The Effects of Fire on Watersheds: A Summary[1]

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Over the past three days we have been presented with the results of a most impressive quantity and quality of research on the effects of fire on watersheds. My attempt to summarize these papers will hardly do them justice, but hopefully will recapitulate some of their more important and generalizable findings. My comments are organized into the following categories: soil temperature, soil nutrients, soil erosion, soil hydrology and streamflow, vegetation structure, stream temperature, and impacts of firefighting.

SOIL TEMPERATURE

Alex Dimitrakopoulos reported the results of a laboratory investigation of the effects of soil heating on soil temperature and on the role of moisture. He and his colleagues found that, except for prolonged heating representative of intense wildfire, extreme soil temperatures are confined to the top 5 cm of soil. Short-duration heating, which approximates conditions characteristic of most prescribed fires, causes temperatures to reach lethal levels for living tissue only within the top 1 cm of soil.

Soil moisture strongly influences the effects of soil heating. Wet soil conducts heat relatively rapidly, quickly attaining the lethal temperature range. Higher maximum soil temperatures were obtained for dry soils than for wet soils, however, and dry soil conditions must be considered typical of most wildfire events in California.

SOIL NUTRIENTS

In his review of fire in chaparral, Leonard DeBano reported that prescribed fire's effects are more extreme in chaparral than in forests because prescribed fires burn the canopy extensively. Chaparral fires tend to affect the physical, chemical, and biological properties of soils. Soil structure and cation exchange capacity change as organic matter is combusted. Availability of nitrogen and phosphorus to plants is particularly affected by soil heating, and fires often volatilize large amounts of soil nitrogen. Vaporized organic matter moves downward through the soil and condenses into a water-repellent layer that impedes infiltration, especially in coarse soils characteristic of shrubby vegetation.

Soil microorganisms, which play important roles in plant growth, are highly susceptible to destruction by soil heating.

Nitrogen released by fire and deposited on the surface in ammonia form often gives a nutritive boost to postfire vegetation establishment. Nitrogen release diminished the need for, and the value of, fertilization immediately following a fire. Once the short-term flush of nitrogen availability ends, however, a long-term nitrogen deficiency sets in. These findings suggest that if watershed rehabilitation investments are made in fertilization, they should be deferred for at least one year following the fire. Although processes of soil nitrogen restoration are poorly understood, nitrogen-fixing vegetation such as some Ceanothus species probably play an important role and should be favored in postfire management.

SOIL EROSION

Wade Wells's survey of postfire soil erosion documented how fire initiates a process of soil movement that continues through subsequent rainstorms. During and following fire, dry ravel fills swales and channels with sediment. With the onset of even light rain, overland flows rapidly create rills that evolve into a complex channel system which provides a highly efficient conduit for saturated sediment flows.

Seeding of annual ryegrass has been the traditional strategy for reducing postfire erosion, but evidence provided by Wells, DeBano, and Glen Klock indicates that ryegrass seeding has limited value and may even be counterproductive for re-establishment of native vegetation, especially species of special concern.

Klock's travelogue through time in a watershed in the North Cascades showed how the speed with which nature is able to restore herself depends on natural conditions, such as elevation and moisture availability, and on postfire management decisions, such as how and during which seasons salvage logging occurs.

SOIL HYDROLOGY AND STREAMFLOW

Iraj Nasseri reported that the combined fire effects of vegetation removal and formation of a water-repellent soil layer can increase runoff by from 200 to over 500 percent in southern California's chaparral.

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[2]Forest economist, Jones & Stokes Associates, Sacramento, Calif.

Peak flows also increase several-fold in response to intense wildfires. Interpreting results of his empirical research combined with simulations using the Stanford Watershed Model, Nasseri found that fires increase the return period of floods associated with moderate and extreme storms. He suggested that flood control structures be designed based on projected runoff from a burned watershed, because fires often give rise to the peak flows that such structures are built to accommodate.

While this observation is extremely apt, I would suggest taking it a step further to remedy a semantic problem of considerable significance. Fires do not lengthen the return periods of floods associated with storms of a specified intensity. Rather, they shorten the intervals between floods of a specified intensity. Flood control agencies such as the U.S. Army Corps of Engineers should recognize the propensity of chaparral vegetation to burn periodically, and consider the effects of such fires in calculating return intervals for floods.

Models for simulating watershed hydrology such as the Stanford Watershed Model and the Sacramento Model, as described by Larry Ferral, are continually enhancing the ability of watershed analysts to project and assess the effects of fires and of several other watershed disturbances of natural and human origin. Such information is critical to urban and regional planning efforts to address the complex problems posed by rapid urbanization of rural lands (as emphasized by Harold Walt in his luncheon speech).

David Parks reported on the hydrologic effects of a forest fire in southwestern Oregon. His results are interesting in part because they contrast significantly with those of Nasseri and others relating to chaparral fires. Parks found that soil hydraulic conductivity, water repellency, and anticipated erosion rates in intensively burned areas varied little in relation to vegetative cover whether the site had been logged before the fire. In fact, intense wildfire was found to have a relatively small overall effect on forest soil hydrology. The increase in water repellency caused by fire in the Oregon forest setting appears small relative to those reported by DeBano and others for chaparral. This difference may be attributable in part to the clay structure of the forest soils. Alternatively, repellency in burned chaparral soils may result from the chemical composition of chaparral vegetation. In any case, based on information presented at this conference, fire-caused soil water-repellency appears to be limited primarily to chaparral soils.

VEGETATION STRUCTURE

Thomas Parker discussed how postfire vegetation structure in chaparral depends on the reproductive strategies of prefire vegetation. Sprouting species generally become re-established faster than species that rely on seed germination. Because reproductive strategies of different kinds of vegetation vary, a diverse flora usually has multiple strategies for postfire revegetation, which increases the likelihood of revegetation success. A diverse flora also reduces risk of wildfire ignition because some of its elements are nearly always green. I would suggest the hypothesis that the benefits of managing for stand diversity are not limited to chaparral but are equally applicable to commercial forest management.

Parker pointed out several implications that revegetation processes have for prescribed fire management. Fire intensity, frequency, season, and diversity of fire-free intervals all affect the rate of establishment and composition of the postfire community. He also noted the importance of fully accomplishing the objectives of a prescribed burn: partial burning may invite a subsequent fire far more destructive than the prescribed burn, or may fail to stimulate germination of desired species.

STREAM TEMPERATURE

Michael Amaranthus and his colleagues found that in a southern Oregon watershed where fire reduced average stream shading from 70 to 10 percent, postfire stream temperatures increased by from 6° to 18° F. Temperature changes were attributable primarily to the increase in solar radiation absorbed by the stream. Temperature increases were also highly correlated with streamflow. Amaranthus found that, in addition to live streambank vegetation and topographic features, standing dead trees were an important source of stream shading, and postfire rehabilitation should retain snags in the riparian corridor.

Watershed analysts whose observations of the political decision-making process have made them somewhat cynical about the significance of their work should take heart from Mr. Amaranthus's report that a forest supervisor changed a streamside salvage harvesting prescription to retain standing dead trees based on the findings of his watershed staff.

IMPACTS OF FIREFIGHTING

We have also seen and heard that fighting wildfires can leave its mark on watersheds. Inevitably, soil disturbance, vegetation removal, and stream sedimentation accompany large movements of firefighters and equipment. Backfires sometimes turn out to be more intense and destructive than anticipated. For example, Logan Norris alerted us to the potential water quality and fishery impacts of fire retardant use, and pointed out the importance of preplanning fire suppression tactics in ecologically sensitive and fire-prone areas.

SUMMARY

It became apparent to me in reviewing these papers that watershed research in and around California has focused primarily on two major vegetation types: the chaparral and the mixed-conifer forest. Some broadening of this focus is especially important when we consider which wildland areas of California are experiencing the most dramatic changes in land use and vegetation cover. I am referring to the foothills of the Sierra Nevada and the Coast Ranges. A sustained commitment by the state to the resource problems of the hardwood range will certainly help focus needed attention on the many watershed-related issues of rapid urbanization. I would expect to see several papers addressing these issues at the next watershed conference.

Papers presented here on the effects of fires on watersheds indicate the major recent gains in understanding of watershed function and response to disturbance. Empirical evidence and comprehensive watershed assessment are replacing casual observation and the narrow doctrinal perspectives of specific scientific disciplines. The opening-up of communication lines between hydrologists, botanists, foresters, soil scientists, and others through this conference and other activities of the Watershed Management Council is particularly encouraging and needs to continue to be fostered by each of us. Although we each have our own agenda and priorities for watershed management and research, we must keep in mind our common goals, among which must be the need to provide future generations with watersheds that work, and by that I mean provide abundantly for both our material and non-material needs.