Final report, Joint Fire Science Program 2005-2 Task 1 Locally important knowledge or data gaps

Project Title: The effect of wildfire on nitrogen dynamics within headwater ecosystems

Project ID: 05-2-1-41

Project Location: Boise National Forest: Canyon Cr Fire Lowman RD, South Fork fire Cascade RD and Danskin Cr Emmett RD. Payette National Forest Hall Fire, Council RD.

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MAIN FINDINGS TO DATE

- **The nitrogen dynamics in upslope and riparian ecosystems are tightly coupled.**
- **The increase in soil nitrogen post fire is due to lower nitrogen *consumption* rates in burned soils relative to unburned soils.**
- **The increase in soil nitrogen post fire is quickly taken up by regenerating plant species.**
- **The soil and water nitrogen effects of prescribed fires do not mimic the nitrogen dynamics of wildfires.**
- **Stream water nitrate concentrations were about two orders of magnitude higher in burned than in unburned watersheds during spring runoff without a decreasing trend over the three-year study period.**
- **Trees that survive wildfire have a reduced capacity to conduct water to their foliage. However, the loss of leaf area due to crown scorch compensates for the loss of hydraulic conductance resulting in normal stomatal function.**
- **These findings will improve the prioritization for restoration activities post fire and determining the target severity for prescribed fires.**

DETAILS BEHIND THE MAIN FINDINGS TO DATE

Changes in upslope soil carbon post fire impact nitrogen cycling.

Forest fires often increase soil nitrogen (N) content for several years. However, we do no know the cause of this increased soil N We investigated gross inorganic N fluxes in mineral soil two years after three wild fires in central Idaho coniferous forests to determine the causes of the elevated soil nitrate (NO_3^-) By understanding the cause and fate of this increased essential nutrient we can better prioritize restoration activities. We monitored soil N production and consumption rates post fire along with key factors that could affect the gross N fluxes, including temperature, soil water contents, pH and available C. We found that there were no significant differences in NO_3^- production rates between burned and control soils. However, NO_3^- *consumption* rates were significantly lower in burned soils than control soils. The decoupling of supply and demand of NO_3^- in burned soils almost certainly caused elevated NO_3^- contents relative to controls. Among the measured key factors, available C was the most significant predictor for NO_3^-

consumption rates with low soil C post fire. In addition, there were no significant differences in ammonium (NH_4^+) contents between burned and controls soils. The NH_4^+ fluxes in burned soils were, however, significantly lower than the controls and the fluxes were positively correlated with available C. We conclude that availability of C is the main factor that regulates inorganic N dynamics in soils burned by forest fires in coniferous forests of central Idaho. Restoration of soil carbon will occur with establishment of vegetation and the renewal of below ground carbon inputs.

Nitrogen dynamics in riparian forests and adjacent aquatic ecosystems respond differently to wildfire relative to prescribed fire.

Soil N dynamics

Riparian forests along headwater streams in the inland Northwest, USA were historically subject to wildfires. More recently, fire suppression has led to accumulation of fuels in the forests of this region. Prescribed fires have been used to reduce fuel loads, and thus, the chances of catastrophic fires. However, prescribed fires in riparian forests have not been widely practiced due to the uncertainty and lack of knowledge about their impacts on aquatic ecosystems. We investigated the effects of fires on gross fluxes of inorganic nitrogen (N) in mineral soils of riparian forests using ^{15}N isotope pool dilution. We also compare the difference between wildfires and prescribed fires and their relative effects on N processes. We found elevated soil NO_3^-contents in burned soils compared to controls in both wildfires and prescribed fires. Elevated NO_3^- contents were caused by significantly reduced microbial NO_3^- uptake in burned soil. There was no significant fire effect on soil NH_4^+ contents in either wildfires or prescribed fires. However, the gross NH_4^+ fluxes were significantly reduced in soils burned by wildfires relative to their controls. There were no such effects on NH_4^+ fluxes in soils burned by prescribed fires. We concluded that measurements of gross N fluxes are necessary to assess impacts of fires on N dynamics in soils. The differences in timing and intensity between wildfires and prescribed fires may explain observed effects on N processes in riparian forests and aquatic systems.

Stream N inputs following wildfire and prescribed fire.

In this study we link soil and stream water nitrogen (N) concentrations and the cascading effects on N concentrations in understory plants and aquatic biota following wildfire. Soil ammonium (NH_4^+) concentrations increased about ten-fold and nitrate (NO_3^-) concentrations increased from below detection limit to 9.4 ± 5.4 mg NO_3^--N kg^{-1} in burned relative to unburned watersheds in the first post-fire year (PFY 1). Streamwater NO_3^- concentrations were about two orders of magnitude higher ($P < 0.05$) in burned than in unburned watersheds during spring runoff without a decreasing trend over the three-year study period. Increased soil and streamwater inorganic N concentrations post-fire were not temporally coupled. Increased soil N represented the net effect of microbial and plant activity over the growing season, whereas the streamwater N was due to flushing of winter and early spring mineralization products before the onset of the growing season. The increases in available N post-fire led to significantly increased ($P < 0.05$) foliar N concentrations in all terrestrial upland species (0.8 % absolute difference between burned and unburned watersheds in PFY 1) and in-stream moss (0.9 % absolute difference across all PFYs) for the same durations as increases were observed in soil and streamwater.

Higher foliar N concentrations in terrestrial plants and in-stream moss represent analogous and important N retention mechanisms. The simultaneous study of many components of watershed ecosystems revealed the importance of complex interactions between biotic, abiotic and hydrological factors influencing post-fire N retention and loss after wildfire. The temporal disconnect between major losses of available N from the soil during snowmelt and the onset of the growing season highlighted the importance of aquatic N retention.

Tree damage and mortality.

Wildfires are a natural and ubiquitous component of forested ecosystems in the northwestern United States. However, wildfires can have potentially dangerous impacts on the water movement in vegetation, which can ultimately lead to mortality or a prolonged state of decline. This replicated study analyzed physiological data from a number of partially-burned conifers found in burned areas of moderate burn severity and compared them to neighboring unburned controls throughout the growing season. Since this study focused on analyzing physiological measurements that influenced the water use efficiency of conifers, measurements of leaf specific conductivity (K_L), stomatal conductance (g_s), soil water potential ($\Psi_{predawn}$), and ^{13}C discrimination ($\delta^{13}C$) were collected from three different wildfire sites located in central Idaho in order to monitor any changes in the tree performance of mature coniferous trees as a result of the fires. Finally, $\delta^{13}C$ was assessed for the understory *Spirea betulifolia* shrubs that survived the wildfires and compared with neighboring controls. Leaf specific conductance did not vary significantly with treatment or throughout the summer. In addition to this, neither midmorning nor midday stomatal conductance (g_s) was impacted by the burn treatment or by time throughout the summer. Although there was no difference in soil moisture contents ($\Psi_{predawn}$) between the treatments, $\Psi_{predawn}$ was influenced significantly by time and became drier throughout the summer. ^{13}C discrimination did not vary with treatment or by year for the conifers. Although leaf area within the partially-burned trees was reduced, there was no shift in g_s, K_L, or $\delta^{13}C$, indicating that hydraulic conductance within the partially-burned trees was reduced. Consequently, the reduction in leaf area compensated for the loss of hydraulic conductivity and allowed the partially-burned trees to maintain a constant g_s, K_L, and water-use efficiency throughout the summer. On the other hand, the shrubs located within the burned plots were significantly more enriched in ^{13}C than their adjacent controls. In conclusion, our research showed that the internal hydraulic conductances of the partially-burned conifers were reduced by the wildfires, yet those trees were able to maintain productivity levels by reducing their leaf area. However, the understory shrubs in the partially-burned treatments increased their water-use efficiencies, which may have been due to an increase in photosynthetically active radiation, PAR, reaching the surface and available nitrogen in the soil which ultimately can lead to an increase in photosynthetic capacity in the understory.

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DELIVERABLES

Proposed	***Accomplished/Status***
Annual progress reports	Annual progress reports completed
Series of 4 or more journal papers	1) Stephan, K and Kavanagh K. submitted. Suitability of the diffusion method for low concentrations of ammonium and nitrate in KCL extracts for 15N analysis at natural abundance. Soil Science Society of America Journal. 2) Stephan, K. Kavanagh K and Koyama A. *To be submitted Nov 2007*. Fate of nitrogen in watershed ecosystems after wildfire in central Idaho: A Multi-year replicated study integrating terrestrial and aquatic ecosystem components. Submit to Ecosystems. 3) Stephan, K., Kavanagh K.L and Koyama A. *To be submitted Jan 2008*. Impact of fire severity on watershed nitrogen cycling using ^{15}N natural abundance in terrestrial and aquatic ecosystem components. Submit to Biogeochemistry. 4) Koyama, A. Kavanagh, K. and Stephan K. *To be submitted Dec 2007*. Wildfire effects on soil gross nitrogen fluxes in coniferous forests of central Idaho, USA. Submit to Nature. 5) Koyama, A. Kavanagh, K. and Stephan K. *To be submitted Dec 2007*. Fire effects on gross inorganic N fluxes in riparian soils in coniferous forests of central Idaho, USA. Wildfires vs Prescribed fires. Submit to Soil Biology and Biochemistry. 6) Thompson, M.T. Koyama, A. and Kavanagh K. *To be submitted Nov 2007*. The effects of wildfire on hydraulic properties in conifers. Submit to Forest Ecology and Management.

Proposed	***Accomplished/Status***
Lab web site with preliminary results linked to JFSP website.	Web site was created www and preliminary results were posted. http://www.cnr.uidaho.edu/jfsp/ We will link this site to JFSP and FRAMES.
Short course to resource professionals containing results of this research.	This research has been presented at 2 short courses. 1) Spring 2006. USFS Fire Mangers Boise ID, 2) Spring 2007. Intermountain Forest Tree Nutrition Coop Annual Meeting. Title. Presentation of results to USFS, BLM, State Agency and private landowners of the region.

Results from this research incorporated in coursework at U of I.	This research has been presented in the U of I Fire Ecology course taught by Dr. Penny Morgan. The graduate students on this project served as guest lecturers for 2 years. Results of this research were used to develop an online lecture covering fire effects as part of the online FOR 401 series from the U of I. http://401series.net/. The success of this research contributed to the development of the first BS in Fire Ecology and Management in the Country. This major began at the University of Idaho in Fall 2007.

Proposed	*Accomplished/Status*
Presentations at JFSP PI meetings and national ESA.	Three posters from this research were presented at the 3rd International Fire Ecology and Management Congress, San Diego. 2006. There was no JFSP PI meeting in 2006. I did attend the 2005 JFSP 2005 meeting but was not assigned a presentation. Three posters form this research were presented at the Ecological Society of America meetings in Montreal, CA 2005 and Memphis TN 2006.