

00-2-05

Final Report on Joint Fire Science Activities

University of Nevada, Reno

D.W. Johnson, W.W. Miller, R.F. Walker

Updated 26 Jan 2006

RECEIVED

APR 30 2008

JFSP - NATIONAL
INTERAGENCY FIRE CENTER

I. Introduction

The University of Nevada, Reno, component of this project was combined with other projects funded by the Nevada Agricultural Experiment Station that involved treating study plots in the Tahoe Basin for biomass removal by mechanical treatment and/or prescribed fire, and to increase the associated outreach activities. The overriding goal of our research is to formulate an adaptive management strategy for improving forest health in the Lake Tahoe Basin and eastern Sierra Nevada that incorporates protection of critical watershed values. Supporting objectives are to evaluate the effects of understory biomass thinnings and prescribed fire on stand health and productivity, site nutrient status, and soil physical properties that influence infiltration, percolation, runoff, and groundwater discharge.

Specific objectives and the extent to which they were met are listed below

Forest Health Task:

1) Inventory of forest floor and understory and overstory vegetation, including duff and litter, coarse woody debris, herbaceous vegetation, shrubs, seedlings, saplings and trees. Outcome: Pretreatment and posttreatment inventory completed for both sites (South Lake Tahoe and Truckee). Paper submitted to Annals of Forest Science dealing with all pretreatment inventory data from South Lake Tahoe site and a second paper submitted to the Journal of Sustainable Forestry dealing with pretreatment and posttreatment duff, litter, and coarse woody debris (ground fuels) data at the Truckee site. Papers presented at the 2003 North American Forest Ecology Conference and 2004 Tahoe Environmental Concerns Conference on all pretreatment data from South Lake Tahoe and another two papers presented at the 2005 National Silviculture Workshop on the ground fuels data and mensurational data from Truckee.

2) Ecophysiological investigation of moisture stress as influenced by treatment, including xylem and soil water potentials.

Outcome: Measurements completed at both sites. Paper submitted to the Journal of Sustainable Forestry dealing with treatment effects on water relations at the Truckee site. Papers presented at the 2003 North American Forest Ecology Conference and 2004 Tahoe Environmental Concerns Conference on treatment (wildfire) effects on water relations at the South Lake Tahoe site.

3) Survey of bark beetle activity as influenced by treatment.

Outcome: Survey completed at both sites. Paper submitted to the Annals of Forest Science on bark beetle infestation and resulting mortality at the South Lake Tahoe site

and papers presented at the 2003 North American Forest Ecology Conference and the 2004 Tahoe Environmental Concerns Conference on same.

4) Fire effects on bole char and crown scorch with subsequent influence on tree mortality. Outcome: Measurements completed at both sites. Manuscript completed for submission to the Journal of Sustainable Forestry from data collected at the Truckee site and a paper presented at the 2005 National Silviculture Workshop on same.

Nutrient Cycling Task

1) Inventory N and P pools in the ecosystems to be studied (vegetation, understory, forest floor and soil)

Outcome: Completed for all sites

2) Estimate N and P export via biomass removal by re-inventorying after harvest

Outcome: Completed for Truckee site, not needed for Gondola site because of unexpected wildfire.

3) Estimate N and P export due to volatilization with prescribed fire using the Ca:N and Ca:P ratio methods (Caldwell, 1999)

Outcome: Completed for all sites.

4) Measure soluble N and P export in soil solution using tension- and resin-lysimeter methods (Johnson et al., 1997; Susfalk, 2000)

Outcome: Completed for all sites

5) Estimate N fixation.

Pending, requiring further data needs for assessment of long-term trends in N fixer growth at the sites.

Soil Physics Task:

1) Investigate the spatial distribution of soil infiltrability and water balance parameters as affected by season and treatment parameters.

Outcome: Seasonal infiltrability measurements are in progress. Measurement of water balance parameters is conducted annually.

2) Characterize soil water repellency, measure surface soil bulk density, and profile excavation for hydraulic assessment.

Outcome: Initial and post-treatment characterization completed. Annual characterization is ongoing. Profile excavation was determined infeasible.

3) Collect, measure, and determine the chemistry of overland/litter interflow relative to study site and treatment using a prototype collection device (Miller et al., *In Press*).

Outcome: Ongoing, measurements are conducted annually.

Forest Health Task:

1) Inventory of forest floor and understory and overstory vegetation, including duff and litter, coarse woody debris, herbaceous vegetation, shrubs, seedlings, saplings and trees.

Outcome: Pretreatment and posttreatment inventory completed for both sites (South Lake Tahoe and Truckee). Paper submitted to Annals of Forest Science dealing with all pretreatment inventory data from South Lake Tahoe site and a second paper submitted to the Journal of Sustainable Forestry dealing with pretreatment and posttreatment duff, litter, and coarse woody debris (ground fuels) data at the Truckee site. Papers presented

at the 2003 North American Forest Ecology Conference and 2004 Tahoe Environmental Concerns Conference on all pretreatment data from South Lake Tahoe and another two papers presented at the 2005 National Silviculture Workshop on the ground fuels data and mensurational data from Truckee.

2) Ecophysiological investigation of moisture stress as influenced by treatment, including xylem and soil water potentials.

Outcome: Measurements completed at both sites. Paper submitted to the Journal of Sustainable Forestry dealing with treatment effects on water relations at the Truckee site. Papers presented at the 2003 North American Forest Ecology Conference and 2004 Tahoe Environmental Concerns Conference on treatment (wildfire) effects on water relations at the South Lake Tahoe site.

3) Survey of bark beetle activity as influenced by treatment.

Outcome: Survey completed at both sites. Paper submitted to the Annals of Forest Science on bark beetle infestation and resulting mortality at the South Lake Tahoe site and papers presented at the 2003 North American Forest Ecology Conference and the 2004 Tahoe Environmental Concerns Conference on same.

4) Fire effects on bole char and crown scorch with subsequent influence on tree mortality.

Outcome: Measurements completed at both sites. Manuscript completed for submission to the Journal of Sustainable Forestry from data collected at the Truckee site and a paper presented at the 2005 National Silviculture Workshop on same.

Outreach

1) Cooperation with the Western Area of Nevada Cooperative Extension (NCE)

Outcome: Web page development (see citation below).

2) Public presentation of results via a variety of NCE delivery methods, including landscape professional certification programs, defensible space curriculum guides, and integrated landscape management workshops for property owners.

Outcome: Regular participation in programs sponsored by the Lake Tahoe Environmental Education Consortium (LTEEC) a joint Nevada and California Cooperative Extension Service organization.

3) Field tours, attractive interpretative signs and displays, and additional interactions with local public interest groups in the Tahoe Basin in cooperation with NCE.

Outcome: Many tours and presentations given (see citations below).

II. Summary of Results

The results of our studies are presented according to: 1) the Truckee, CA, mechanical/prescribed fire study site; 2) the Gondola, Stateline, NV, wildfire study site; and 3) an overlapping modeling component not included in the original proposal.

Outreach activities are also summarized.

A. Truckee Mechanical/Prescribed Fire Site

In cooperation with the U.S. Forest Service, Truckee Ranger District, Tahoe National Forest, we have installed five replicated plots of each of the following six treatments in an eastside pine stand near Truckee, CA, on soils of volcanic origin: (1)

control, (2) burn, (3) thin and cut to length, (4) thin and cut to length plus burn, (5) thin and whole tree harvest, (6) thin and whole tree harvest plus burn. All vegetation, understory, and woody litter on these plots has been inventoried and soils have been sampled prior to the controlled burn which took place in June of 2002, fulfilling objectives 1, 2, 3, and 4 in the Nutrient Cycling component and portions of objectives 1 and 2 of the Soil Physics component. During 2002-2003 and 2003-2004 and 2004-2005, we have collected soil solution (ceramic cup lysimeters), cumulative soil flux of nitrogen and phosphorus (using resin lysimeters), rainfall precipitation, snowmelt, and surface runoff (in small runoff plots within a subset of the treatment plots), fulfilling objective 4 in the Nutrient Cycling component and objectives 1 and 3 of the Soil Physics component. This data is being used along with data from the control plots to assess the effects of prescribed fire on stand production, soil nutrient status, water balance and discharge water quality.

Results to date have shown that prescribed fire resulted in significant decreases in forest floor C and N contents in all treatments, significant losses of forest floor S in the cut-to-length treatment, and significant losses of forest floor K in the whole-tree harvest treatment. Burning caused significantly higher pH, water-extractable ortho-P, bicarbonate-extractable P, and water-extractable SO_4^{2-} in some horizons of some treatments, but these effects were generally, small and, in the case of ortho-P, much less than the temporal variation in both burned and unburned plots. There were no statistically significant effects of burning on soil C, N, C:N ratio, Bray-extractable P, exchangeable Ca^{2+} , K^+ , or Mg^{2+} . Burning had no significant effect on soil solution pH, ortho-P, SO_4^{2-} , NO_3^- , or NH_4^+ as measured by ceramic cup lysimeters and no effect on the cumulative leaching of ortho-P, NO_3^- , or NH_4^+ as measured by resin lysimeters. Burning had no effect on needle weight or nutrient contents as measured by the vector analysis. We conclude that the major effect of prescribed fire on the site was on the loss of N from the forest floor, and the Ca data indicated that the Ca ratio method was adequate for estimating such losses in this case. At this stage, we have only minimal estimates of N fixation rates in the form of biomass and N content of N-fixing species (*Purshia tridentata* and *Ceanothus prostratus*).

We have detected consistently measurable amounts of inconspicuous nutrient laden surface runoff in the form of both overland flow and litter interflow (Miller et al., *In Press*). Concentrations of biologically available N (NO_3^{-1} -N, NH_4^{+1} -N) and P (PO_4^{3--} P) in the runoff were 2.5-3 orders of magnitude greater than those measured in the corresponding snow and soil solution. The 3-year database is currently being analyzed as to the effects and interactions among treatments. Data clearly suggest, however, that these nutrients are derived from the mature O-horizons, and that there has been little contact with the mineral soil or rootzone where strong retention and/or uptake of these ions would be expected. We lack as yet a clear delineation of the area from which the runoff originates. What we do know, however, is that water with high nutrient concentrations is present as lateral flow through the litter layers (O_e and O_i -horizons), and that the litter layer has increased in mature forests because of fire suppression, perhaps exacerbating N and P discharge and the degradation of water quality in natural systems.

B. Gondola Wildfire site

The Gondola Wildfire site on soils of granitic origin was originally designated for treatments similar to those in Truckee. However, a wildfire (the Gondola fire) burned approximately half the site (9 of 16 plots) in July of 2002. We had pre-treatment data on this site for vegetation, forest floor, soil, soil solution, some runoff, and soil leaching by resin lysimeters, offering an unprecedented opportunity to study the effects of a wildfire with two sets of controls: 1) before and after sampling, and 2) replicated plots which did not burn, fulfilling objectives 1-4 of the Nutrient Cycling and portions of objectives 1-3 of the Soil Physics component. Soils were sampled in these plots in Sept. 2002 and again in the summer of 2003. Results to date have shown that the fire and post-fire erosion caused large and statistically significant losses of C, N, P, S, K, Ca, and Mg from the forest floor. One year after the burn, soils showed significant losses of C and N in surface horizons, significant increases in water-extractable SO_4^{2-} in all horizons, and a significant increase in pH in most horizons. The pH increases were accompanied by apparent increases in exchangeable Ca^{2+} , but the latter were not statistically significant. The fire had no statistically significant effects on exchangeable Mg^{2+} or on Bray-, bicarbonate, or water-extractable-P concentrations in any horizon. Fire effects on exchangeable K^+ were limited to an apparent increase in the C-horizons, which we suspect was spurious. Prior to the burn, there were no significant differences in leaching, but during the first winter after the fire, soil solution concentrations of NH_4^+ , NO_3^- , ortho-P, and (especially) SO_4^{2-} were elevated in the burned area, and resin lysimeters showed significant increases in the leaching of NH_4^+ and mineral N. Resin lysimeters showed no effect of the fire on ortho-P leaching, however. We conclude that the fire had major short-term effects on the quality of natural waters and major long-term effects on site N status. The Ca ratio method, unfortunately, did not prove adequate for estimating C and N losses in this site because of the erosional event and also probably because of ash convection during the fire, resulting in the redistribution of ash Ca over the site.

Overall, runoff volumes were significantly greater during the winter/spring collections (Dec-Apr), compared to summer/early fall collections (May-Nov). The first two samplings following the wildfire (one during a summer event and another in early fall) depicted significantly less runoff from the burned plots. This may have been due to the development of a 5 cm layer of wettable soil above a subsurface water repellent layer in the burned areas. This effect is caused by intense heat, which volatilizes the organic coatings on the mineral surfaces, then re-condenses with depth. Once the wettable layer has saturated (e.g., during snowmelt) one would expect greater runoff, which was generally the case. In contrast, water repellency was typically found at the litter/mineral soil interface in the unburned areas, was most pronounced during late summer and early fall (Jul-Aug, October-November), and diminished over winter.

An apparent seasonality for elevated nutrient discharge was also identified, with the highest concentrations typically associated with runoff collected during the months May-November. Wildfire increased the frequency and magnitude of elevated nutrient discharge concentrations for all three parameters even though the seasonal effect remained. Wildfire seems to increase the immediate mobilization of nutrients, and we now hypothesize that the lack of O-horizons after burning will ultimately reduce discharge concentrations over time.

C. Modeling

The Nutrient Cycling Spreadsheet model (NuCSS; Verburg and Johnson, 2001) was modified and adapted for simulating fire and post-fire N fixation. This model focuses on nitrogen, includes a nitrogen-fixation component, and simulates for as long as 250 years. The model as currently written does not deal with water quality but only total N leaching in units of kg ha^{-1} , and this is by design because these values are easily checked with resin lysimeters that give cumulative N leaching flux (Susfalk and Johnson, 2002). The resin lysimeters are cheap, very portable and very low maintenance collectors that can be deployed on a large geographical scale in order to check model predictions. The model also predicts forest floor accumulation, a parameter that we hypothesize is very important for water quality in the Tahoe Basin because it appears to be the source of high concentrations of mineral N and P (Miller et al., *In Press*). Thus, we hypothesize that the thicker the forest floor, the higher the concentrations of mineral N and P in runoff.

D. Outreach Activities

Numerous tours, presentations, professional publications, and other outreach activities were conducted during the course of this study and are listed below.

I. Presentations:

Carroll, E.M., W.W. Miller, D.W. Johnson, L. Saito, P. Szameitat, and R.F. Walker. Spatial analysis of an ash/sediment flow following a Sierran wildfire. ASA Annual Meetings, Nov 2005, Salt Lake City, UT.

Johnson, D.W., and W.W. Miller, Leaders, California Forest Soils field tour of Gondola fire, 29 July 2004.

Johnson, D.W., J.D. Murphy, C.M. Stein, W.W. Miller, R.F. Walker and R.F. Powers. 2004. The effects of wildfire and prescribed fire on nutrient budgets in and near the Tahoe Basin. Presented at the 2nd Biennial Conference on Tahoe Environmental Concerns, Crystal Bay, NV, 17-19 May 2004.

Johnson, D.W., W.W. Miller, and R.F. Walker. 2005. The effects of fire on ecosystem nitrogen budgets. Presented at the Symposium on Nitrogen Eutrophication in Xeric Wildland and Agricultural Systems, Riverside, CA 19-20 Jan 2005.

Johnson, D.W., W.W. Miller, R.F. Walker, J. Murphy, and C. Stein. 2005. Effects of fire on forest carbon and nutrient budgets. Presented at the American River Watershed Conference, Sacramento, CA, 21-23 April 2005.

Loupe, T., W.W. Miller, D.W. Johnson, E.M. Carroll, D. Handseder, D. Glass and R.F. Walker. Nutrient content in O-horizon leachate from a mixed conifer Sierran forest. ASA Annual Meetings, Nov 2005, Salt Lake City, UT.

Miller, W.W., T. Loupe, E. Carroll, D.W. Johnson, J. Murphy, R.F. Walker, and D. Glass

2004. Effects of wildfire on runoff water quality in Sierran mixed conifer Watershed. Presented at the 2nd Biennial Conference on Tahoe Environmental Concerns, Crystal Bay, NV, 17-19 May 2004.

Miller, W.W., D.W. Johnson, T. Loupe, E. Carroll, J. Murphy, and R.F. Walker. 2005. Effects of litter and fire on water quality in upland Sierran Watershed. Presented at the American River Watershed Conference, Sacramento, CA, 21-23 April 2005

Walker, R.F., D.W. Johnson, and W.W. Miller. Decadence and moisture stress in an eastern Sierra Nevada mixed conifer stand. 4th North American Forest Ecology Conference, June 16-20, 2003, Oregon State University, Corvallis, OR.

Walker, R.F., R.M. Fecko, W.B. Frederick, W.W. Miller, and D.W. Johnson. Forest health in a Lake Tahoe Basin mixed conifer stand: Bark beetles, dwarf mistletoe, blister rust, and fire. 2nd Biennial Conference on Tahoe Environmental Concerns, May 17-19, 2004, Crystal Bay, NV.

Fecko, R.M., R.F. Walker, W.B. Frederick, D.W. Johnson, and W.W. Miller. Forest health in a Lake Tahoe Basin mixed conifer stand: Water relations and fire. 2nd Biennial Conference on Tahoe Environmental Concerns, May 17-19, 2004, Crystal Bay, NV.

Walker, R.F., R.M. Fecko, W.B. Frederick, J.D. Murphy, D.W. Johnson, and W.W. Miller. Thinning and underburning effects on ground fuels in Jeffrey pine. 2005 National Silviculture Workshop, June 6-10, Tahoe City, CA.

Fecko, R.M., R.F. Walker, W.B. Frederick, W.W. Miller, and D.W. Johnson. Thinning and underburning effects on productivity and mensurational characteristics of Jeffrey pine. 2005 National Silviculture Workshop, June 6-10, Tahoe City, CA.

2. Publications:

Johnson, D.W. 2005. Nutrient cycling in the Sierra Nevada: The roles of fire and water at Little Valley, Nevada. Pp. 109-111 IN: D.D. Murphy and P.A. Stein (eds). Proceedings of the Sierra Nevada Science Symposium. USDA Gen. Tech. Rep. PSW-GTR-193.

Johnson, D.W., R.B. Susfalk, T.G. Caldwell, J.R. Murphy, W.W. Miller, and R.F. Walker. 2004. Fire Effects on Carbon and Nitrogen Budgets in Forests. Water, Air, and Soil Pollut. Focus 4: 263-275.

Johnson, D.W. J.D. Murphy, R.B. Susfalk, T.G. Caldwell, W.W. Miller, R.F. Walker, and R.F. Powers. 2005. The effects of wildfire, salvage logging, and post-fire N fixation on the nutrient budgets of a Sierran forest. Forest Ecology and Management 220:155-165.

Johnson, D.W., J.D., Murphy, R.F. Walker, and W.W. Miller. Wildfire Effects on Forest

Carbon and Nutrient Budgets: Comparison of Reconstructed versus Measured Values. Ecological Engineering (in review)

Miller, W.W., D.W. Johnson, C. Denton, P.S.J. Verburg, G.L. Dana, and R.F. Walker. 2005. Inconspicuous nutrient laden surface runoff from mature forest Sierran watersheds. *Water, Air, and Soil Pollution* 163:3-17.

Miller, W.W., D.W. Johnson, T. Loupe, E. Carroll, J. Murphy, R.F. Walker and D. Glass. Wildfire and water quality in the Lake Tahoe basin. *California Agriculture* (in press).

Murphy, J.D., D.W. Johnson, W.W. Miller, R.F. Walker, E.F. Carroll, and R.R. Blank. Wildfire 2006. Effects on Soil Nutrients and Leaching in a Tahoe Basin Watershed. *J. Env. Qual* (in press).

Murphy, J.D., D.W. Johnson, W.W. Miller, R.F. Walker, and R.R. Blank. 2006. Prescribed Fire Effects on Forest Floor and Soil Nutrients in a Sierra Nevada Ecosystem. *Soil Science* (in press).

Walker, R., R. Fecko, W. Frederick, D. Johnson, and W. Miller. Stand conditions in second growth eastern Sierra Nevada mixed conifer: A forest health case study. *Annals of Forest Science* (Submitted).

Walker, R.F., R.M. Fecko, W.B. Frederick, J.D. Murphy, D.W. Johnson, and W.W. Miller. Thinning and prescribed fire effects on forest floor fuels in the east side Sierra Nevada pine type. *Journal of Sustainable Forestry* (Submitted).

Walker, R.F., R.M. Fecko, W.B. Frederick, D.W. Johnson, W.W. Miller, D.E. Todd, and J.D. Murphy. Influences of thinning and prescribed fire on water relations of Jeffrey pine: I. Xylem and soil water potentials. *Journal of Sustainable Forestry* (Submitted).

3. Theses:

Murphy, J.D. 2004. Soil Chemical Changes Following Wildfire and Prescribed Fire In Sierra Nevada Forest Soils. M.S. Thesis. Graduate Program in Hydrologic Science, Univ. of Nevada, Reno.

4. Website:

<http://www.ag.unr.edu/forestfires/>

References

Susfalk, R.B., and D.W. Johnson. 2002. Ion exchange resin based soil solution lysimeters and snowmelt collectors. *Comm. Soil Sci. Plant Anal.* 33: 1261-1275.

Verburg, P.S.J. and D.W. Johnson. 2001. A spreadsheet-based biogeochemical model to simulate nutrient cycling processes in forest ecosystems. *Ecological Modelling* 141: 185-2000.