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Research article

Return on investment from fuel treatments to reduce severe wildfire and erosion in a watershed investment program in Colorado

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A B S T R A C T

A small but growing number of watershed investment programs in the western United States focus on wildfire risk reduction to municipal water supplies. This paper used return on investment (ROI) analysis to quantify how the amounts and placement of fuel treatment interventions would reduce sediment loading to the Strontia Springs Reservoir in the Upper South Platte River watershed southwest of Denver, Colorado following an extreme fire event. We simulated various extents of fuel mitigation activities under two placement strategies: (a) a strategic treatment prioritization map and (b) accessibility. Potential fire behavior was modeled under each extent and scenario to determine the impact on fire severity, and this was used to estimate expected change in post-fire erosion due to treatments. We found a positive ROI after large storm events when fire mitigation treatments were placed in priority areas with diminishing marginal returns after treating >50–80% of the forested area. While our ROI results should not be used prescriptively they do show that, conditional on severe fire occurrence and precipitation, investments in the Upper South Platte could feasibly lead to positive financial returns based on the reduced costs of dredging sediment from the reservoir. While our analysis showed positive ROI focusing only on post-fire erosion mitigation, it is important to consider multiple benefits in future ROI calculations and increase monitoring and evaluation of these benefits of wildfire fuel reduction investments for different site conditions and climates.

1. Introduction

Large, severe wildfires can negatively affect forested watersheds, jeopardizing critical ecological functions and ecosystem service benefits. These impacts include post-fire erosion and flooding, increased carbon emissions, loss of timber and non-timber forest products, loss of recreation access or quality, changes in habitat and biodiversity, and changes in scenic beauty (Kline, 2004; Mason et al., 2006; Loudermilk et al., 2014; Milne et al., 2014). Each of these effects can have substantial economic and social costs in addition to the direct costs of a wildfire, which include loss of life or property, fire suppression costs, and evacuation and administrative costs (Lynch, 2004). The prevalence, severity, and intensity of wildfire is increasing in the U.S. due to a combination of changing climate (Westerling et al., 2006; Flannigan et al., 2009; Van Mantgem et al., 2013; Rocca et al., 2014) and past fire suppression policies that led to the accumulation of fuels in many forest types (Stephens and Ruth, 2005). Coupled with an increasing number of homes in and near wildfire-prone ecosystems means the costs of federal fire management are also growing, and it is projected that 67% of the U.S. Forest Service's budget will be devoted to wildfire suppression by 2025 (USFS, 2015). These increasing costs affect the ability of federal agencies

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to meet other land management responsibilities and have led to repeated calls for more rigorous evaluation of the benefits and costs of wildfire risk reduction efforts (ERI, 2013).

Payments for ecosystem services (PES) are an increasingly important approach to conservation finance where the beneficiaries of ecosystem services pay for or incentivize the production of those services from ecosystem service providers (Wunder, 2015). The U.S. has more than 40 active PES programs focused on water related ecosystem services (Huber-Stearns, 2015), and this mimics a much broader global effort to increase government and private investments in securing watershed services from green infrastructure (Bennett and Carroll, 2014). Watershed investment programs are a specific type of PES program where downstream water users and upstream landowners collaboratively develop and fund activities to safeguard water supply (Ozment et al., 2016). A small but growing number of watershed investment programs focus on wildfire risk reduction (Bennett et al., 2014); experience with past fire events is often the catalyst for the creation of such programs (Emelko et al., 2011; Thompson et al., 2013; Bladon et al., 2014; Writer et al., 2014). For many of these programs municipal water providers are the primary beneficiaries and funders, and they are interested in reducing the large and direct costs to water delivery that occur following a fire (Ozment et al., 2016). One example of these costs is the effect of the Buffalo Creek and Hayman fires on Denver Water, in Denver, Colorado. The water utility spent more than $26 million post-fire on water quality treatment, sediment and debris removal, reclamation techniques, and infrastructure projects (Denver Water, 2016).

As a result of these high costs, Denver Water is involved in several watershed investment programs focused on wildfire risk reduction. It is part of the U.S. Forest Service's Forests to Faucets project, an arrangement between water utilities and the U.S. Forest Service that finances wildfire risk mitigation practices on federal lands that produce their source drinking water. In the Forests to Faucets partnership, Denver Water has spent over $11.5 million between 2011 and 2015 to conduct fuel reduction work and reforestation in previous high severity burn areas across three national forests and five watersheds, and they plan to invest an additional $16 million between 2016 and 2020 (Denver Water/USFS, 2014). Additionally, Denver Water is a key partner in the Upper South Platte Partnership (USPP); the USPP formed in 2015 to promote fire mitigation activities on private lands in the Upper South Platte watershed that complements work being conducted on federal lands through the Forests to Faucets program (CFRI, 2016). To date this partnership has raised millions of dollars to invest in wildfire risk mitigation. Colorado is not alone in these watershed investments to reduce wildfire risk, with similar efforts occurring in California, New Mexico, and Arizona (Bennett et al., 2014).

PES programs are increasingly being asked to provide evidence of the impact of their investments on ecosystem service outcomes as opposed to reporting implementation accomplishments (Ferraro and Pattanayak, 2006; Asbjornsen et al., 2015). However, few PES programs have conducted impact assessments, especially with more traditional economic frameworks such as cost-benefit analysis or return on investment (ROI) calculations (Boyd et al., 2015). Calculating ROI from wildfire risk reduction activities could aid watershed investment programs in demonstrating to stakeholders a need for proactive fire mitigation interventions that adaptively manage where and how much they invest and help secure additional funding. Financial and practical constraints limit the extent of wildfire risk reduction interventions, thus development of a system to prioritize management activities is crucial. In this paper we used a ROI framework to identify how the quantity and placement of wildfire risk reduction interventions would affect ROI in the Upper South Platte River watershed, southwest of Denver, Colorado. The Upper South Platte River watershed is a high priority site for Denver Water, as 80% of the water used by the 1.4 million residents of the Denver metropolitan area passes through this watershed. A series of large, severe wildfires have adversely affected water quality and sediment delivery to the main reservoir in the past (e.g., Moody and Martin, 2001).

Our overarching research question was: how do the quantity and placement of wildfire mitigation activities affect ROI? To answer this question we simulated fuel reduction activities (e.g., mechanical tree thinning), allowing the extent of fuel mitigation activities to vary between 5% and 100% of forested area within the watershed using the following placement strategies: (a) a strategic prioritization map and (b) accessibility. Potential fire behavior was modeled under 97th percentile fire weather conditions for each fuel mitigation placement scenario to determine the impact of fuel reduction interventions on predicted fire severity. We then calculated the expected change in post-fire erosion with and without fuel treatments for each of these modeled fire scenarios and used this to estimate the economic benefits and costs of investing in pre-fire wildfire risk reduction activities. The modeling approach presented here can be adopted for other PES programs to inform decisions about investments in wildfire risk reduction activities aimed at enhancing the resilience of forested watersheds to wildfire.

2. Background

Quantifying the impact of wildfire risk mitigation efforts on the probability of large, severe wildfires and their associated post-fire costs is a complex and challenging endeavor (ERI, 2013; Kalies and Kent, 2016). In the case of mitigating post-fire water quality impacts, the benefits from wildfire risk reduction depend on their ability to: (a) reduce the severity and/or probability of wildfire; (b) mitigate post-fire water quality outcomes such as erosion, debris flows, and increased chemical levels; and (c) reduce the costs to water utilities or other beneficiaries resulting from degraded water quality, loss of reservoir storage capacity, sediment removal from water intake facilities, and damage to infrastructure (Fig. 1). The estimated human benefits are highly dependent on the presence of wildfires and the magnitude of the precipitation after a fire. The type, quantity and placement of fuel reduction interventions within the watershed can influence the likelihood that any one of these outcomes will occur (Kalies and Kent, 2016; Sidman et al., 2016).

The decision of how much and where to invest can be informed by understanding the ecological, hydrological, and socioeconomic conditions of the watershed as well as the interactions among these. For example, a watershed investment program is likely to yield the most watershed service benefits in areas with potential for high severity wildfire resulting in complete overstory tree mortality and minimal ground cover, biophysical conditions that favor erosion and high sediment delivery (e.g., steep slopes, erodible soils, frequency and severity of rainfall, etc.), and where existing water infrastructure is susceptible to post-fire watershed impacts. Related to the latter point, each water utility or other beneficiary has different vulnerabilities to wildfire impacts due to both geographical characteristics such as spatial location of reservoirs and infrastructure and the type of gray, or built, infrastructure already in place to deal with these post-fire events. Therefore, spatial prioritization is critical for assessing the areas at highest risk and the associated placement of wildfire risk reduction efforts (Thompson et al., 2013).

Predicting the outcomes of wildfire risk reduction efforts requires linking potential fire behavior to runoff and erosion models to calculate the impact on watershed services that would occur with and without these efforts. Very few studies have tried to show