Ecological Restoration Institute

***Fact Sheet**: Estimating the Effects of Forest Restoration on Water Resources in Northern Arizona*

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Estimating the Effect of Forest Restoration on Water Resources in Northern Arizona

By Frances O'Donnell

Introduction

The ponderosa pine ecosystem is a vital source of water resources. Though they cover just 20 percent of the watershed area, about 50 percent of the water in the Salt River originates from areas covered by ponderosa forest. It is possible that restoration treatments will increase the amount of streamflow coming from forests. By reducing forest density, thinning treatments reduce the amount of water used by trees, allowing more to run off into streams and recharge into aquifers. They also increase open spaces where snow accumulates and melts rather than being intercepted by tree canopies where a large fraction evaporates. When forest restoration is performed over large areas through the Four Forest Restoration Initiative (4FRI), which proposes to treat 1 million of the 2.4 million acres of ponderosa forest in northern and eastern Arizona, the effect on flow in major rivers may be detectable. The objective of our study was to estimate the increase in streamflow that can be expected following restoration.

Methods

Because of the high amount of year-to-year variation, producing reliable estimates of streamflow through measurements in the field requires years of data collection. Therefore, actual measurements of restoration effects on streamflow are not currently available. As a substitute, we analyzed data from the Beaver Creek Experimental Watershed that was operated south of Flagstaff in the 1950s–80s (Figure 1). Scientists installed weirs to measure flow in small streams and performed experimental logging ranging from light thinnings to clearcuts on the forests upstream from many of the weirs. By monitoring streamflow following logging and comparing to both pre-treatment flow measurements and streamflow from untreated forest, they determined the increase in flow due to logging. We used mathematical modeling to develop an equation based on the Beaver Creek data that predicts the increase in streamflow following thinning.

Figure 1. Stream-gauging weir, Beaver Creek Experimental Watershed. *Photo courtesy Sharon Masek Lopez, Northern Arizona University*

Ecological Restoration Institute, P.O. Box 15017, Flagstaff, AZ 86011, 928.523.7182, FAX 928.523.0296, www.nau.edu/eri

Research Findings

The runoff increase depends on the amount of winter (October through April) precipitation received, how much basal area was removed by the thinning, and the time since the thinning was performed. Due to the regrowth of understory vegetation, increases in streamflow only persist for six to 10 years following thinning. Winter precipitation is the most important determinant of streamflow increase, and it is possible that no increase will be observed if conditions are dry in the years immediately following thinning.

While our approach provides a reasonable first estimate of the effect of restoration on streamflow, there are several issues that need to be addressed:

- The thinning techniques used at Beaver Creek were similar, but not identical, to modern forest restoration (Figure 2). Direct monitoring of restored forests is needed to determine if the effect on streamflow is different.
- It is possible that maintenance treatments—controlled burns and thinning to maintain an open forest structure—may be able to reverse the decline in streamflow increase that occurs in the years following thinning. However, no streamflow data have been collected following maintenance treatments, so their effect is unclear.
- A large majority of precipitation in ponderosa forests is returned to the atmosphere by plant water use and evaporation. This amount could increase in a warmer climate, reducing the potential for streamflow increases.

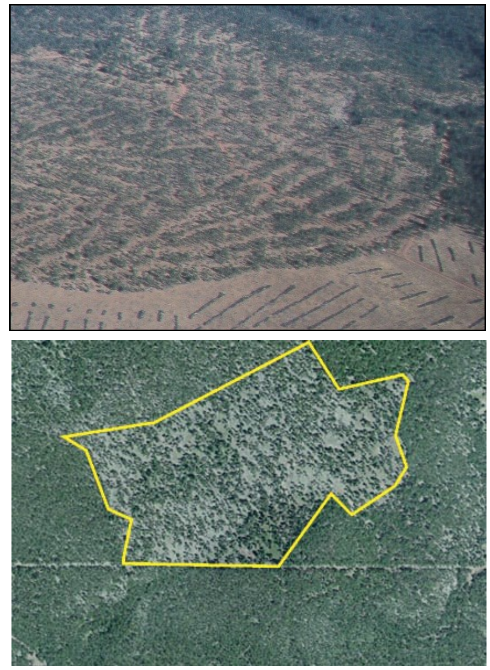

Figure 2. (Top) Strip-cut thinning, Beaver Creek. *Photo courtesy of USDA Forest Service.* (Bottom) Modern forest restoration, Centennial Forest, Flagstaff, Ariz.

Management Implications

- If 4FRI treatments are carried out as planned, an increase in runoff of up to 12 percent is possible, but the reliability of the increase is low. Little to no increase is expected in dry years when water resources are most stressed. Therefore, water resource managers should not rely on increases from forest restoration to meet demand.
- Streamflow increases are undetectable six to 10 years after treatment (Table 1), but the 4FRI is expected to take 20 years. Because only a fraction of the 4FRI treatment area will be producing increased streamflow at a time, managers of water resources from large rivers, such as the Salt and Verde rivers, should not expect large increases, even in wet years.
- Though more study is needed, our best hypothesis is that reducing understory regrowth following thinning will maximize runoff. Therefore, land managers wishing to maximize the hydrologic benefits of forest restoration should consider including maintenance treatments in restoration plans.

Years Since Treatment	0	1	2	3	4	5	6
Maximum Runoff Increase (inches)	1.9	1.7	1.5	1.3	1.0	0.8	0.6
Chance of No Increase	7.2%	9.2%	13.2%	17.1%	22.5%	28.5%	39.4%

Table 1. Model-based estimates of the maximum increase in runoff that can be expected and the chance that no increase will be observed in each year following a thinning treatment due to variability in precipitation. The values are based on the range of precipitation observed during the Beaver Creek Experimental Watershed Study.

Contact
Dr. Abe Springer, Abe.Springer@nau.edu