Fire and Drought Effects on Soil Nutrients

MONTANA STATE UNIVERSITY EXTENSION

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In addition to direct loss of crops and livestock, drought and fire can affect soil properties and nutrient management.

FIRE

The impact of fire is highly dependent on its intensity, duration and the proportion of plant material that is burned. Timber and shrubs will burn hotter and longer with greater impact on soil than range- or crop land fires. Fast moving grass fires have minimal impact on soil nutrients and soil health compared to slow moving, smoldering fires in moderate to heavy fuels (Table 1). Heat penetrates deeper in moist than dry soils; sandy soils are better insulated against heat transfer than loams.

Immediate impact Fires can reduce the pool of nutrients stored in plant residue and organic matter and release a flush of plant available nutrients. Available nitrogen (N) is especially increased after low intensity fires, even though a portion of N and sulfur (S) is lost to the air. Phosphorus (P), potassium (K), and micronutrients are more stable and not lost directly through combustion, but rather can be lost through blowing ash. Although these losses are not trivial, they are similar to or smaller than removal by harvest and average losses to wind erosion, and they are small compared to the average pool of nutrients in the top 6 inches of soil (Table 2).

Table 1. Fire related temperatures and their impact.

Process	Approximate temperature range (°F)[a]
P, K, S, and micronutrient loss to air	> 1400 - 1600
Shrubland and aspen forest fire soil surface temp[b]	*1100*
½ the N in SOM is lost to air	930
Complete combustion of surface SOM	860
Aspen forest fire - soil 2" depth[b]	*845*
Increase in soil pH (liming effect)	840
Destroy water repellent layer	535 - 750
Grassland fire - soil surface[b]	*675*
Organic matter C and N loss to air	390 - 600
Develop water repellent layer	340
Stubble fire – soil surface[c]	*300*
Urea/MAP N loss, MAP P solubility loss[d]	265
Water boiling point	212
Microbial mortality; Mycorrhizal loss	125 - 250
Seed mortality	160 - 195
Biological tissue, root death	105 - 160
Shrubland fire - soil 2" depth[b]	*105*
Grassland fire - soil 2" depth[b]	*65*

[a] Source: Knicker, 2007, unless otherwise noted; [b] Archibold et al., 1998; [c] Scott et al., 2010; [d] IPNI

Table 2. Approximate nutrient amount in top 6-inches of soil and removed by grain or straw harvest, burning of straw, and wind erosion on a dry no-till field with stubble.

	Soil (lb/acre in top 6")	Grain harvest[a] (lb/25 bu)	Straw harvest[a] (lb/ton)	Straw burned[b] (lb/ton)	Wind erosion[c] (lb/ac/year)
Nitrogen	3,000	32.3	14.5	14.2	11
Phosphorus (P_2O_5)	2,700	15.5	3.6	0.4	13
Potassium (K_2O)	48,000	9.5	25	4.3	172
Sulfur	-	2	3.7	2.5	-

[a] *Fertilizer Guidelines for Montana Crops;* [b] Heard et al., 2006; [c] Merrill et al., 1999

Fire kills bacteria and fungi at the soil surface but microbes rapidly recolonize from deeper soil layers, except in severe fires that sterilize soil several inches deep. Microbial activity can actually increase with the flush of nutrients available after a fire. However, new input of plant material is important to sustain their populations.

Long-term impacts generally come from loss of plant residue and organic matter. Cropland fires rarely burn hot enough to decrease soil organic matter. The bigger concern is loss of surface plant residue, which protects agains wind erosion and the physical sealing impact of raindrops. Ash particles also contribute to reduced water infiltration as they plug soil pores. All these factors increase the risk of water runoff and soil erosion.

Compounds in the burnt litter of forest and shrubland fires can create a water repellent layer within the top 2 inches of soil. The depth and thickness of this layer can vary greatly, and it can affect infiltration for several months to years. This layer should not form on grassland or stubble fires.

Intense forest and shrubland fires can burn soil organic matter, reducing the soil nutrient pool, aeration, water infiltration/retention, and the soil's ability to hold nutrients coming from ash or fertilizer. The available N created by burnt organic material can be lost through leaching as few active plant roots are left to take up either the nitrate or soil water. This N loss can have long term impacts on the productivity of forest and rangeland ecosystems, but can be minimized or counteracted by fertilizing on croplands.

Post-fire management Soil test for N, P and K to calculate fertilizer needs. When drought precedes fire, it is likely that fields have N that wasn't used prior to the fire, so less might be needed the following spring. When soil sampling burnt fields, be sure to select representative sites, avoid areas where there may have been a windrow, bale, or other high accumulation of straw or residue.

Establishing ground cover is high priority where possible. Spreading manure can be very beneficial post-fire but this is rarely available or reasonable at large scales.

DROUGHT

Post-drought soil nitrate levels are likely higher than normal due to low plant growth and nitrogen uptake. Soil nitrate is best determined by spring soil testing to help adjust N fertilizer rates. If possible, planting a fall crop or cover crop can help catch soil nitrate to minimize nitrate leaching loss.

Reduced crop production also means less nutrients are removed. Or, if the crop is salvage harvested as forage rather than going to a grain harvest, different amounts of nutrients are removed than generally accounted for in 'normal' harvests (Table 3). For example, haying a grain crop can remove more K than if grain had been harvested.

Drought can alter P and K recycling which may slightly change their soil levels. If there is fall moisture and the crop residue is composed of plants that died immature, there can be a flush of P and K. However, if there is no fall moisture, then P and K recycling into the soil pool is limited. Phosphorus and K distribution may be more variable in the field than usual due to a more variable harvest.

Table 3. Approximate amount of N, P, K and S removed by harvest of wheat grain, straw and hay (from *Fertilizer Guidelines for Montana Crops*)

Wheat	Amount/acre	N	P_2O_5	K_2O	S
		.... lbs			
Grain	40 bu	50	25	15	3
Straw	1.8 ton	26	7	45	7
Hay	2 ton	50	20	76	4

References and for more information:

Archibold et al., 1998. Canadian Field-Naturalist 112:234-240.

Heard et al., 2006. Better Crops 90(3):10-11

IPNI http://anz.ipni.net/article/ANZ-3294

Knicker, 2007. Biogeochemistry 85:91-118.

Merrill et al., 1999. Soil Science Society of America Journal 63:1768-1777

Neary et al., 1999. Forest Ecology and Management 122:51-71.

Scott et al., 2010. https://www.csu.edu.au/__data/assets/pdf_file/0007/922723/stubble-retention.pdf

The following can be found at http://landresources.montana.edu/SoilFertility/publications.html

Developing Fertilizer Recommendations for Agriculture (MT200703AG)

Fertilizer Guidelines for Montana Crops (EB0161)

Soil Sampling and Laboratory Selection (Nut. Mgt. Module #1, 4449-1)

Soil Sampling Strategies (MT200803AG)

International Plant Nutrition Institute publications on crop nutrient management after drought http://www.ipni.net/article/IPNI-3277