Slicing and Dicing Gallatin Valley Soils: Pitfalls of Litho-, Pyro- and Climo-sequences

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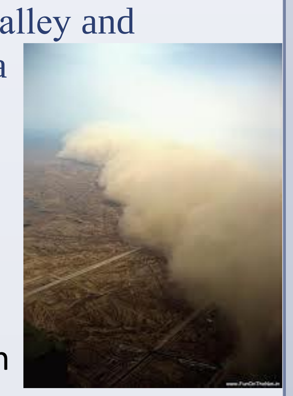
INTRODUCTION

What factors are responsible for soil properties in the Gallatin Valley and surrounding areas. Local climate creates a semiarid environment that promotes salt accumulation in the valley and leached, wetter conditions in the higher elevations of the surrounding mountains. A 'climosequence' from the Horseshoe Hills (~1300 m) to Sacajawea peak (~3000 m) will determine if there are climate-related pedogenic thresholds on soils overlying 250- to 500-million-year-old limestones. Aeolian loess or wind blown dust accumulations increase plant-available water and nutrients in valley soils, but similar meter-thick packets of loess are not found in soils in a Hyalite 'lithosequence' near Langohr Campground. How far up mountainsides can loess be found and what might that mean for watershed-scale nutrient and carbon cycling? Physical and chemical fingerprinting techniques will be used to quantify a "fraction loess" for valley and mountain soils. Finally, how are soil properties altered as a function of disturbances such as fire, which is expected to be six times more prevalent in the near future? And how do fire effects interact with climate and/or underlying lithology to influence soil properties?



Loess deposition

OBJECTIVES

Determine the parent material or origin of the Gallatin Valley soils: loess, rock, or both.

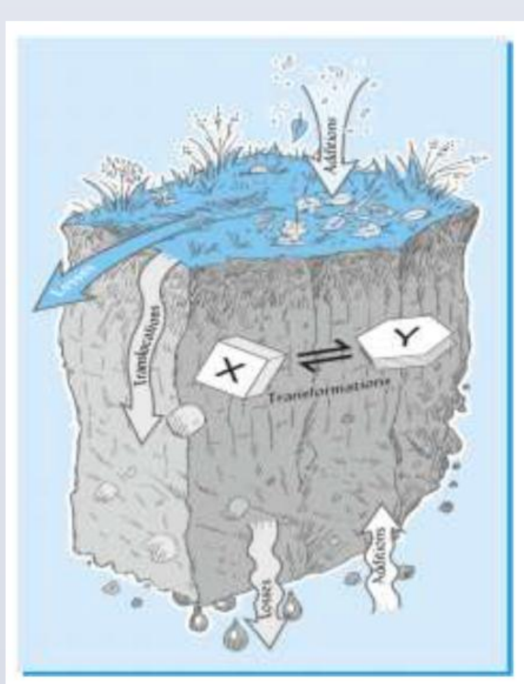
Determine the impacts of an increasingly wet climate on limestone from Manhattan to the ridge of the Bridger Range

Characterize the changes wrought on soils formed on varying lithologies by fire.

Soil Forming Factors and Processes

Jenny (1941)
Climate
Organisms
Relief
Parent Material
Time

Study one factor by holding the others constant
S = f(cl, o, r, p, t)



HYPOTHESES

Parent materials shift from loess at low elevations to underlying rock with increasing elevation.
Effective precipitation increases at higher elevations decreasing soil fertility.
Fire increases plant macronutrients in the short term, but reduces them in the long term.

Chemical Weathering Rates (τ)

For more on τ

Assumptions: Unweathered parent rock
Chemical Weathering (vs. Physical Erosion)
Mobile and Immobile Elements gauge inputs and losses
τ – loss or gain of mobile element

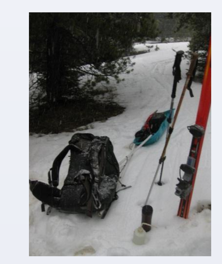
$$\frac{[\text{Mob.Soil}]*[\text{Imm.Rock}]}{[\text{Mob.Rock}]*[\text{Imm.Soil}]} - 1 = \tau$$

decades of weathering in NYC

METHODS

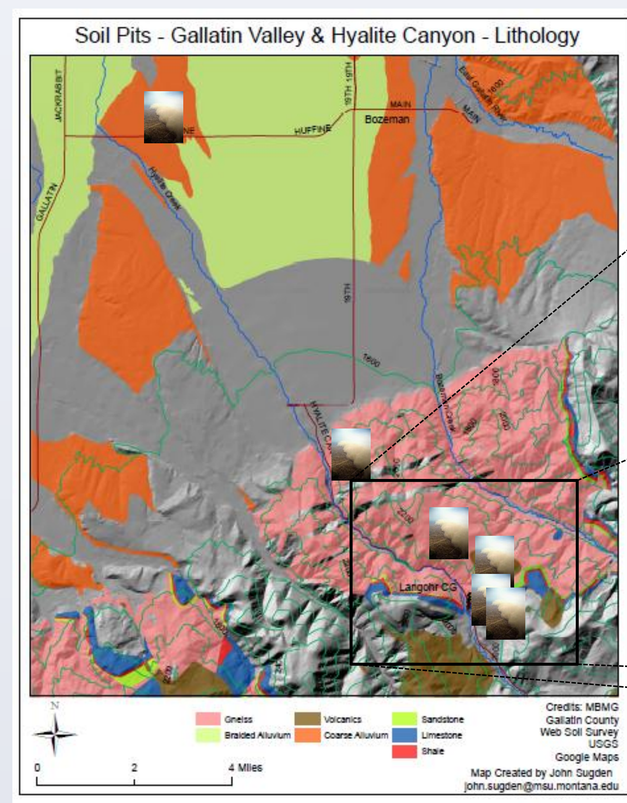
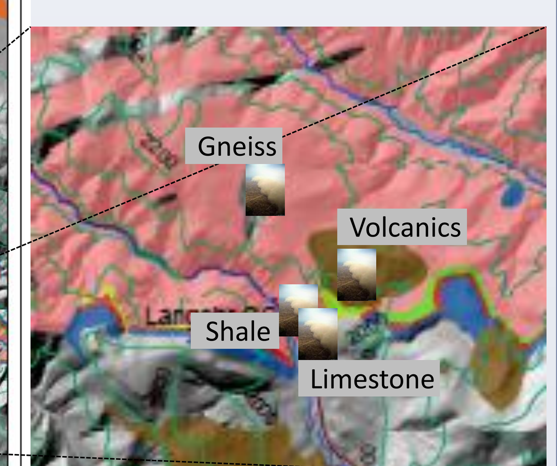
Get Soil, Dust & Rock
Run Physical Properties
Run Chemistry – Major and Rare Earths
Baseline Soil Data
Quantify Disturbance Effects

Dust Sampler

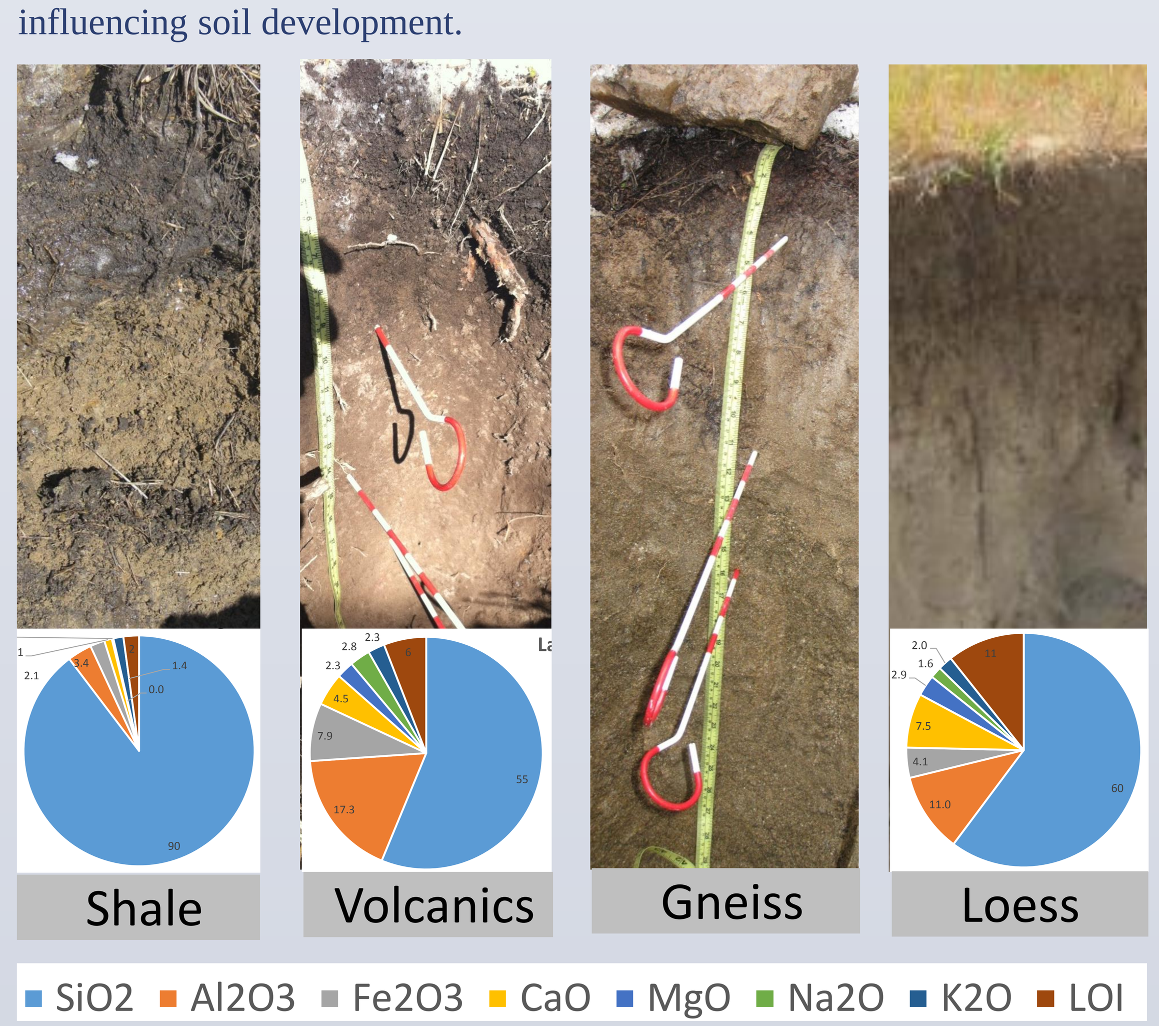


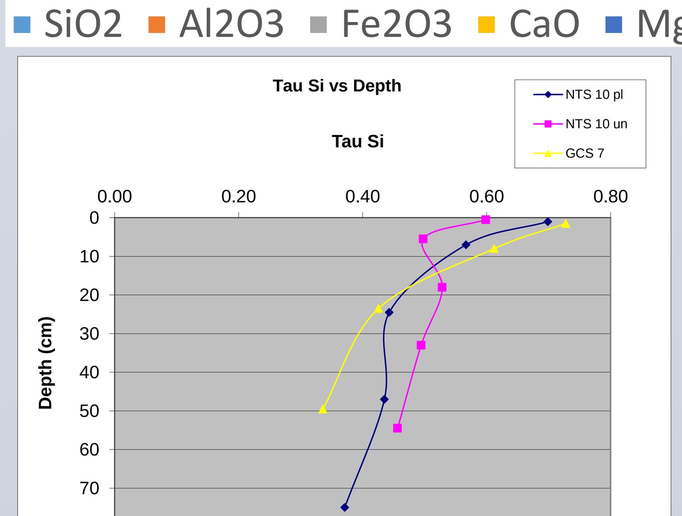
Winter Sampling Tools

LITHOSEQUENCE

The Post Farm site consists of loess atop braided alluvium. The depth to alluvium at Post Farm is unknown, but greater than five feet. The soils at sites near Langohr Campground are thought to be free of loess. This interpretations is supported by new major elemental analysis found below. Intermediate sites between Post Farm and Langohr Campground will be charactrized in the 2013 field season at what elevation the loess stops influencing soil development.





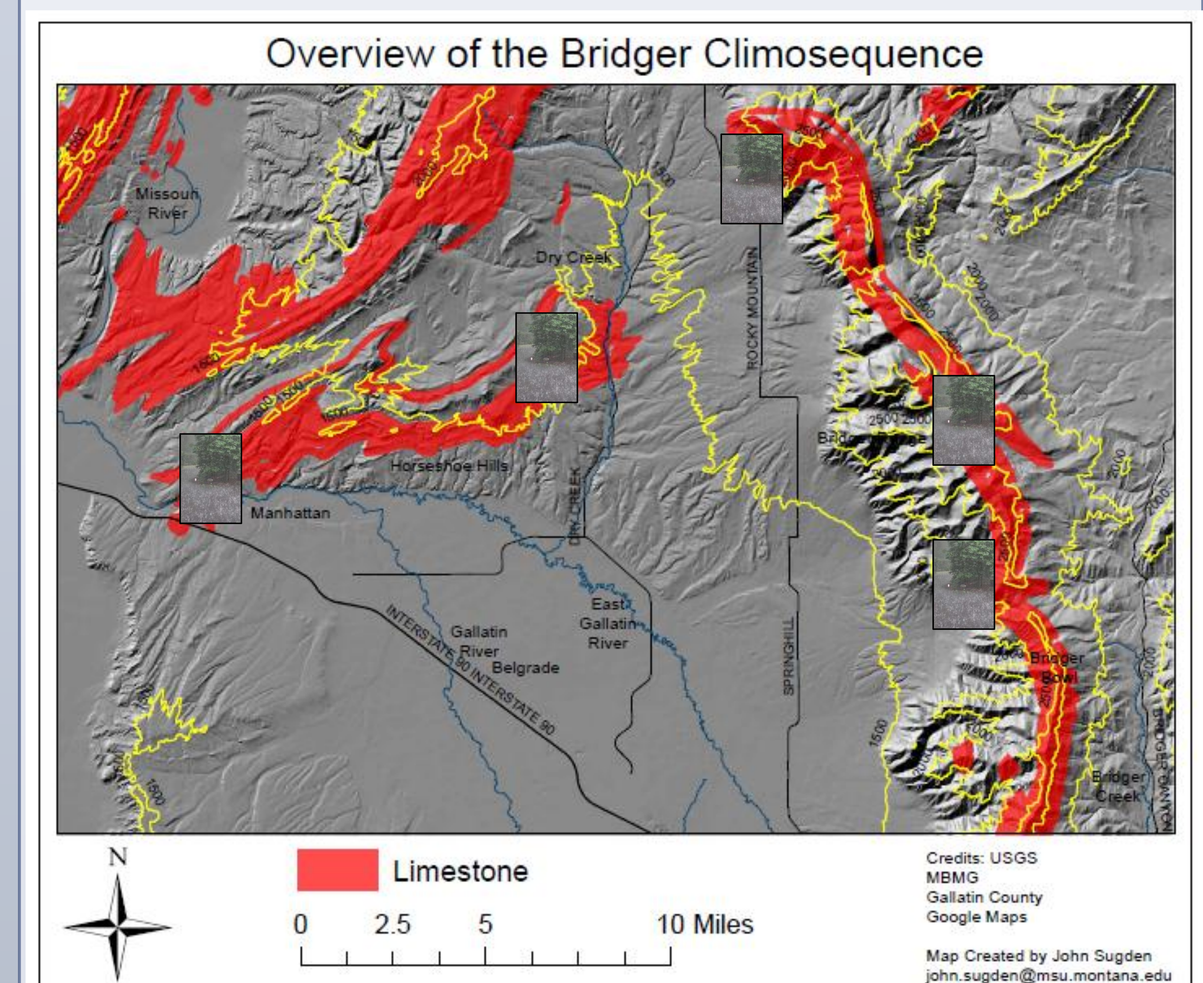
Decreasing τ of silica with depth.

The power of τ: In this case, τ suggests the greatest inputs of silica occur on the surface affecting soil development in Arizona. Values greater than zero suggest net gains of the mobile element, whereas values less than zero suggest a net loss of the element.

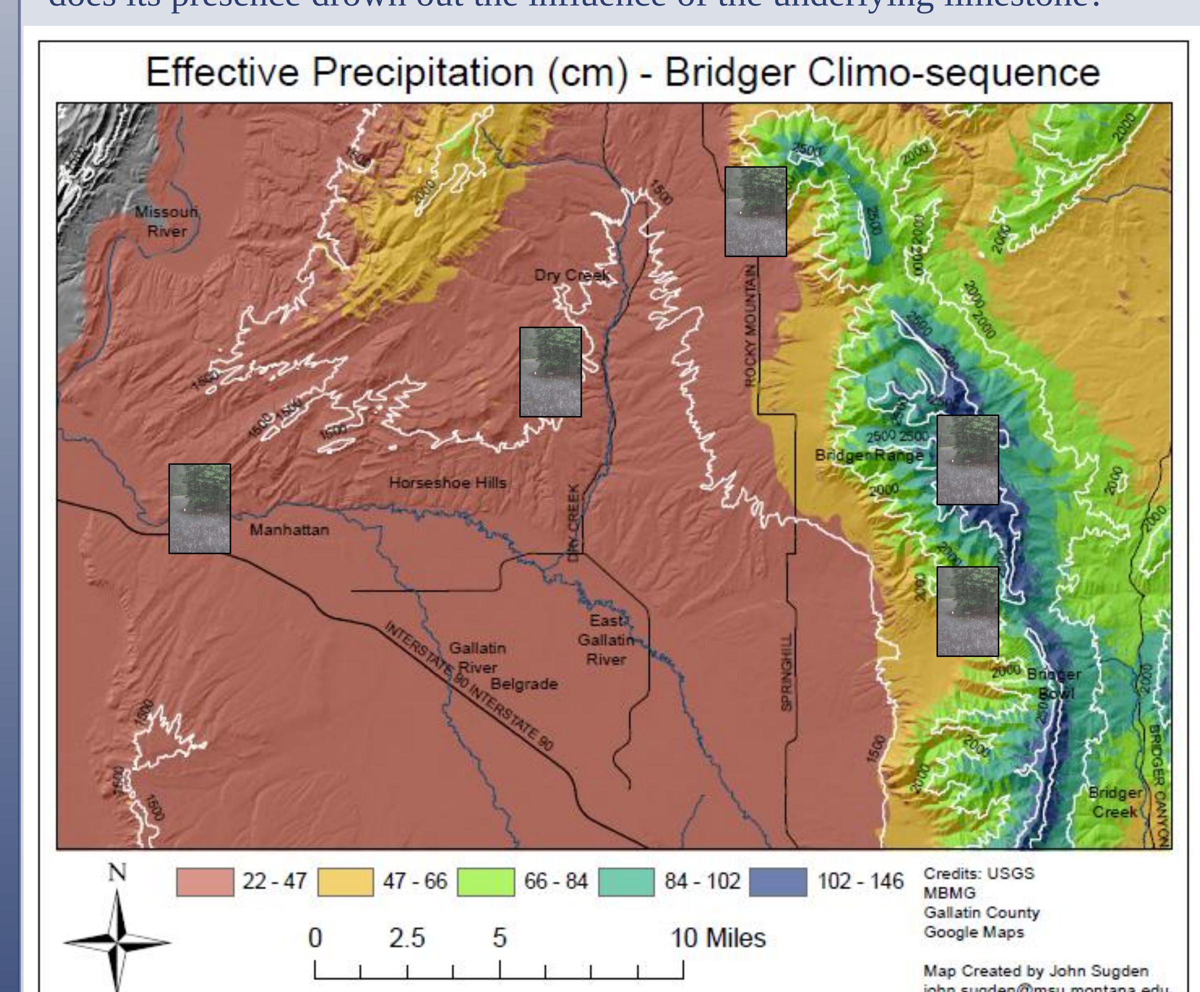
BRIDGER CLIMOSEQUENCE

Limestone as a potential parent material of soil can be followed from the Gallatin River near Manhattan, MT east over the Bridger Range; this transect brackets a range in elevation from 1,200 meters to 3,000 meters ASL. The climatic conditions that occur on this elevation transect range from semiarid to cold and wet. This rapid change in effective precipitation (liquid and frozen precipitation gains – evapotranspirational losses) across a relatively uniform lithology (limestone) provides a spectacular 'backyard' opportunity to test whether—and if so, to what extent—this gradient represents a suitable climosequence for teasing apart the role of climate in shaping and influencing soil processes.

Abundant precipitation can remove soil fertility and change soil characteristics.



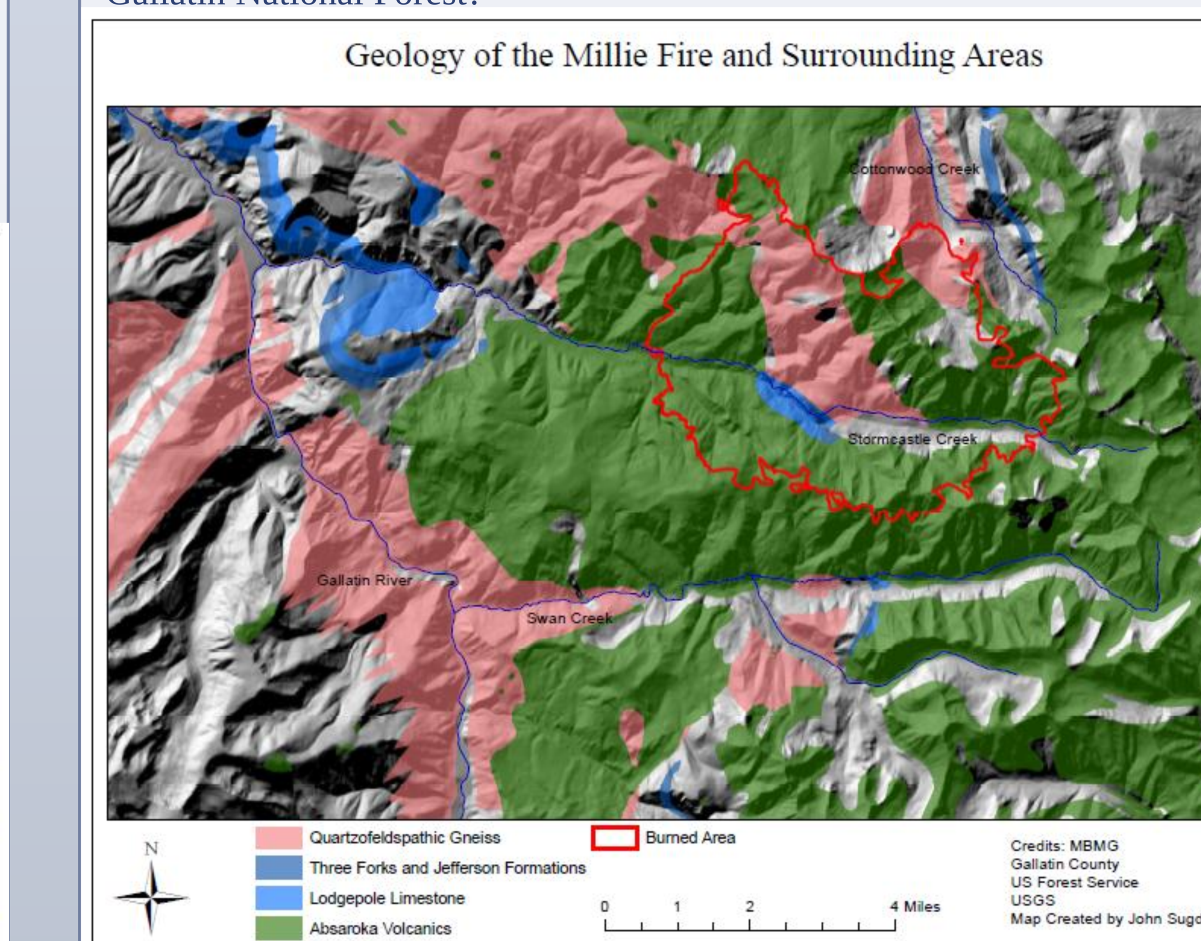
These approximate sites were chosen as they are thought to represent an increase in effective precipitation as depicted in the PRISM data below. These sites will be finalized, sampled and characterized during the 2013 field season. The analysis, similar to the lithosequence, will also assess the extent to which loess has accumulated on these five sites and may influence soil development at those sites. If these sites do contain loess, does its presence drown out the influence of the underlying limestone?



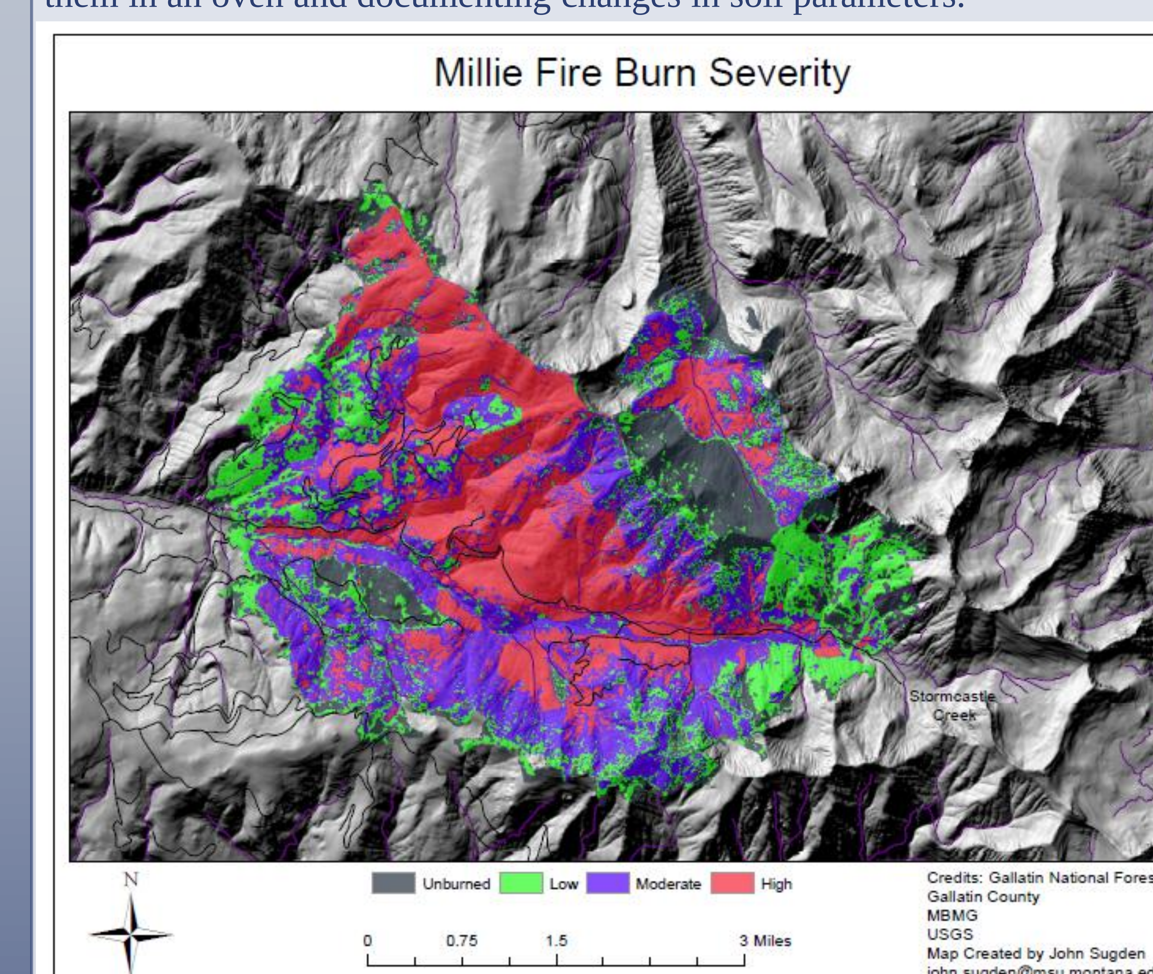
Effective precipitation values are derived from modelled PRISM data.

PYROSEQUENCE

How will regional soils respond to increasing fire frequency and severity. This project will assess these responses. The Millie Fire, which burned in August and September 2012 scorched soils that formed on the same lithology as those in Hyalite: Volcanic and Gneiss. The soils that form on these lithologies are polar opposites. Gneiss generally forms a sandy soil with thin dark horizons, whereas volcanics generally form soils of finer texture, thicker dark horizons which can generally hold more water. What are the effects of fire on these soils in the Millie fire and elsewhere in the Gallatin National Forest?



Soils will be sampled during the 2013 field season on both gneiss and volcanics burned and unburned to compare changes imposed by the fire. Sampling will likely occur in and just out of the northwest portion of the fire polygon above. We intend to simulate fire on other area soils by placing them in an oven and documenting changes in soil parameters.



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