Contributions by the Rocky Mountain Research Station to the Four Forest Restoration Initiative: Silviculture, Wildlife and Watershed Management

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The 2.4 million acres of ponderosa pine (*Pinus ponderosa*) forests and the many resources that they provide are the basis for the wide range of interests and concerns relative to their stewardship by management agencies, special interest groups, and the general public. As might be expected, therefore, there are conflicts of interest among stakeholders. These conflicts often concern the impacts of tree cutting activities on non-market benefits such as wildlife habitats, streamflow regimes, and scenic beauty. A recent issue of conflict has been the application of prescribed or managed fires to reduce the large accumulations of flammable fuels that can cause damaging wildfires when ignited - especially ignitions in the wildland-urban-interface. However, silvicultural practices such as the application of prescribed fire or mechanical forest stand treatments that can reduce the accumulations of fuels are opposed by some members of society. Collaboration among the supportive but sometimes conflicting interests of the involved parties is necessary to resolve any difficult conflicts and thus provide more unified management of ponderosa pine forests.

Silvicultural Background

Natural ponderosa pine forests occur as irregular, uneven-aged stands consisting of small even-aged groups varying up to several acres in size (Pearson 1950, Cooper 1961, Schubert 1974). These forests can be open-grown and poorly stocked although many groups of trees are overstocked. Interspersed meadows and parks are common. Wildfires that frequently burned through the forests prior to European settlement affected natural regeneration and forest structure (Shepperd et al. 1983). Commercial exploitation of ponderosa pine forests began in the 1870s with completion of the transcontinental railroad. Early timber harvests removed 70 to 80% of the merchantable trees (Schubert 1974). Research results from Fort Valley provide a foundation for the Four Forest Restoration Initiative, a collaborative effort to restore the structure, pattern, and composition of ponderosa pine forests on 2.4 million acres in northern Arizona. Many of the stands in the forests are overgrown with thickets of small-diameter unhealthy trees that can fuel severe high-intensity wildfires. Much of the earlier silvicultural understanding of ponderosa pine forests in Arizona was done by USDA Forest Service scientists, many based on the Fort Valley Experimental Forest. This research contributed to the current restoration efforts.

Following increases in timber sales into the 1960s with removals generally one-third-to-two-thirds of the merchantable volume, the level of timber harvesting remained relatively flat into the 1980s.Timber harvesting began to decline in the early 1990s after a series of lawsuits filed by environmental organizations challenged many of the sales. These challenges evolved from a perceived failure of the Forest Service to adequately protect biological diversities and habitats for rare, threatened, and endangered species. A lack of merchantable trees and unfavorable market conditions also contributed to this situation. With curtailment of timber harvesting, the lack of active stand management resulted in unmanaged and undesirable changes in the structure, stocking, and growth of today's ponderosa pine forests.

Increases in the size and severity of large wildfires have also amplified changes in the structural character of the impacted ponderosa pine forests. Stands burned by high-severity fire have been damaged or destroyed and their ecological functioning has been disrupted. Stands burned at lower severities were impacted less. As a consequence, ponderosa pine forests consisting of a mosaic of stands that had burned at varying severities with intermingling unburned stands have been created. Large-scale infestations of bark beetles and other damaging insects have added to the present structural mosaic.

The objective of this paper is to review the role of silviculture, biological, and hydrologic research done by the Rocky Mountain Research Station scientists in developing the restoration initiative being initiated on four national forests in cooperation with local, state and national entities interested in improving the health of ponderosa pine forests in Arizona. Specific applications of silvicultural research are described for enhancing species habitats and evaluating hydrologic responses to treat-

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ments. The creation and development of the Four Forest Restoration Initiative are described.

Development of the Four Forest Restoration Initiative for Improving Forest Health

The recognition of rapidly declining forest health in ponderosa pine forests and the associated environmental degradation led to the initiation of efforts to improve the health of the forests by a joint effort of private, state, and federal wildland managers. Of particular concern was past fire exclusion which allowed dense and unhealthy stand of small-diameter trees to become established and increased the likelihood of high severity wildfires and insect and disease outbreaks.

The Four Forest Restoration Initiative (4FRI) is an example of applying silvicultural knowledge in collaborative management of ponderosa pine forests. In addition to the concerns about the potential for high severity wildfire and insect infestations, there also were concerns about protecting sites used by two threatened species – the northern goshawk (*Accipter gentilis*) and the Mexican spotted owl (*Strix occidentalis lucida*). Because of these issues, then Arizona Governor Janet Napolitano formed the Arizona Governor's Forest Health Council in 2003. The council was comprised of representatives of federal, state, and county management agencies, politicians and other decision-makers, academics, and environmental groups. Subsequently, the Statewide Strategy for Restoring Northern Arizona's Forests evolved in 2007 and became the basis for initiating forest restoration efforts by demonstrating the broad support in Arizona for landscape-level forest restoration efforts (Provencio 2013). These actions were largely prompted by the Rodeo-Chedeski Wildfire in 2002 that burned 465,000 acres of forests, woodlands, and shrublands on the White Mountain Apache Nation and Apache-Sitgreaves National Forests, and severely damaged or destroyed 400 homes and other buildings (Ffolliott et al. 2011). Another human-caused conflagration – the Wallow Wildfire in 2011 – burned 538,000 acres of forests and woodlands and destroyed 72 homes on the Apache-Sitgreaves National Forests. Occurrences of these two wildfires reinforced the need for increased and improved restoration activities. It was observed that stands that had been thinned before these wildfires occurred were largely left intact by the burning events. This observation led to increased interest in applying silvicultural treatments (prescribed fire, mechanical operations to reduce stand densities) to mitigate the often disastrous impacts of large wildfires.

The 4FRI is funded by the Collaborative Forest Landscape Restoration Program that was established in 2009. The vision of the initiative is to restore forest ecosystems that will support natural fire regimes while posing little threat for the occurrence of future large and destructive wildfires. Other objectives are to provide functioning communities of native plants and animals; protect critical watershed landscapes, and support forest industries that strengthen local economies while conserving natural resources and aesthetic values (U.S. Forest Service 2010). The initiative involves restoration treatments on the Kaibab, Coconino, Tonto, and Apache-Sitgreaves National Forests in northern and eastern Arizona. The operational plan for the initiative was developed with contributing inputs from representatives of federal, state, and county agencies and private institutions including environmental groups. Collaboration among management disciplines – especially those with responsibilities for forest, fire, and wildlife management – was essential in planning the initiative. The focus is placed primarily on thinning stands of small-diameter trees, creating small openings in forest overstories, and managing stand structures to reduce the accumulation of flammable fuels. By accomplishing these objectives, forests within the 4FRI area will be better protected from catastrophic wildfires (Wilent 2013).

The objective of the 4FRI is to implement restoration treatments on 2.4 million acres of ponderosa pine forests by initially treating 30,000 acres annually for 20 years. These acreages treated under 4FRI are in addition to the total acreage already treated by the respective national forests on an annual basis. The management plan for the 4FRI includes a call for the increased harvesting and thinning of forest stands and the use of prescribed fire to meet the restoration objectives. Sackett and Haase (2008) studied the use and impacts of prescribed fire in the ponderosa pine stands at the Fort Valley Experimental Forest. Another objective is to attract and support local wood-utilization industries to help in defraying the costs of the treatments through wood purchases while providing sustainable employment of the inhabitants of the neighboring communities. A private firm – Good Earth Power – assumed the contract to undertake the prescribed restoration treatments (Wilent 2013). The firm plans to construct a saw mill, pellet mills, and other processing facilities as part of the agreement. It is hoped that the initiative will achieve long-term and landscape-scale restoration (U.S. Forest Service 2010).

General Directives of the Initiative

Directives for the Coconino and Kaibab National Forests state that uneven-aged management of the forests will be emphasized while also prescribing even-aged systems to provide variations in stand structures and species diversity (McCusker 2013). Directives for the Tonto National Forest and the Apache-Sitgreaves National Forest are based on five-year plans (Hart, W; pers. comm.; April 2014). Trees will be cut to control dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) infestations, increase growth of residual trees, and improve tree-vigor and the resistance of these trees to insects and diseases. These efforts should also sustain or even improve biological diversities. Gambel oak (*Quercus gambelii*), juniper (*Juniperus* sp.), pinyon (*Pinus edulis*), especially larger trees, and quaking aspen (*Populus tremuloides*) trees will be retained to benefit wildlife species. Thinning from below will be recommended where feasible. Tree groups selected for regeneration will be located to achieve a diverse distribution of the groups. The general directives are to manage to ensure a sustainable level of nest/roost habitat distributed across the landscape (McCusker 2013). Tree harvesting is limited in other areas unless there is a silvicultural benefit such as reduced crown competition and increased growing space.

4FRI Treatment Impacts on Endangered Bird Species and Watersheds

Two impacts of the 4FRI treatments are considered in this paper. Protecting rare, threatened, and endangered species has been and will remain paramount in the thinking of managers responsible for implementing the treatments. A second impact relates to possible effects of the restoration treatments on streamflow regimes. High severity fires not only result in increased base flows but also in flood flows and erosion. The latter impact is considered to be significant by the authors of this paper because of its contribution in providing a water resource to the people of the state.

Protection of Rare, Threatened, and Endangered Species

Among the issues specifically addressed in the 4FRI, a very important one relates to the protection of rare, threatened, or endangered wildlife species. More specifically, silvicultural prescriptions in 4FRI are designed to protect or create Protected Activity Centers (PAC) areas for Mexican spotted owl and provide favorable habitat conditions for northern goshawk. The desired habitat conditions for Mexican spotted owls are a targeted basal area level of 150 ft^2/acre, 30% or more of total stand density index (SDI) in ponderosa pine trees equal to, or greater than, 18 inches in diameter at breast height (d.b.h.), 15% of SDI in ponderosa pine trees between 12 and 18 inches in d.b.h. ($\geq$20 trees per acre $\geq$18 inch d.b.h.), and $\geq$20 ft^2/acre of Gambel oak basal area (McCusker 2013). An average of two snags 18 inches in d.b.h. or larger will be retained on each acre. There are also recommendations for the retention of dead-and-down woody materials. Trees larger than 24 inches in d.b.h. will not be cut in Mexican spotted owl habitats. There also will be a 100-acre no-treatment zone around known nest or roost sites for the two species. Intermediate thinning would be prescribed to increase tree health and vigor and reduce fire hazard. Stands will be managed for irregular tree spacing to create canopy gaps and other conditions that would be conducive to low-severity prescribed fires.

The general directives for treating goshawk areas were developed from research by Reynolds and his associates (1992) from the Rocky Mountain Forest and Range Experiment Station and the Forest Service's Southwestern Region. The objectives for these areas are to manage for uneven-aged stand conditions for live trees and retain live reserve trees, snags, downed logs and woody debris. The goal is to sustain as much old-growth forest structure as possible, provide for groups of trees with interlocking crowns, and maintain a variety of forest densities. One idea is to maintain habitat for goshawk prey species. Desired habitat conditions for northern goshawk call for a highly interspersed and heterogeneous pattern of tree groups and sizes that are interspersed across the landscape (McCusker 2013). Groups of trees with interlocking crowns and the intermingling presence of Gambel oak and quaking aspen regeneration are also desired. Regeneration openings should account for 10 to 20% of tree groups. Tree groups of different age classes will be managed by retaining individuals and clumps of vigorous pine seedlings, saplings, and poles within larger mid-aged and older trees. More than 40 potential treatment options are being considered based on vegetative and site characteristics. Selected silvicultural prescription include single-tree selection, thinning, stand improvement; spacing between tree groups; site characteristics; and preferred Mexican spotted owl or northern goshawk habitat requirements. Wildland-urban-interface concerns have been recognized. Interspace requirements are indicated in the prescriptions.

Watershed Responses

High severity fires can result in increased base flows but also in flood flows and erosion. Immediate post-fire runoff and erosion are probably of more concern to watershed managers and hydrologists than is base flow or increased water yields because of the loss of soil and nutrients, decreases in site productivity due to erosion, possible downstream flood damage and the effects on downstream water quality because of the nutrients and suspended sediments. Hydrologists and watershed managers are interested in knowing how the 4FRI treatments involving applications of prescribed fire and mechanical thinning might impact the generation of streamflows in the treated ponderosa pine stands. Impacts on the generation of streamflow are generally smaller with prescribed fire treatments than those widely recorded for wildfire (DeBano et al. 1998). Unless one of the objectives of a fire prescription is to convert a forest to an herbaceous cover type, it is not necessarily a purpose of the fire to drastically modify the structure of a forest overstory to where there will be significantly less evapotranspiration losses and, therefore, more streamflow. At the same time, it is not necessarily a purpose of prescribed fire to consume all of the litter accumulations and other decomposed matter on extensive areas with the consequent alternations in streamflow regimes. Therefore, impacts of the prescribed fire treatments on the generation of streamflow are likely to be minimal. To further support this conclusion, annual stream flows were not significantly changed in the 6 years following a prescribed fire in the ponderosa pine forests on 43% of a watershed on Castle Creek (Gottfried and DeBano 1990). However, the main purpose of the Castle Creek treatment was to eliminate 40% of the heavy fuels and 70% of the fine fuels on the watershed, and it was achieved.

The effects of mechanical thinning on streamflow have been studied on the Beaver Creek watersheds (Baker and Ffolliott 1999) and the West Fork of Castle Creek (Gottfried et al. 1999). Silvicultural research at Fort Valley and its relationship to watershed management were summarized by Gottfried et al. (2008). Increases in annual streamflows of 12 to 30% occurred following the implementation of prescribed thinning and overstory clearing treatments on experimental watersheds at these two sites. The effectiveness of these treatments in increasing streamflow was largely related to the level to which the tree densities were reduced by thinning, the proportion of a watershed that was cleared of its overstory, or combinations of these two silvicultural interventions. However, the observed increases in streamflow were relatively short-lived from 4 to 20 years.

It is likely, therefore, that the 4FRI treatments will not affect the long-term generation of streamflow (Neary et al. 2008, Poff and Neary 2008). However, it is difficult to reliably predict the actual impacts of the 4FRI treatments on streamflow because of the varying nature of the prescriptions for the restoration treatments; site conditions; juxtapositions of the stands to be treated by these prescriptions; spatial locations of the restored stands within a watershed boundary; and sequencing of implementing the restoration treatments through time. The potential impact of climate change on forest watershed hydrology is also unknown. In matter of fact, these effects can only be hypothesized in the absence of instrumented watersheds.

Faculty and students at Northern Arizona University and their colleagues are planning on establishing 12 instrumented watersheds throughout the 4FRI areas in northern Arizona to ascertain the impacts of treatments on streamflow (Masik-Lopez 2014). The Salt River Project, which is responsible for water supplies in the Phoenix Metropolitan Area, is interested in the possibilities of 4FRI treatments resulting in increased water yields.

SUMMARY

Implementing silvicultural prescriptions on most public lands today involves collaboration among many stakeholder groups with often divergent views of what constitutes "good" silviculture. The 4FRI is a recent effort of applied silviculture for collaborative management of Arizona ponderosa pine forests. The emphasis at this time on the protection of listed bird species is a result of collaboration among the stakeholders. Support for the use of prescribed fire is another change in operating procedures for the management of ponderosa pine forests. Effects of the restoration treatments on the generation of streamflow appear largely minimal but maintaining other hydrologic values, such as soil surface protection, of the treated stands can be a realistic goal. Much of the scientific basis for the development of the specific recommendations in the Four Forest Restoration Initiative have been provided by the results of studies conducted by scientists of the Forest Service's Rocky Mountain Research Station. This includes a better understanding of silviculture, fire behavior, fire history, prescribed burning, watershed responses, runoff and erosion, and wildlife habitat in the ponderosa pine forests of Arizona.

The article focuses on two impacts that need particular consideration in program planning – the impact on rare, threatened, and endangered species and the impact on streamflow regimes. The need for careful collaboration and multi-disciplinary and skilled operational planning is obvious here if conflict is to be reduced. However, the overall picture is limited somewhat by the choice of these two impacts for primary consideration. The origin of the program rests in the desire to change the fire pattern in these forests and the impacts of the large and intense fires of the present. The benefits of such a program over a 20-year period may be hard to predict, whether in terms of habitat improvement, changes in watershed performance, numbers of homes destroyed, stand composition, acres burned, or fire budgets, for example. But the stakes are increasingly high and we need to move, increasing our knowledge and reducing our uncertainty as we go.

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