Piñon mortality and summer monsoon rains affect extracellular enzyme activity of soil microbial communities living beneath tree canopies in a Piñon-Juniper woodland

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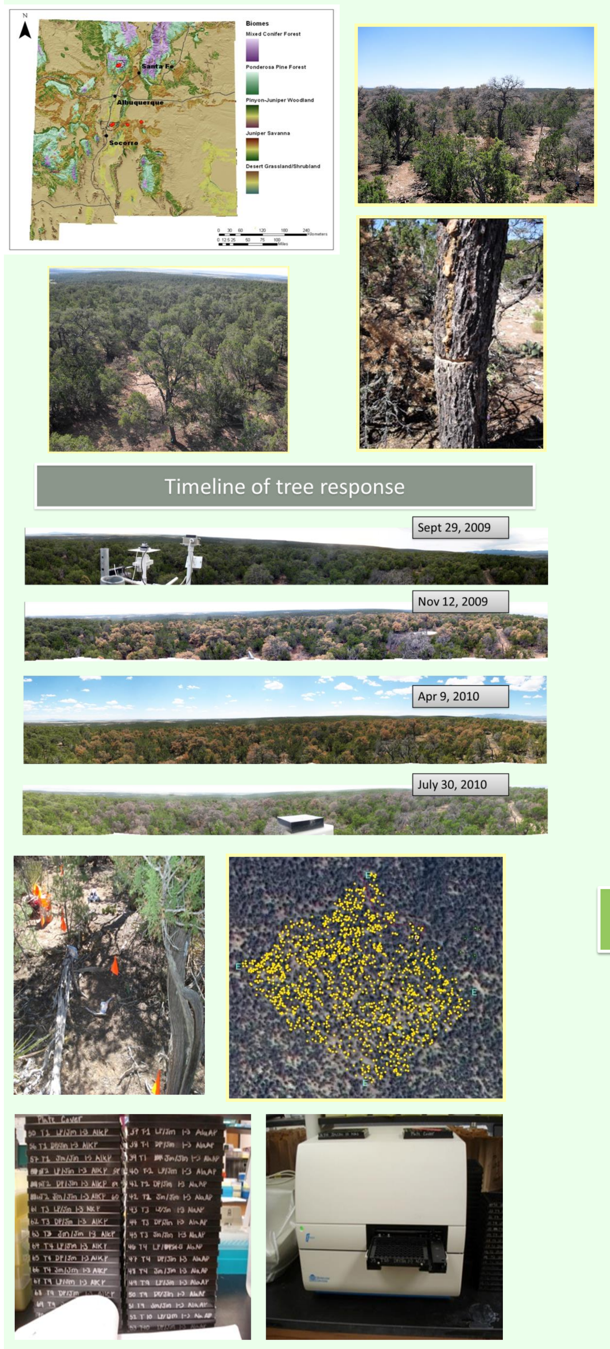
AbstractPiñon (*Pinus edulus*) - Juniper (*Juniperus monosperma*) (PJ) woodlands cover 17+ million hectares in the western US, and approximately 4.2 million hectares, in New Mexico alone. However, these numbers are currently changing, due to multiple, prolonged, drought induced die-offs among the piñon trees. Further piñon die-offs will likely influence the functional activities of the resident soil microbial communities, and the strength of their involvement in key soil processes rates. Therefore, to assess the aggregate impacts of piñon mortality on microbial activity, we collected soil samples in both the dry and wet seasons, from beneath piñon and juniper canopies at two different PJ woodland sites. One site included the widespread presence of dead piñons, while the other site did not. We analyzed eleven soil physicochemical properties, fungal biomass, sap-flow rates in both piñons, and junipers, and the activities of alanine aminopeptidase, alkaline phosphatase, β-D-glucosidase, and β-N-acetyl glucosaminidase (NAGase). At the level of individual rhizospheres, soil enzyme activity patterns varied as a consequence of neighbor identity, status and soil moisture. For example, β-glucosidase activities under intraspecific juniper canopies were consistently higher than the rates observed from beneath intraspecific piñon canopies, but only when piñon mortality was prominent. In contrast, when dead piñon presence was minimal this trend was reversed as soil moisture increased from 3% to 11%. At the whole site level, where piñon mortality was minimal, NAGase activity responded negatively to increased soil water availability, fungal biomass, β-Glucosidase activity, and peptidase activity; however, when tree mortality was prominent, NAGase responses to all four of these factors was reversed. These results illustrate how widespread piñon mortality, can significantly affect the functional behavior of root associated microorganisms. Further, the magnitude of these effects varies across the growing season, in association with the dynamics of summer monsoon rains

Introduction

- Arid systems cover 40% of terrestrial surface
  - Store 2x the C as temperate forests (Anderson-Teixera et al. 2011)
  - Desert and aird ecosystem especially sensitive to climate change (Diffenbaugh et al. 2008; IPPC 2007)
- Piñon (*Pinus edulus*) - Juniper (*Juniperus monosperma*) (PJ) woodlands cover approximately 4.2 million hectares, in New Mexico alone
  - Numbers shrinking due to drought induced pinon mortality
- Mortality events likely to be more common over next 100 years
  - Will likely affect soil ecosystem processes
  - Long term effects remain understudied

Materials and Methods

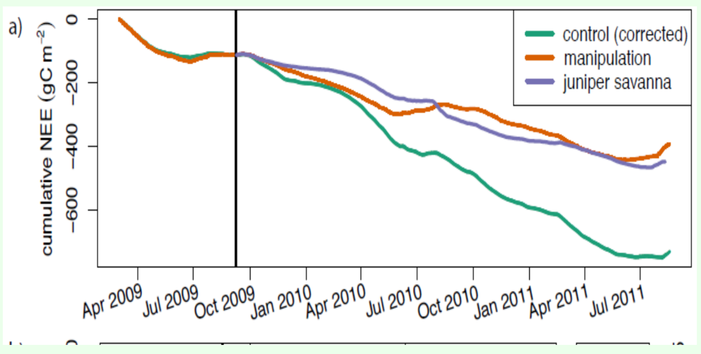
- Collected soil samples in both the dry and wet seasons
- One site included the widespread presence of dead piñons, while the other site did not

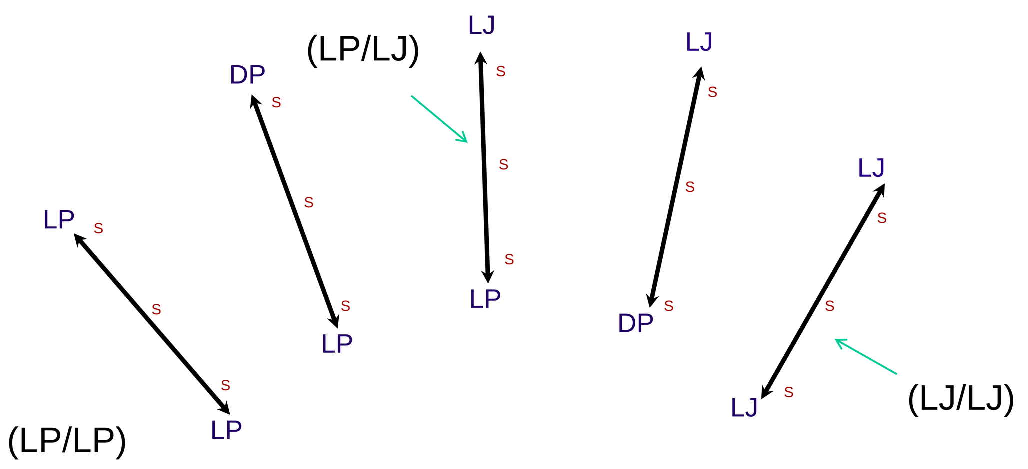


Extracellular Enzyme Assays

Substrates	Target enzymes	Enzyme hydrolyzes
L-Alanine-7-amido-4-methylcoumarin	Amino peptidases	Proteins
4-MUB–phosphate	Phosphatases	Phosphoesters
4-MUB-β-D-glucoside	Cellulases	Cellulose and hemi-cellulose (Plant cell walls)
4-MUB-N-Acetyl-β-Glucosaminide	NAGases	Chitin and Peptidoglycan (Bacterial and fungal Fungal cell walls)

Carbon sequestration two years post- girdling very similar to juniper savanna





S= Sample (3cores/sample)
DP=Dead piñon
LP=Live piñon
LJ=Live juniper
Samples collected June, and September

During data analyses, both samples collected from under LP in (LP/LP), and from LJ in (LJ/LJ) gradients were pooled into single groups, e.g. all LP from (LP/LP) analyzed together. All data analyzed with ANOVA. All post-hoc comparisons performed by comparing each pair with a student's t -test

Nearest neighbor level responses

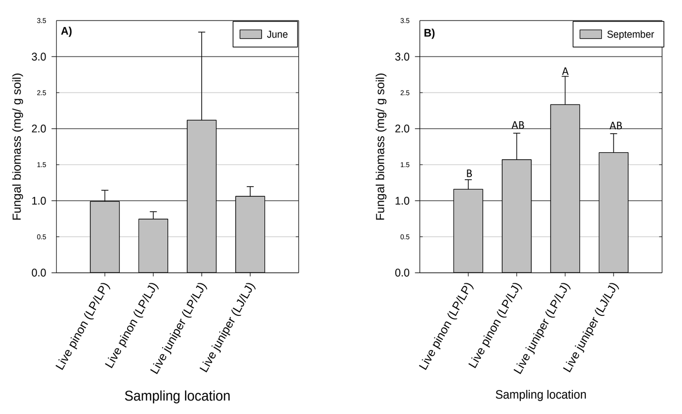


Figure 1: Mean soil fungal biomass from samples collected at the control site in A) June 2011, and B) September 2011. Error bars represent one standard error of the mean.

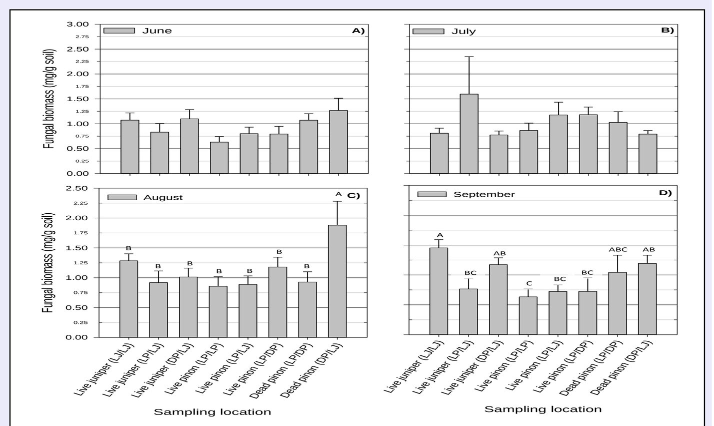


Figure 2: Mean soil fungal biomass from samples collected beneath tree canopies at the girdled site, for A) June 2011, B) July 2011, C) August 2011, and D) September 2011. Error bars represent one standard error of the mean.

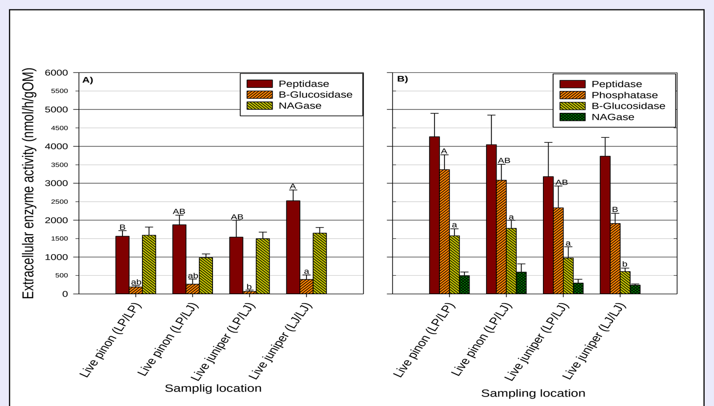


Figure 3: Mean soil enzyme activity rates from the control site, for both A) June 2011 and B) September 2011. Y axis scale is the same, for both panels

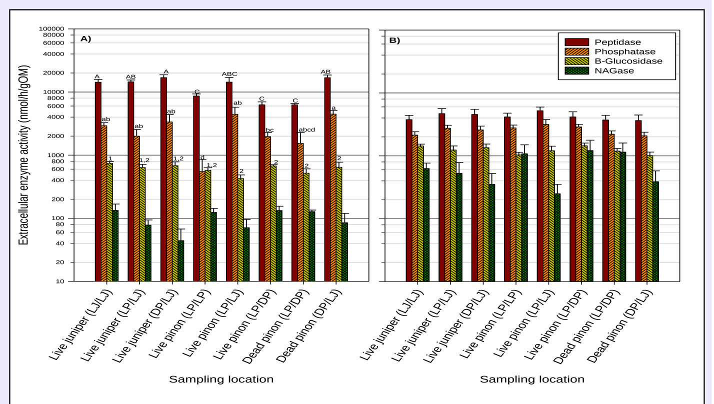


Figure 4: Mean soil enzyme activity rates for A) June and B) July 2011, from the girdled site. Y axis scale is the same, for both panels.

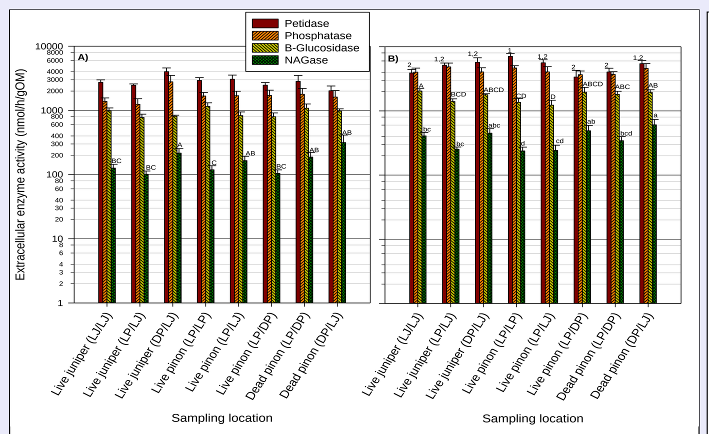


Figure 6: Mean soil enzyme activity rates for A) August and B) September 2011, from the girdle site. Y axis scale is the same for both panels

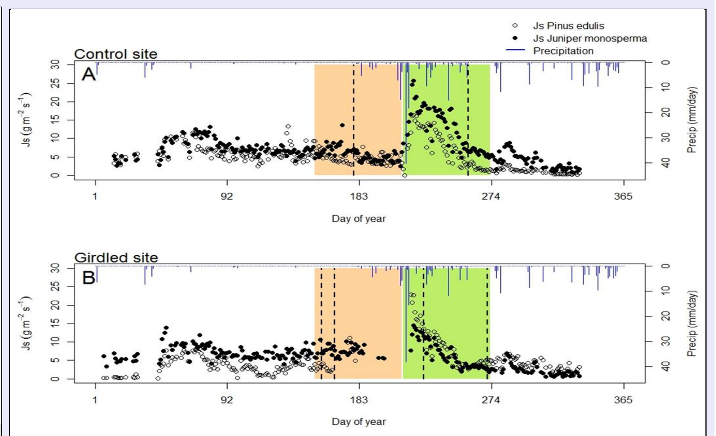


Figure 7. Piñon and juniper daily means of sap flow density (Js) for year 2011.Dry (June-July) and wet (August-September) periods considered in this work have been highlighted in brown and green respectively. Dashed line is showing soil-sampling dates at both sites. There were no sap flow data collected on July 19th from the girdled site, which is day number 200 on the y axis.

Site level responses

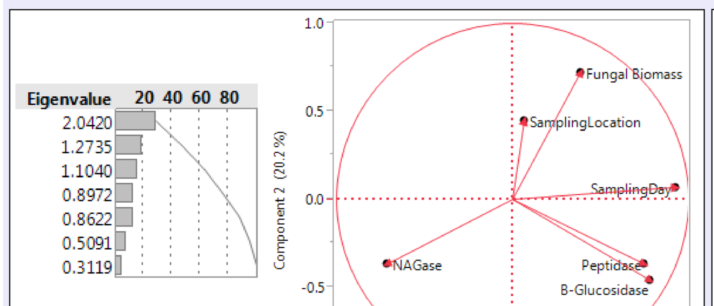


Figure 7: Graphical results from PCA analyses of all data from the control site

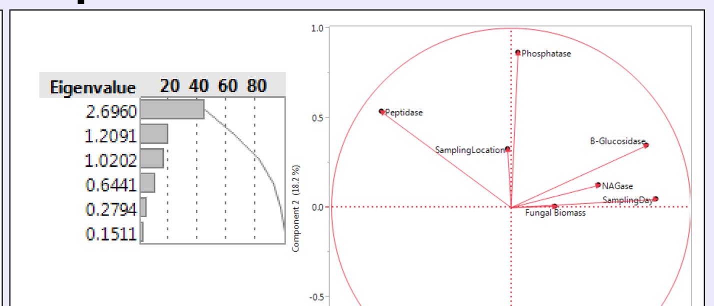


Figure 8: Graphical results from PCA analyses of all data from the girdled site

Literature Cited:

Anderson-Teixeira KJ, Delong JP, Fox AM, Brese DM, Litvak ME (2011) Differential responses of production and respiration to temperature and moisture drive the carbon balance across a climatic gradient in New Mexico. *Global Change Biology*, 17, 410–424.

Diffenbaugh NS, Giorgi F, Pal JS (2008) Climate change hotspots in the United States. *Geophysical Research Letters*, L16709.

IPCC (2007) Climate change 2007: Impacts Adaptation and Vulnerability. Contribution of working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC 2007, Cambridge, UK

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Results summary and Discussion

Control site nearest neighbor effects:

- June: all results, e.g. fungal biomass and enzyme activity rates, NS for all samples from under trees
  - Record drought, 6 months w/o rain
- September: Alkaline phosphatase and β-D-glucosidase activities both higher under piñon canopies in (LP/LP) than under juniper canopies in (LJ/LJ).

Girdled site nearest neighbor effects :

- June: Fungal biomass and 3 of 4 enzyme activity rates higher under junipers canopies (LJ/LJ), than under piñons in (LP/LP)
  - Junipers anisohydric while junipers are isohydric junipers and thus maintain higher photosynthetic activity during drought
- September: Fungal biomass, N-acetyl-β-glucosaminidase, and β-D-glucosidase activity rates all higher intraspecific Piñons (LP/LP) than intraspecific Junipers (LJ/LJ)
  - Peptidase activity higher under piñon canopies in (LP/LP) than under juniper canopies in (LJ/LJ)

Sight level effects:

- NAGase activity at the control site responded negatively to increased soil water availability, fungal biomass, β-Glucosidase activity, and peptidase
- NAGase activity at the girdled site responded positively to all four of these factors

Discussion:

- Junipers (LJ/LJ) at girdled site, support more fungi than living piñons (LP/LP)
  - No biomass differences at control site
  - Junipers at girdled site may be providing fungi with more substrates
- Higher enzyme activities under juniper canopies coupled with higher fungal biomasses (β-Gluc and NAG)
  - Scavenging for soil for C and N from cell wall materials
- Opposite trend in peptidase (AlaAP) activity despite lower fungal biomasses
  - Ability of microbial community to cope with host stress
  - Increased demand for N among small surviving piñons
- Variation across enzyme activity rates highlight necessity of multiple sampling dates
  - See different trends depending on enzyme/ date