Supporting Information

Legacy of microbial composition matters in simulating climate-driven litter decomposition

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This document serves to appendix the main text with parameterization of DEMENTpy, forcings across the climate gradient in Southern California, and model formulation, supporting text and results, as structured and detailed below:

1. DEMENTpy
2. Climate gradient, DEMENTpy forcings, and microbial communities
3. Supporting results

1 DEMENTpy

1.1 Bridging osmolytic production and drought tolerance

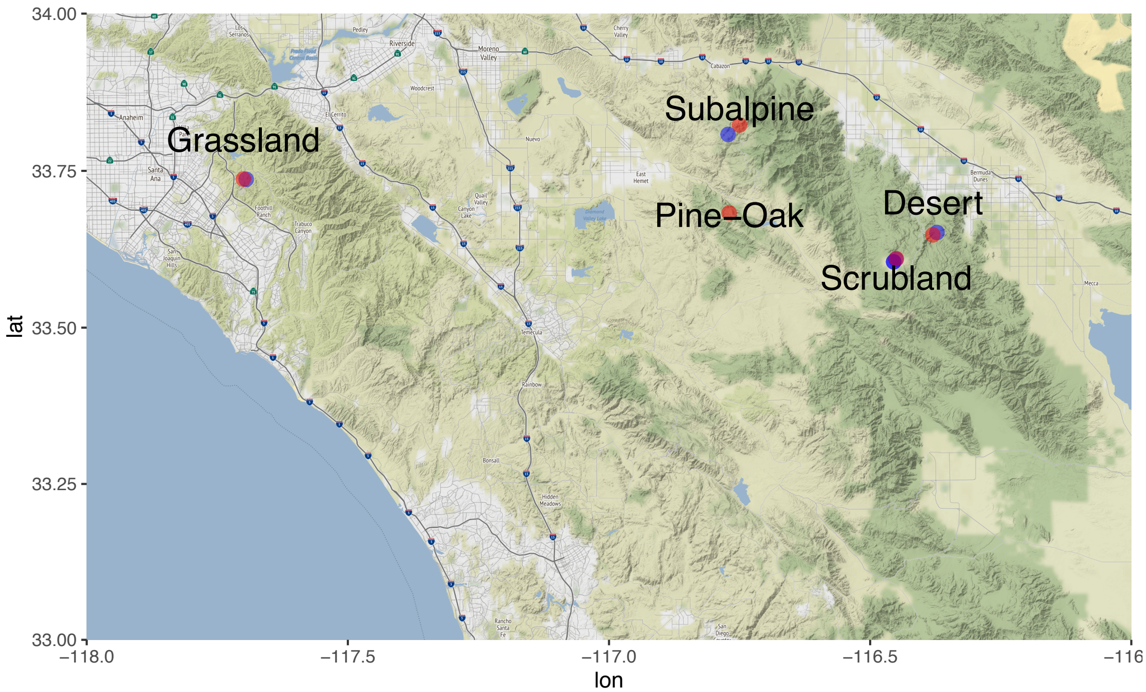
1.2 Dispersal

Dispersal is a key process in microbiome assembly and functioning. DEMENTpy deals with dispersal explicitly with a few assumptions on environmental factors controlling dispersal rate (R_d), which follows:

$$R_d = ?? \tag{1}$$

2 Climate gradient, DEMENTpy forcings, and microbial communities

This document details the preparation for DEMENTpy inputs at each of the five sites simulated across the climate gradient (**Figure 1**). In detail, inputs including water potential, soil temperature, and litter chemistry were processed and derived. Water potential was derived from precipitation via an intermediate step of converting the precipitation data. Python code [in the format of Jupyter Notebook(.ipynb)] underlying all of the processing is accessible at a GitHub Repo (`https://github.com/bioatmosphere/microbiome-climate-gradient.git`). With step-by step demonstrations, those readers who have a keen interest are supposed to be able to easily reproduce these preparations.



Supporting Fig. 1. Location of the five sites across the gradient. Map source:stamen.

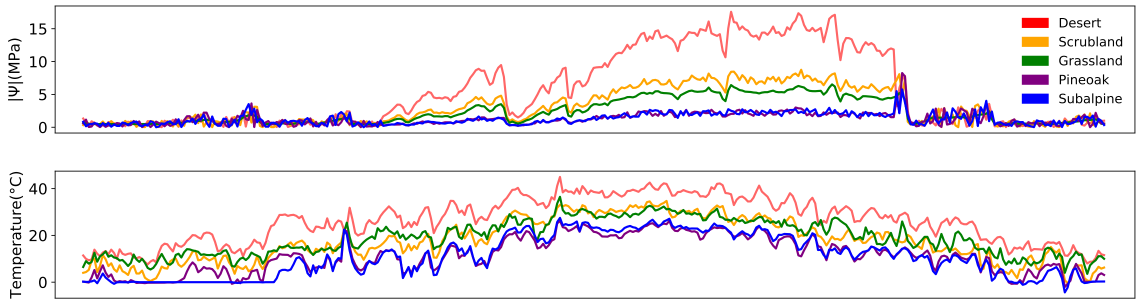
2.1 Ecosystems across the Southern California climate gradient

Table 1. Five sites across the climate gradient.

Site	Latitude	Longitude	Elevation
Desert	33.648	-116.38	275
Scrubland	33.610	-116.45	1280
Grassland	33.737	-117.70	470
Pine-Oak	33.683	-116.77	1710
Subalpine	33.823	-116.75	2250

All five sites (**Table 1**) are located on granitic parent material and experience Mediterranean precipitation patterns (cool, wet winters; hot, dry summers). This climate gradient covers a temperature range from ... to...

2.2 Environmental Forcing



Supporting Fig. 2. Forcings of the five sites across the gradient. Note that the water potential is shown in absolute values.

2.2.1 Water Potential (ψ)

As there are no leaf water potential (ψ; unit: MPa) across the gradient readily available, a method of approximation was applied. Two approximation methods are developed based on the only available, indirectly derived water potential data at the grassland site. With available measurements of water content (θ; unit: g H_2O g^{-1} wood) of grassland litter, daily water potential was derived by Allison & Goulden (2017) at the grassland site for a record of 3 years(2011-2013). This derivation of water potential followed a conversion from water content to water potential as per the equation [Dix (1985), referenced in Allison & Goulden (2017)]:

$$\psi_{grassland} = -10^{0.118-0.114\log_{10}\theta} \tag{2}$$

One way is extrapolating the other four sites from the grassland site by a simple scaling relationship. Water potential (ψ_{site}) of each of the other four sites was then derived by linearly scaling grassland site water potential ($\psi_{grassland}$) with Total Annual Precipitation (**TAP**; unit: mm) and annual mean temperature at each site following:

$$\psi_{site} = \frac{TAP_{site}}{TAP_{grassland}}\psi_{grassland} \tag{3}$$

One condition that makes this approximate scaling legitimate is the same Mediterranean precipitation patterns across the climate gradient (cool, wet winters and hot, dry summers). However, snowfall is not explicitly considered The derived water potential is further smootheed to reduce noise. A detailed implementation of the derivation is presented in the Jupyter Notebook `precipitation_v1.ipynb`.

The alternative is a machine learning-based approach with a simple linear regression algorithm. A linear regression model of water potential as a function of precipitation and temperature is built from the grassland site data. This model is then used to obtain water potential for the 5 sites from 2017-2019.

2.2.2 Temperature (°C)

DEMENTpy is conceived using litter temperature at a daily resolution in principle. In practice, soil surface temperature is used instead to approximate the litter temperature. Soil temperature data at a sub-daily time step across the gradient at each of five sites were measured. Details with regards to the measurement method, pre-, and post-processing are documented in Glassman et al. (2018). These data are openly accesible at `https://github.com/stevenallison/UCIClimateExperiment/tree/master/updatednames`. From these field measurements, daily soil temperature was derived by averaging all (replicates?) measurements in each day, which was further smoothed. A step-by-step demonstration of this derivation is presented in the Jupyter Notebook `soil_temperature.ipynb`.

2.3 Litter Chemistry and Input

DEMENTpy requires substrate-specific inputs in terms of C, N, and P (**Table xx**). **Phospholipids** (i.e.,OrgP1 in the model) are a key component of all cell membranes (`https://en.wikipedia.org/wiki/Phospholipid`). Though compound-specific stoichiometry is clear for determining concentration by element, substrate-specific concentration ((Sub_i); unit: mg cm^{-3}) needs to be determined. This derivation followed:

$$Sub_{s,i} = f_{s,i} Ts \tag{4}$$

where s is one of the five sites, i is one of the 10 substrates, $f_{s,i}$ is the percentage of substrate i in site s, and T_s is the total concentration of initial substrates (C+N+P) in site s. f was informed by field measurements of litter chemistry at each site as presented in Baker & Allison (2017). T was assumed the same across sites. As per the observation by Baker & Allison (2017), standing litter pools are largest in the grassland and pine-oak site, reduced in the subalpine site, significantly reduced in the scrubland site, and negligible in the desert site. A detailed script implementing these processes is presented in the Jupyter Notebook `litter_chemistry_v1.ipynb`.

2.4 Microbial communities across the gradient

Microbial systems after four years presented significant differences across the gradient with respect to decomposition and community-level enzyme investment and drought tolerance. Enzyme investment was different among the five sites ($P < 0.05$). However, the drought tolerance

composition (biomass):

traits:

decomposition:

References

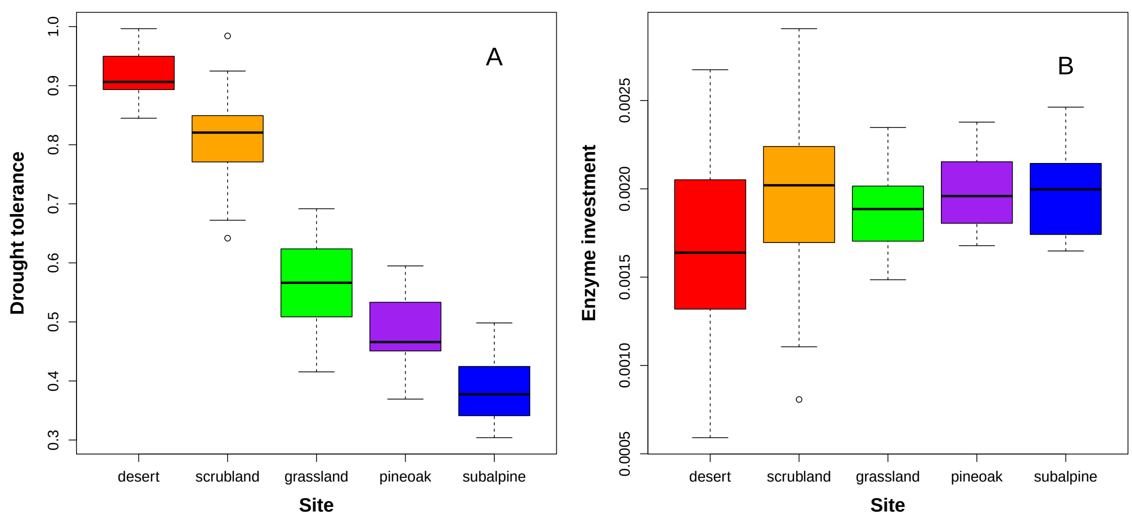
Allison, Steven D, & Goulden, Michael L. 2017. Consequences of drought tolerance traits for microbial decomposition in the DEMENT model. Soil Biology and Biochemistry, **107**, 104–113.

Baker, Nameer R, & Allison, Steven D. 2017. Extracellular enzyme kinetics and thermodynamics along a climate gradient in southern California. Soil Biology and Biochemistry, **114**, 82–92.

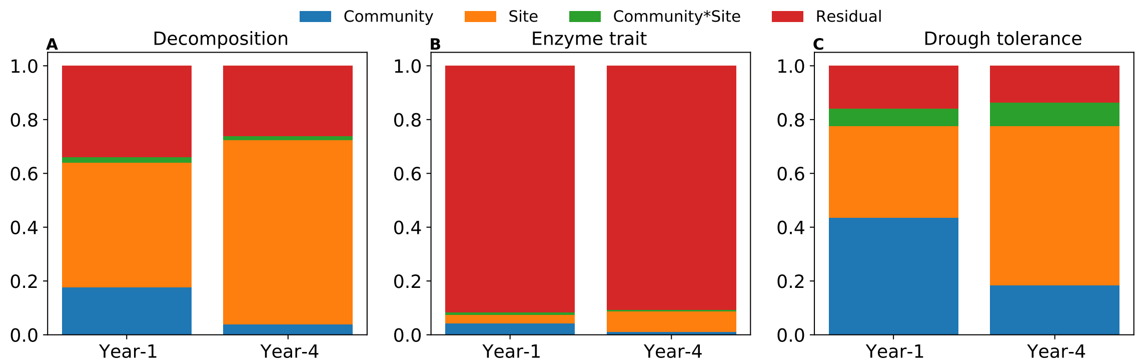
Dix, NJ. 1985. Changes in relationship between water content and water potential after decay and its significance for fungal successions. Transactions of the British Mycological Society, **85**, 649–653.

Glassman, Sydney I, Weihe, Claudia, Li, Junhui, Albright, Michaeline BN, Looby, Caitlin I, Martiny, Adam C, Treseder, Kathleen K, Allison, Steven D, & Martiny, Jennifer BH. 2018. Decomposition responses to climate depend on microbial community composition. Proceedings of the National Academy of Sciences, **115**, 11994–11999.

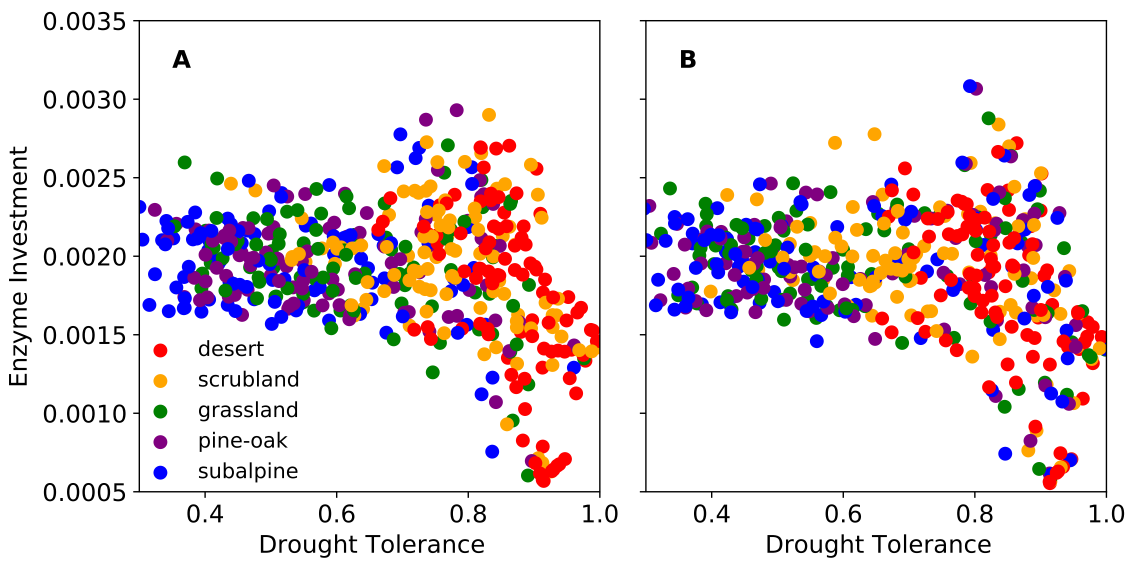
3 Supporting Results



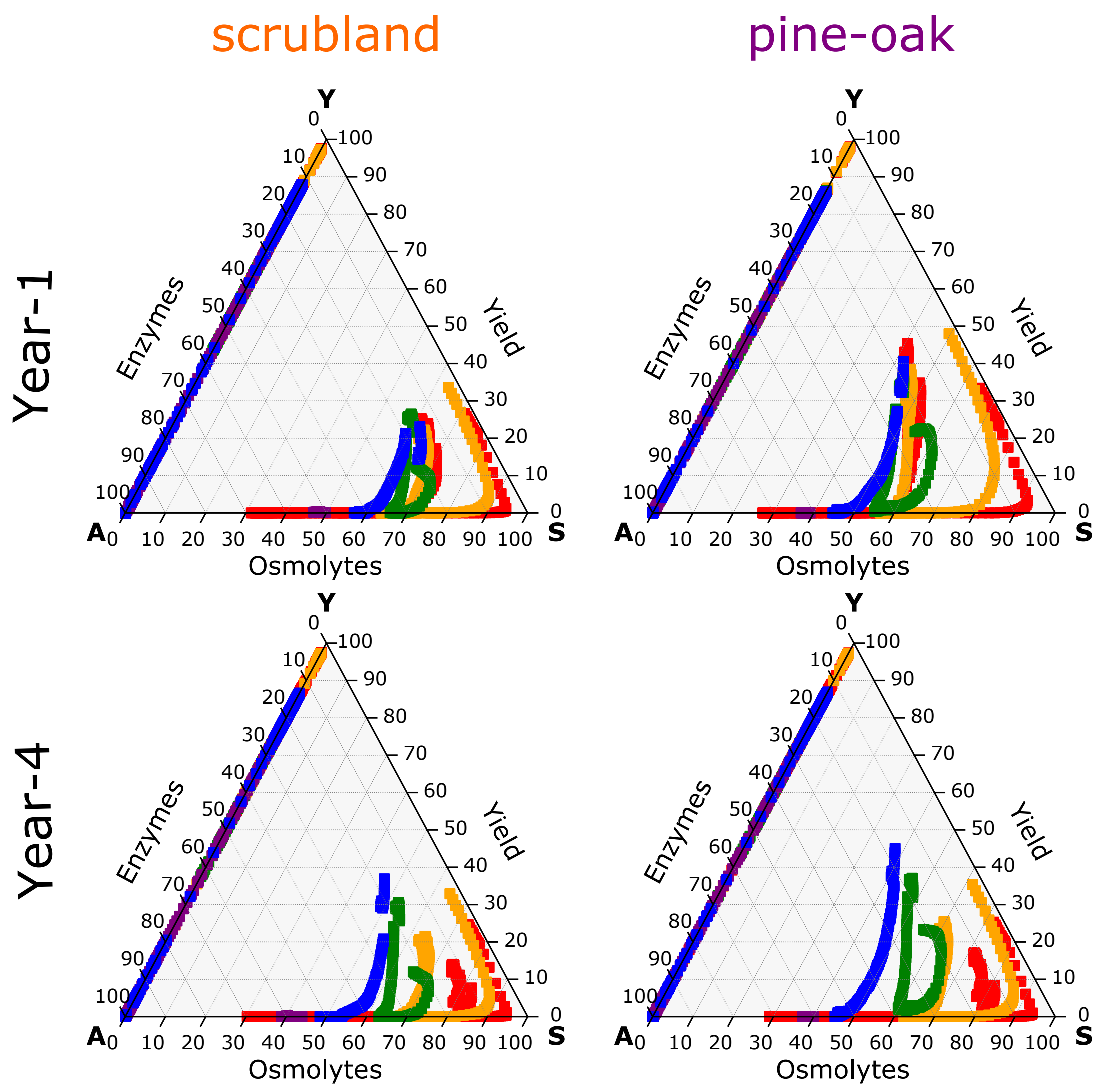
Supporting Fig. 3. Community traits at the five sites across the gradient before transplant.



Supporting Fig. 4. Variance partitioning of decomposition (A), Enzyme trait (B), and Drought tolerance (C). Note in panel B only site and community are significant in year-1, and site significant in Year-4.



Supporting Fig. 5. Enzyme investment versus drought tolerance by the end of year 1 (A) and year 4 (B) after the transplant. Data across the gradient were pooled together and colored by site.



Supporting Fig. 6. Ternary plots of allocation among enzyme, osmolyte, and yield. Y, A, and S corresponding to Yield, Acquisition, and Stress tolerance