the landscape level would better balance succession classes based on more accurate successional timelines and patch sizes. Burn planning and implementation would be less controversial if the effects of fire exclusion could be better described. As the climate warms and residential development continues to encroach into forested areas, this knowledge will be increasingly important.

Archival aerial photography, such as the 1945 Teton County set used in this pilot study, shows great promise for detecting and investigating ecological processes and fire regimes at the local and landscape scale. While scanning and geo-referencing require both time and money, the resulting imagery is highly valuable as a tool for resource management and scientific investigation.