Succession of Nitrifying Bacteria in Ponderosa Pine Forest Soils After Wildfire and its Effect on Nitrification Rates

Andrea Russie, Francisco Llarena, Andrew Sposato, Peter Chapman, Janis K. Bush, J.K. Haschenburger
The University of Texas at San Antonio, San Antonio TX, 78249

Abstract

Fire releases or increases soil inorganic nitrogen which can, through microbial facilitated processes, result in a net loss of nitrogen from forest systems. This is a major concern for forests in the southwestern United States, which are experiencing increased frequency and higher severity fires. The combination of combustion and heat transfer creates steep temperature gradients within soil during fire, which influences the mortality of the microbial community and therefore the pattern of succession post fire. This study evaluates the effect of fire severity and hillslope gradient on the succession of nitrifying bacteria within the microbial community and the effect of this succession on potential nitrification rates in ponderosa pine forest soils after wildfire. The study was conducted in the Valles Caldera National Preserve, New Mexico which was partially burned by a wildfire in the summer of 2013. There are two fire treatments (high and low severity) and two hillslope gradients (moderate and gentle slope). There are two replications for each treatment. A control area (no burn) was also sampled. Samples will be taken during the spring, summer, and fall. Composite soil cores will be analyzed in two cm depth increments. Community structure and function will be analyzed by using the Most Probable Number method, Community Level Physiological Profiling using Biolog EcoPlates, and the nitrification rates. Other variables that may influence microbial community growth and succession, such as vegetation, soil compaction, pH, light intensity, erosion rates, and water repellency, will be also be measured.

Introduction

Fire suppression has led to increased fuel loads and therefore fires with greater burn severity in the western United States (Neary, Klopatek et al. 1999). Temperature profiles in the soil can affect microbial composition and population depending on the severity of the fire (Dunn, Barro et al. 1985) . Soil heating affects microorganisms by either killing them directly or altering their reproductive capabilities. Nitrifying bacteria appear to be particularly sensitive to soil heating.

Nitrification is a two-step microbial facilitated process. Ammonia-oxidizing -bacteria such as the genus *Nitrosomonas* first convert ammonia to nitrite. In the second step of nitrification, the oxidation of nitrite to nitrate, is mainly performed by bacteria from the genus *Nitrobacter*. It has been documented that fire can increase rates of nitrification immediately after fire (DeLuca, MacKenzie et al. 2006). This can result in net loss of nitrates of post-burn forest systems through leaching, denitrification, and lack of plant uptake. The three main factors that influence growth in soils of nitrifying bacteria are substrate availability, soil moisture, and temperature. However, these main factors are themselves influenced by a multitude of variables that form complex interactions (see Figure 1). Further work is needed to better understand the role of nitrifying bacteria in the microbial community following fire.

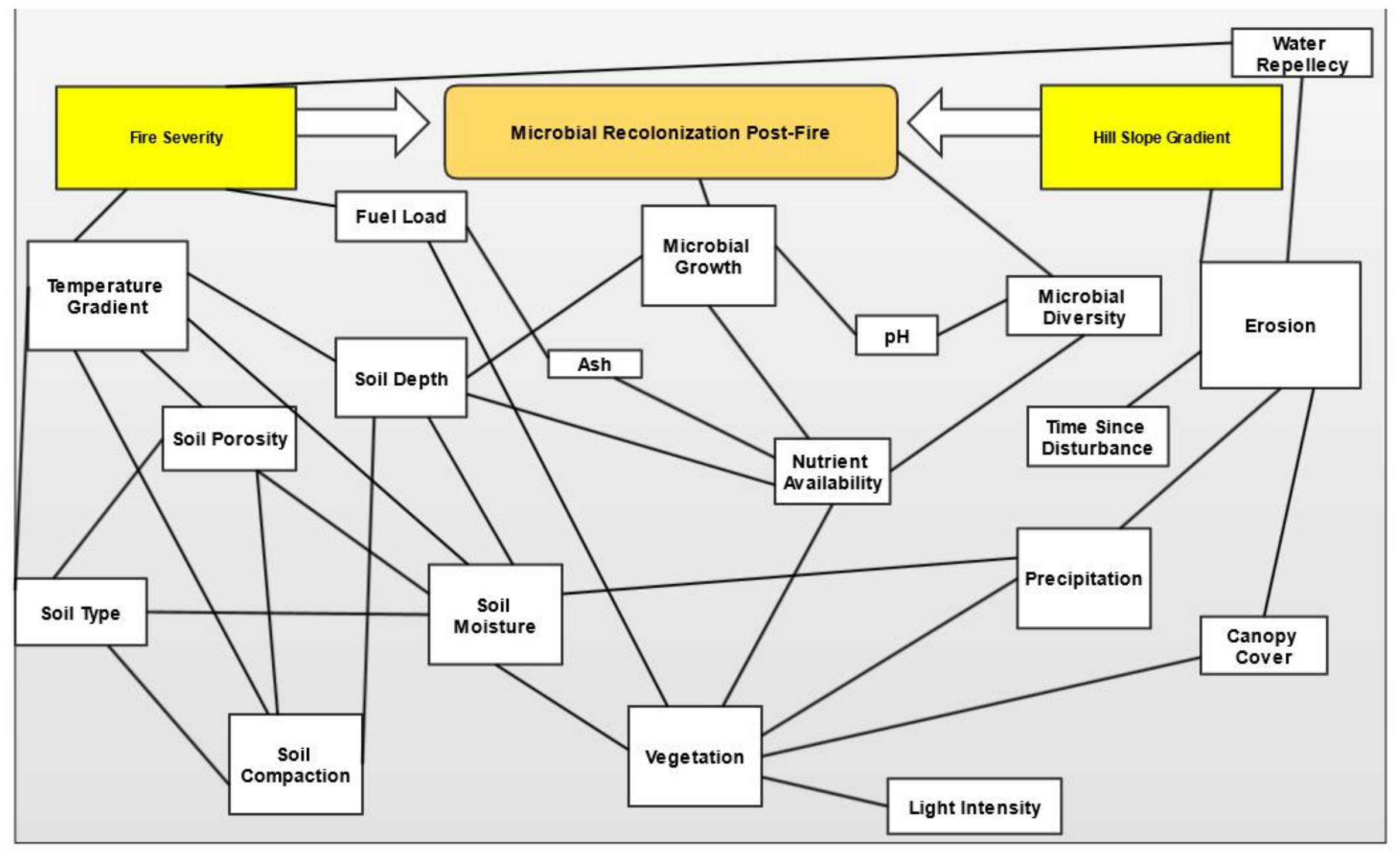

Figure 1. Connections of influencing factors between current study treatments (yellow) and other variables (white) in microbial recolonization

Purpose

The purpose of this study is to evaluate the effects of fire severity and hillslope gradient on the re-establishment of nitrifying bacteria within the context of the microbial community, and the effect of this succession on potential nitrification rates in ponderosa pine forest soils after wildfire. There are three main questions:

Given the degree of soil heating, what is the recovery trajectory of nitrifying bacteria as a function of soil depth?

What is the effect of soil erosion on the recovery of nitrifying bacteria within the microbial community?

Given the different temperature sensitivities of nitrifying bacteria, what is the relation between the nitrifying bacteria based on recovery rates and subsequent effects on nitrification rates?

Study Sites and Methods

The Valles Caldera National Preserve, New Mexico serves as the study site where the Thompson Ridge fire occurred in June 2013 (Figure 2).

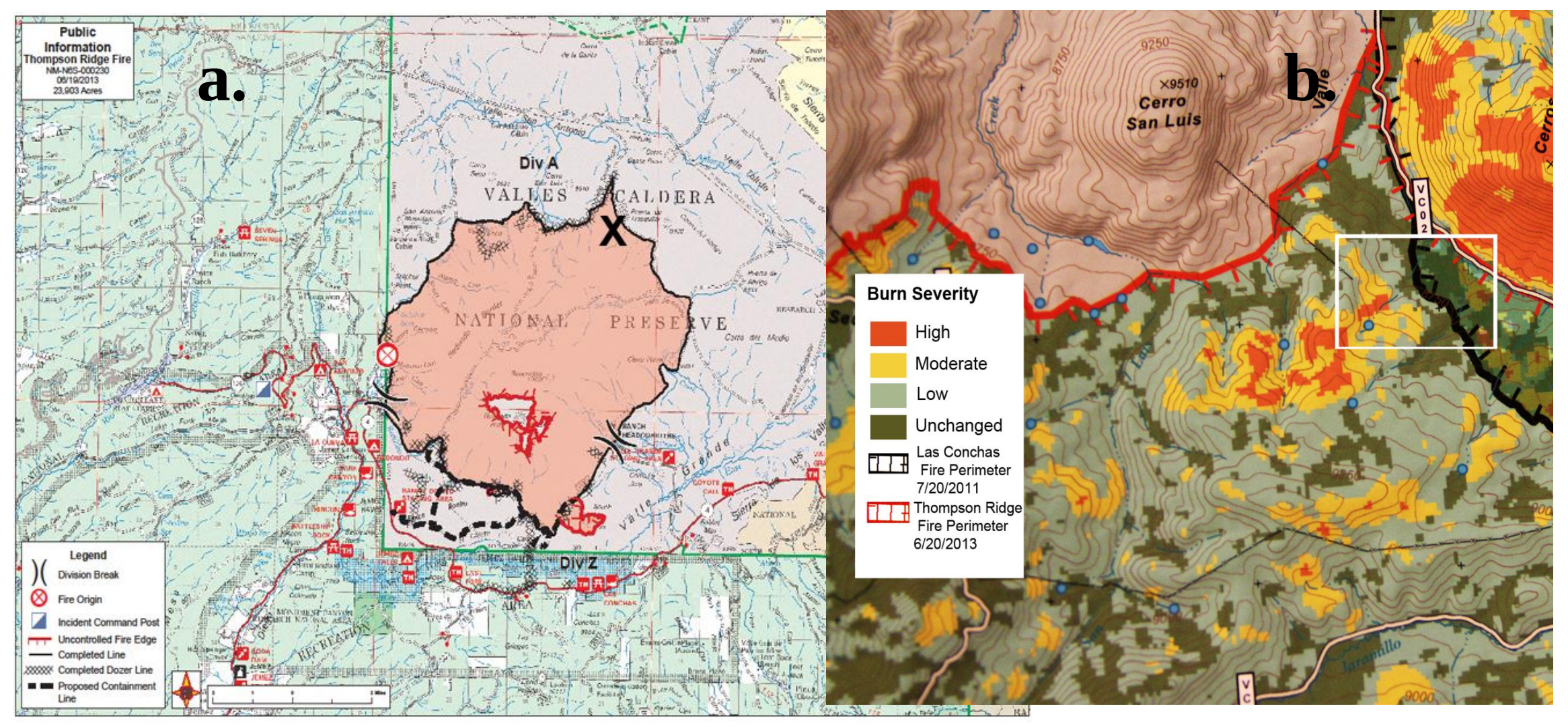

Figure. 2 a) Map of Thompson Ridge Fire outlined in the Valles Caldera National Preserve. Study sites marked with X. b) Fire severity map of Thompson Ridge fire. Study sites outlined in white box. Photo Credit Inciweb.org

Two fire severity (high and low severity) were identified based on a fire severity map provided by the Valles Caldera Trust. (Figure.3) Within each fire severity, two hillslope gradients were selected (gentle slope and moderate). There were two replications of each treatment combination for a total of eight plots (Figure 3).

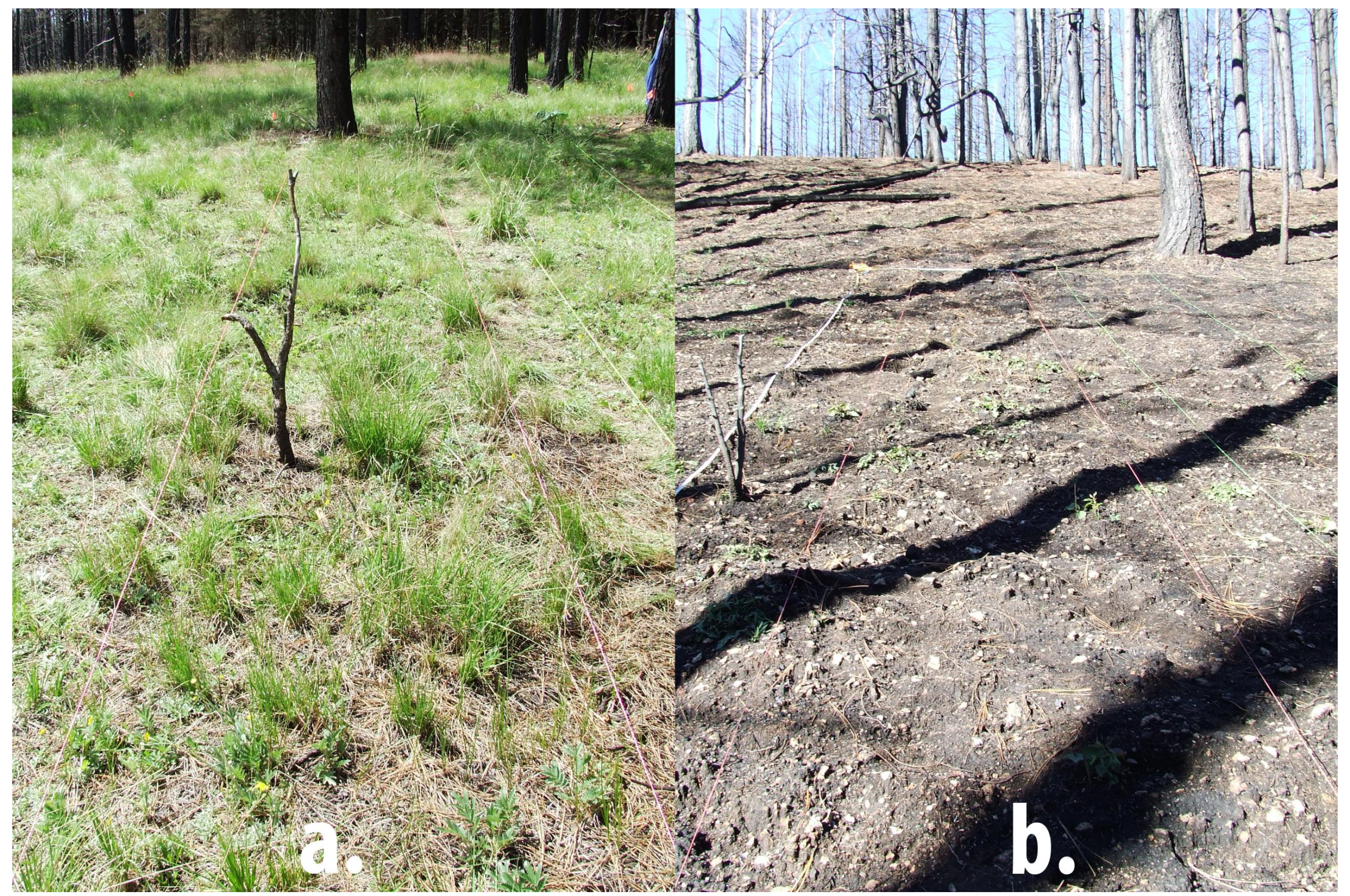

Figure 3. A) Soil plot at a low severity site with gentle slope, b) soil plot at a high severity, moderate slope.

Plot gradients were determined by measuring the change in height over the plot length using a hand-held distometer laser. Gentle slopes range from 0.11 to 0.13 m/m, while moderate gradients range from 0.13 to 0.31 m/m. Each treatment contains 10 soil plots (1 x 2 m), 20 vegetation plots (1 x 1 m), and one erosion plot (3 x 10 m). All plot were established from upslope to downslope so that changes could be measured as a function of position on the slope. There were two 1 x 10 m strips established for both soil and vegetation sampling. The erosion plot was established in the center, with the strips on either side. Within each strip, 5 quadrats (1 x 2 m) were established for soil sampling and 10 quadrats (1 x 1 m) for vegetation sampling (see Figure 4).

Figure. 4 Upslope view of high severity, moderate slope showing plots layout. Microbial sampling is exclusively from soil plots.

Three soil cores were extracted from a 20 cm x 20 cm randomly selected area within each 1 x 2 m soil plot. Soil samples were extracted using a soil corer. Cores were divided into 2 cm increments down to a 10 cm depth, and composited by depth for each 1 x 2 m quadrat (Figures 5 and 6).

All samples were placed at 32°C in the field and stored in a freezer at -40°C in the laboratory.

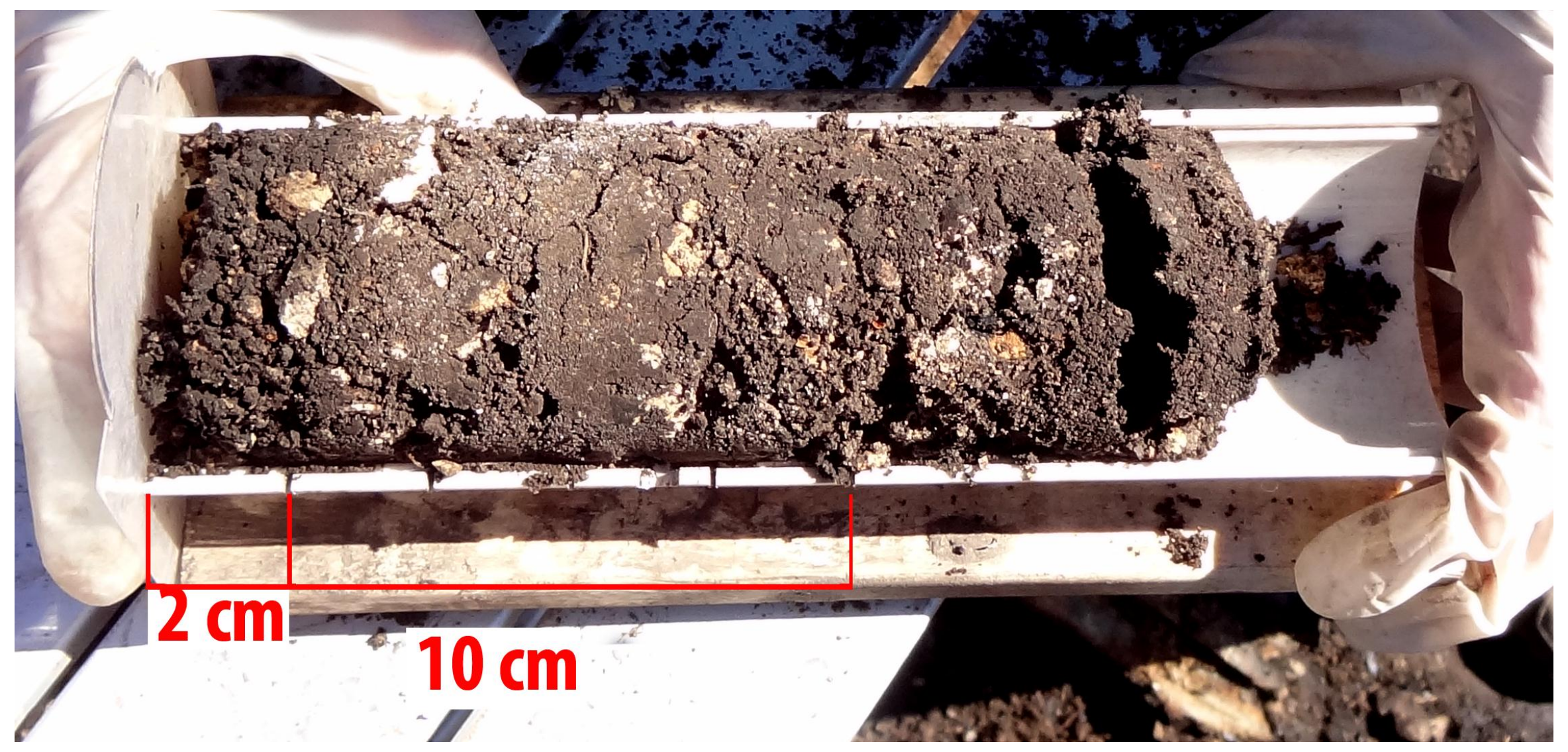

Figure 5. A soil core from a high severity, moderate slope site inside a pre-cut cylinder made to assist in dividing soil cores

Figure 6. Soil coring process. A) Taking samples with the soil corer and slide hammer, B) removing soil core sample from ground with the aid of a wrench to minimize disturbance to surrounding soil, and C) removing soil core sample from slide hammer.

Samples were taken in July 2013 approximately one month after the fire, and at the end of September 2013. Additional sampling will take place in the spring and summer of 2014 in order to analyze recovery over time. Further analysis for nitrifying bacteria community structure and function will be made by the MPN method, community level physiological profiling (CLPP) using Biolog Eco Plates, and potential nitrification rates. Other variables that will be measured are noted in Figure 1.

Expected Results

It is anticipated that the recovery of the two genus of nitrifying bacteria will vary by depth and down slope.

It is hypothesized that the recovery rates of *Nitrobacter* will be limited by the recovery of *Nitrosomonas* in high severity sites and will decrease potential nitrification rates.

It is also expected that higher rates of erosion will decrease recovery rates for nitrifying species through the removal of these species from the surface in high severity sites.

References

DeLuca, T. H., M. D. MacKenzie, et al. (2006). "Wildfire-Produced Charcoal Directly Influences Nitrogen Cycling in Ponderosa Pine Forests." Soil Science Society of America Journal **70**(2): 448-453.
Dunn, P. H., S. C. Barro, et al. (1985). "Soil moisture affects survival of microorganisms in heated chaparral soil." Soil Biology and Biochemistry **17**(2): 143-148.
Neary, D. G., C. C. Klopatek, et al. (1999). "Fire effects on belowground sustainability: a review and synthesis." Forest Ecology and Management **122**(1–2): 51-71.

Acknowledgements

This project was supported by the TREE Program funded by a USDA HSI grant, private donations from Vale/Walker/Alvarez, J.K. Bush, and the UTSA College of Sciences. We would also like to thank Dr. Parmenter and the Valles Caldera Trust.