THIRTY YEARS OF WILDLAND FIRE USE: EFFECTS OF MULTIPLE FIRES ON STAND STRUCTURE IN TWO SOUTHWESTERN WILDERNESS AREAS

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AUTHORIZATION TO SUBMIT THESIS

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Abstract

Land use change and fire exclusion have severely altered many southwestern ponderosa pine forests. Fire is an important component of forest restoration, but little is known about the effects of repeated wildland fires on forest structure. Ponderosa pine forest stand structure was measured in the Rincon Mountain Wilderness Area, AZ and the Gila Wilderness Area, NM in unburned, once, and multiple burned areas. Areas that had burned in the mid-century and then again under WFU were also compared. We observed significant differences in the number of small diameter trees between unburned areas and areas burned multiple times in both areas but no significant differences in numbers of large diameter trees. Areas that burned mid-century had significantly different tree size class distributions than all other treatments, suggesting that timing of fires in the last century has been critical to the development of current stand structures. In the Gila Wilderness, densities of large (>47.5 cm) snags were measured using line intercept sampling in once, twice and thrice burned areas. Mean snag densities were significantly higher in once burned areas but did not differ between twice and thrice burned areas, suggesting that repeated wildland fires may leave many large snags standing. Stand structure and snag sampling was stratified using digitized fire atlases. Landsat TM imagery was used to map two historical fire perimeters in the Gila Wilderness. Separability of burned and unburned areas for several common spectral indices and two novel thermally enhanced spectral indices were compared, and imagery-derived fire perimeters were compared with fire atlas perimeters for both fires. The thermally enhanced index NBRT performed slightly better than other spectral indices and correspondence between imagery-derived and atlas perimeters was high, generally confirming our snag and stand structure sampling for plots within those two fire perimeters.

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Thesis Introduction and Overview

Ponderosa pine (*Pinus ponderosa var. Laws.*) is one of the most broadly distributed tree species in North America, extending from Mexico to southern Canada. Evidence from pollen records and packrat middens suggest that current distributions have been the same for approximately the last 8000-11000 years. Evidence from pollen records, peat bogs, fire-scarred trees and charcoal implicates fire as a major disturbance agent in ponderosa pine forests. Tree ring studies suggest that for at least the last 500 years, fires have occurred frequently in ponderosa pine forests, with mean fire return intervals varying from 3-30 years.

Fire strongly influences the structure and function of ponderosa pine forests. Nutrient cycling, plant community composition, tree size distributions and spatial arrangement are largely determined by fire. It is now widely believed that prior to European settlement, fires in most ponderosa pine forests burned on the ground, consuming surface fuels and killing smaller diameter seedlings and saplings without damaging many of the thicker barked, large-diameter trees. Relatively frequent fires are likely responsible for the large trees and open forests found by early settlers in the southwestern United States. Early work by Weaver (1943), Cooper (1960) and then White (1985) fomented what has become an extensive body of literature which documents the role of fire in shaping the structure of ponderosa pine forest stands. Accounts from the early 1900's famously described ponderosa pine forests in New Mexico and Arizona as "park-like" and "open". Trees were large and widely spaced. Small diameter trees were thought to have been largely absent, and understory vegetation was abundant.

A suite of factors brought on mainly by the settlement of the west began to change the historically frequent fire regimes of the southwestern United States. Livestock grazing around the 1850's became intense and widespread. The resulting reduction in understory grasses that carried fires during the dry season had the effect of reducing fire size and spread. Roads, development and agriculture have all interrupted the continuity of fuels, reducing the size of fires. In the early 1900's, acting on the common perception that fire was detrimental to forest health, the Forest Service formally implemented a policy of fire suppression. This policy was extremely effective in the short term. Rather than removing fire completely, however, fire exclusion ultimately altered the fire regimes of many ponderosa pine forests in fundamental and dramatic ways. Dense surface fuels (needles, litter and duff) have accumulated. Pulses of tree seedling during wet years, without the thinning effect of fire led to higher densities of small-diameter trees than were thought to have occurred historically. The effects of unchecked seedling regeneration were exacerbated by selective logging or "high-grading", where more valuable large-diameter trees were preferentially harvested, leaving behind smaller trees. Ponderosa pine forests today are generally much denser. Average tree size is smaller, and tree density is higher.

The structural and ecological changes in many ponderosa pine forests across the western United States have significantly increased risks associated with burning. Changes in vegetation structure, composition and surface fuel loading have created conditions under which fire size, intensity and resulting post-fire effects are often extreme. As human populations have expanded along the margins ("wildland-urban interface") of fire-prone

forests across much of the West, large wildfires frequently threaten homes and human lives. Intense or severe fires can seriously impact and degrade ecological conditions by destroying overstory vegetation, altering belowground processes and enhancing soil erosion.

There is now a widely acknowledged need to restore fire to most ponderosa pine forests. Land management agencies now accept that fire is an important natural component of most ecosystems. Prescribed burning to reduce surface fuel loads and thin overstocked forests has become a common practice across the West. Mechanical thinning, especially along the wildland-urban interface has become a common practice as well. However, millions of hectares of ponderosa pine forests have been altered by years of fire exclusion. Thinning is expensive, and prescribed fire operations are typically small, (10's to 100's of hectares). Millions of acres of wilderness and primitive areas lack roads, making access and treatment of these areas impractical. In addition, most areas will require multiple treatments in order to sufficiently reduce surface fuel loads and tree density to levels where fires are less likely to become stand-replacing or catastrophic. These factors make the scale and magnitude of the challenge of restoring fire-excluded forests truly daunting.

In 1968, the National Park Service began a "Prescribed Natural Fire" or "Wildland Fire Use for Resource Benefit" (WFU) program. Under the WFU program, naturally ignited fires were allowed to burn in designated wilderness areas, where threats to homes and lives were minimal and adequate personnel and resources were available to manage or suppress fires, should they exceed acceptable boundaries. The first WFU fires burned in Kings Canyon National Park in 1968. The United States Forest Service soon followed suit. WFU is now

being implemented across the United States. In 2001, the Congressional Budget Office evaluated the costs associated with fire management and suppression and concluded that Wildland Fire Use was so cost-efficient, that each Forest Service unit should include a WFU Component in their fire management plan by the year 2004. With this mandate, and the successful implementation of WFU programs in some areas of the western United States, it now appears that WFU is destined to become the new paradigm in fire management. With this shift come new challenges and questions. Where and when can fires be safely applied without degrading ecological conditions? What are the effects of multiple fires on ecological and structural conditions? While thousands of fires have now burned in the United States under WFU, the effects of many of these fires have not been measured.

In 1974 and 1975, respectively, the Rincon Mountain Wilderness (a sub-unit of Saguaro National Park) and the Gila Aldo Leopold Complex implemented Wildland Fire Use programs. After more than 30 years of active WFU programs in both the RMW and GALWC hundreds of fires have now burned in both areas. These fires, along with older fires, have been carefully documented and recorded in digitized historical fire perimeter databases or "fire atlases". The rich history of fires in both places have created mosaic patterns of areas that have burned once, twice, thrice and in some places as many as 8 times in the last century. Surprisingly, the ecological effects of these fires have been little studied. The unique and well-documented histories of these areas make them ideal natural laboratories in which to study the effects of repeated historical fires and their timing on structural restoration of ponderosa pine forests in the southwestern United States. The objectives of this research project were to measure the effects of historical wildland fires on forest structure in the

GALWC and RMW. Specifically, our goal was to compare stand structure (tree density across size classes) and snag densities (snags/ha) between unburned, once-burned and multiple-burned areas.

This thesis consists of three manuscripts to be submitted for publication, with each manuscript comprising a chapter of the thesis. The first manuscript, which includes Dr. Penelope Morgan, Dr. Paul Gessler, Dr. Alistair Smith and Dr. Matt Rollins as co-authors, describes the use of Landsat TM imagery for mapping fire perimeters in the Gila Wilderness, NM, and the development and application of a novel spectral index for identifying burned areas. This manuscript was accepted for publication in April 2005 to The International Journal of Remote Sensing. The second chapter, which includes Dr. Penelope Morgan, Dr. Gerald Wright and Dr. Matthew Rollins as co-authors, compares snag densities in areas of the Gila Wilderness, NM that have burned one, two and three times. This manuscript has been submitted to Forest Ecology and Management for publication. The third manuscript, which includes Dr. Penelope Morgan, Dr. Matthew Rollins and Dr. Kathleen Kavanagh as co-authors, compares ponderosa pine forest stand structure in areas that have experienced zero, one, two and three wildland fires. The bibliographies for each manuscript vary according to specifications of the journals targeted for publication.