Fire, Soil, and Post-Fire Recovery

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The California fires of 2018 and the Australian fires of 2019 have raised awareness about the risk of large scale catastrophic fires. Unfortunately, it has also resulted in a great deal of conjecture about the occurrence, control and impact of fires. The purpose of this short summary on fire effects on soil is to inform readers about the role of fires in ecosystem function, discuss the primary legacies of fire, describe the influence of fire on nutrient cycling, and briefly describe the process of soil recovery after fire.

Fire: A Natural Disturbance in All Ecosystems

First it is important to keep in mind that all biomass has the potential to burn, the difference is how frequently are different ecosystems exposed to fire and how does fire behave in those ecosystems. Great Plains prairies burned every one to five years, western ponderosa pine burned every 10 -- 35 years, higher elevation lodgepole pine every 100 -- 200 years and spruce hemlock forests perhaps every 400 years. Fire is a naturally occurring disturbance in all forest ecosystems. In high fire frequency systems such as ponderosa pine, the fires tend to be low severity and rarely kill the large legacy trees. The net effect of the fire is one of rejuvenation of the forest, reduction of live and dead fuels and resprouting of plants and germination of seeds that were otherwise dormant.

Over the last century the USFS pursued a program of active suppression of fire, which at start proved to be exceptionally good at controlling low severity fires, achieving about 97% success in suppressing fires over the years. That combined with extensive timber harvest in the 60s to 80s followed by a period of limited timber harvest and the fact that 1950 - 1988 was an unusually wet and cool period resulted in an unusual buildup of live and dead fuels that are ripe for large scale stand replacing fires across a variety of forest types in the west.

More recently, anthropogenic climate change has resulted the lengthening of the dry, hot seasons in which fires take place. The net effect of intersection of these factors is that we are experiencing longer, hotter, drier fire seasons that yield larger, higher severity fires than had been seen since Europeans arrived in the western US in the late 1800s (https://royalsocietypublishing.org/doi/10.1098/rstb.2015.0345).

Fire Effects on Soil and Fire Legacies

When a fire burns a forest, one might ask what is left behind after the fire? The forest initially is left with dead organisms (trees, shrubs, herbs, microorganisms), surviving living organisms, charcoal, and ash. Importantly, fire volatilizes some nutrients (nitrogen and carbon volatilize at relatively low temperatures) where alkaline metals, transition state metals, and oxyanions are concentrated in the ash. Carbon (C) and nitrogen (N) are primarily lost from the needles, twigs, and leaves of trees, shrubs and herbs, and from the combustion of the forest floor (or soil organic horizon, the layer that sits on top of the mineral soil). Charcoal remaining after fire can remain in the soil for decades serving as C storage and it can have a direct and indirect influence on various soil processes (https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/070070)

A Scots pine seedling thrives amidst moss and charcoal fragments five years after fire in a research forest in northern Sweden (photo: T.H. DeLuca)

The surface mineral soil remains surprisingly intact during wildfires. Soil is highly porous (generally in excess of 50% porosity) and thus is an amazing insulator against heat transfer into soil. A wildfire with surface temperatures of 500˚C burning for an hour will have mineral soil temperatures of 50˚C at 20 cm deep or perhaps 30˚C if the soils are moist (https://www.sciencedirect.com/science/article/pii/S0048969717313621). This means that most microorganisms and roots in the mineral soil are tolerant of the temperatures reached at those depths during wildfire. In extremely hot fire events where surface fuel loading is great, surface soils can lose a lot of organic C and N making recovery a slower process.

Post-fire Ecosystem Nutrient Cycling and Recovery

During a wildfire event in a boreal Scots pine or lodgepole pine forest, approximately 150-450 kg N ha-1 are lost to volatilization. In spite of this net loss, N availability in the mineral soil is actually increased after a fire event. Inorganic N (NH4+, NO3-) are the two mineral forms of N most readily available for plant uptake. The plant availability of these two forms of N increases significantly after fire (https://www.sciencedirect.com/science/article/abs/pii/S0038071701001808?via%3Dihub). And charcoal left behind after fire helps stimulate nitrification years after being deposited in soil (https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj2005.0096). Nitrate is an important form of N shortly after fire as it is highly soluble, and anionic (repelled by clay particles) and thus can move by mass flow (rather than diffusion) satisfying the N uptake demand of young tree seedlings that rely on a soluble N source prior to establishing their mycorrhizal networks. After a fire event, many people look at the forest as dead, but a closer inspection will reveal a rapid recovery of microbial activity. Even after particularly hot fires, microorganisms recolonize the soil from above (dust inputs) and below.

Obviously, if N lost during every fire event isn't replenished, the ecosystem would eventually run out of N. However, as it turns out, fire tend to simulate the growth and development of N2 fixing plants and microorganisms. Only bacteria and archaea are capable of fixing N2 from the atmosphere. Legumes and actinorhizal species are common in temperate and tropical systems, whereas feather mosses and their partner cyanobacteria fix N in boreal forest ecosystems. The feather mosses can rebuild the N lost during a fire event in 100 -- 200 years in a Scots pine boreal forest (https://www.nature.com/articles/nature01051) where there are few woody or herbaceous N fixing species. In temperate and tropical forest systems, light loving legumes and actinorhizal species can rapidly grow after fire and rebuild soil N pools in 30 to 100 years.

Some take away messages from this article: Fire is a natural form of disturbance in forest ecosystems. Fire stimulates rejuvenation in forests. Climate change and fire suppression are changing fire severity and fire behavior. Fires do not "sterilize" mineral soils. Fires tend to reduce total N but increase N availability.

Hand Washing in Refugee Camps

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As the world faces the COVID-19 crisis, hand washing is a key strategy to prevent the spread of the virus. Access to hand washing facilities is vital, but it varies greatly across countries and communities. In refugee camps, COVID-19 adds more urgency to a longstanding challenge: how do you provide hand washing facilities where there is little or no water and sanitation infrastructure?

Designs for hand washing stations in refugee camps need to be low cost, low maintenance, and easy to assemble and transport. They have to work with limited water supplies in harsh environments and cater to large numbers of people. The following are a few of the designs available.

The "tippy tap" design was "officially" first used in the 1980's. Oxfam uses a jerry can held up with three sticks. A