Changes in above- and below-ground phenological relations across type-converted invaded grasslands in southern California

Request for funding from the Shipley-Skinner Reserve- Riverside County Endowment

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$19,987
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Introduction

Terrestrial plant ecosystems are steadily invaded with the continued intensification of human activity (i.e. agriculture, urban development, and commerce). Invasions have widespread effects on resource availability, community composition, disturbance regimes and other ecosystem functions (Antonio & Vitousek 1992). Community type conversion is facilitated by invasion through changes in resource availability and soil microbial communities. In southern California high levels of urbanization, agricultural production and nitrogen deposition from automobile emissions make type conversion of coastal sage scrub and chaparral to non-native grassland a serious problem (Antonio & Vitousek 1992).

The shift from evergreen chaparral shrubs to non-native grassland has widespread effects on ecosystem services to human populations such as erosion control and watershed quality (ref). Species invasions often occur when the invader possesses physiological traits (such as growth rate, specific leaf area, and life span) different from natives that allow it to take advantage of immediately available resources (Dickens and Allen 2014). These differences in traits manifest in mechanisms that affect ecosystem function, such as vegetation growth rate and carbon content both above and below ground. For example, species with high levels of photosynthetic activity will cycle carbon from the soil to the atmosphere more rapidly than species with a more conservative photosynthetic strategy (De Deyn et al. 2008). Non-native grasses are fast-strategist annuals that provide a large amount of litter seasonally, while chaparral communities include slow growing species that are associated with low litter deposits as well as conservation of carbon and nitrogen and within soils. Faster growing species are associated with lower nitrogen and carbon retention and can lead to decreased soil carbon storage (De Deyn et al. 2008). In addition, fast strategist species employ different hydrologic strategies than our native drought tolerant flora. The effect of type conversion on ecosystem function is being extensively studied, however the seasonality of belowground dynamics between vegetation type remains poorly understood. To manage and restore these type converted lands, a deeper understanding of belowground processes is greatly needed.

Background and Rationale

One explanatory mechanism for successful invasion is phenological plasticity (Willis et al. 2010). In addition to being able to quickly use resources, invasives can flexibly respond to seasonality. This response could include acclimation to earlier spring temperatures, unseasonally early rains or changes in flowering time (Willis et al. 2010). Climate models predict rises in global average temperature and substantial changes in local and regional precipitation regimes. Plastic responses to temperature or precipiation could make invasive species better suited for changing climate when compared to natives (Willis et al. 2010). Although multiple studies have shown that invasives may have adaptive phenological responses, most studies focus on shoot growth, flowering, fruiting or leaf shedding with few studies that focus on belowground phenological responses and fewer still in heavily invaded systems(Wilson 2014).

Roots experience a longer growing season than shoots, demonstrated by a delayed peak of productivity in roots relative to shoots (Wilson 2014). Fine roots also have longer life spans than leaves. These concepts make temporal variation in nutrient uptake an important consideration for belowground studies (Wilson 2014). However, research on belowground phenology is usually focused solely on roots with little attention given to mycorrhizal fungi. Both roots and mycorrhizae have important roles in nutrient and water uptake as well as carbon storage dynamics (De Deyn et al. 2008). Research on mycorrhizal phenology has examined responses to changes in soil moisture and temperature, but has not studied relation to aboveground phenology(Hernandez & Allen 2013). Previous studies on root phenology have not taken into account the effect of seasonal variation in plant-microbe competition for nutrients. This competition will likely vary between vegetation types because of differences in community composition. Research on plant-microbe competition has found that microbes immobilize N in the fall shortly after plant senescence and release it after snowmelt, but no previous studies have been conducted in Mediterranean systems(De Vries & Bardgett 2012). More information on the seasonality of microbial community composition, root and hyphal biomass and how these affect above-ground measures of nutrient and water uptake will add greatly to the current body of knowledge.

Measures of above- and below-ground phenological interactions have not been consistent across vegetation type, with some literature suggesting a decoupling of root-shoot phenology in invasive species (Wilson 2014). Studies of above- and below-ground interactions show that there is not a clear relationship between increased aboveground biomass and carbon storage, with more information needed on the role of below-ground processes (Wilson 2014). Studying the relationship between below- and above-ground phenology is essential to understanding how the vegetation life cycle will respond to shifting temperature, precipitation and drought patterns.

Research Aims

The proposed research aims to fill knowledge gaps in the role of root and hyphal phenology on water and nutrient uptake while also comparing belowground phenological responses to aboveground vegetation response. The research questions and hypothesis are as follows:

How do above- and below-ground phenological responses vary across vegetation type?

H_1: If non-native grasses exhibit plastic phenological responses, aboveground biomass will respond rapidly to temperature changes and water availability resulting in relatively larger investments in aboveground biomass than belowground biomass.

H_2: If natives are less phenologically plastic than non-natives, they will exhibit coupled phenological response following historic trends resulting in a more even ratio of aboveground and belowground biomass with belowground biomass peaking later in the growing season.

How does water and nutrient uptake vary seasonally across vegetation type?

H_3: If non-native grasses are more phenologically plastic than natives, then non-natives will rapidly uptake available resources before natives can respond resulting in earlier phenological peaks.

H_4: If competition for belowground resources is greatest during the growing season, then microbial community composition will vary seasonally and evidence for plant-microbe competition will be highest when belowground saprophyte functional diversity, abundance, and activity are greatest.

Study Site

The San Dimas Experimental Forest (SDEF), located in the San Gabriel Mountains northeast of Los Angeles, is 6,945 ha (17,153 acres) of California chaparral and woodlands. A small portion of the forest was purposely type converted from native chaparral to grassland in the 1960s to study the relationship between ecohydrology and community type (Dunn et al. n.d.). This site is an exceptional site for the proposed studies because there is a gradient of type conversion from fully converted to undisturbed. This project would be in collaboration with a post-doctoral scientist studying aboveground phenological response, allowing me to leverage existing resources during data collection. The research site is relevant to understanding chaparral type-conversion currently happening at the Shipley-Skinner Reserve.

Research Plan

In the summer of 2015, I will install an automated minirhizotron (AMR) in type converted grassland and undisturbed chaparral(Allen & Kitajima 2013). Currently there are two far infrared phenological cameras installed at the site that take multiple photos a day. From these pictures we are able to calculate NDVI (Normalized Difference Vegetation Index) which is a measure of greenness that is used as a proxy for plant productivity (Cleland et al. 2007). In addition to this continuous phenological data a suite of physiological measurements will be taken to measure water usage. On the mature chaparral shrubs, there will be thermal dissipation sap flux sensors installed (Granier 1987). For the grassland, leaf-level gas exchange measurements will be taken with a Li-Cor LI-6400 multiple times throughout the season. Soil moisture and temperature sensors will be installed alongside AMRs and sap flux sensors. Seasonal measures of soil respiration using Li-8100, will monitor soil microbial activity. Sap flow sensors will allow for measurement of whole shrub water use, while leaf level gas exchange will include measurements of photosynthetic rate and stomatal conductance. The use of sap flow sensors can be incorporated into long-term monitoring efforts and together will form a comprehensive approach towards measuring above-ground physiological function.

The AMR imagery will allow me to calculate total root and hyphal biomass throughout each season as well as after rain and drought events(Allen & Kitajima 2013). Total root and hyphal biomass will be correlated to NDVI data for aboveground phenological events such as leaf flushing (“green up”), peak productivity (“greenness”), flowering, and photosynthetic senescence (“brown down”). Estimates of aboveground biomass will be calculated using NDVI and leaf area index (LAI) (ref). This approach will add significantly to our understanding of root and hyphal response to rain and drought events.

Soil and tissue samples will be taken at equal intervals three times per season and processed for total carbon and nitrogen. Seasonal gas exchange data will give insight into seasonal changes in productivity as well as above-ground carbon and water fluxes. To assess microbial community structure, DNA will be sequenced seasonally using the Illumina MiSeq instruments located in the UCR Genomics Core Facility. The 16-S V4 gene rRNA will be amplified for the bacterial and archeal communities and the ITS-2 region will be amplified for fungal communities (Ihrmark et al. 2012).The sequences generated will be matched to sequences in the Genbank database to obtain species level identification (Orgiazzi et al. 2015). This will allow me to track the diversity and abundance of the saprophytic microbial community throughout the year. This data will allow for a better understanding of seasonal shifts in microbial populations and how these shifts affect plant-microbe competition for nutrient uptake.

At the end of spring 2016, I will have three seasons of data composed of hyphal and root biomass (correlated with NDVI), aboveground biomass, plant and ecosystem water use and photosynthetic activity of both grasses and shrubs. Seasonal variation of abundance and functional diversity of the saprophytic community will be correlated to soil respiration as well as soil and leaf nitrogen to assess seasonal plant-microbe competition for nutrients. Using molecular techniques to characterize the microbial community will also allow me to track seasonal shifts in ectomycorrhizal community composition associated with shrub species. The relationship of belowground biomass to water usage will also be examined seasonally using gas exchange and soil moisture data. This project will fill in large, long-standing research gaps by quantifying the effect of belowground phenology on aboveground phenology and physiological function. This comprehensive approach will bridge three sub-disciplines and allow for a holistic understanding of processes driving seasonal change in the chapparal of southern California. The results from this research will be useful for active restoration of type converted communities and will add to the scientific knowledge base about both above- and below-ground phenological response to changing seasonal patterns.

Budget

GSR Salary Su 2015, F 2015 for Michala Phillips	12758
Fees (GSHIP & PRF) F15	5120
Benefits at 3.68%	470

Travel (majority of travel will include carpooling with post-doctoral collaborator)	330
(.5867/mi * 81 mi rt * 4 days) + (34.457/day *4) days	
Supplies (Mo Bio DNA Isolation Kit)	263
Analyses (This is the cost of sequencing at UCR Genomics core)	1046
Total	19,987

Budget justification

We request one summer plus one fall quarter of GSR plus fees and benefits for Michala Phillips during Su15 and F15 at $18348. She will need transportation to the field site during the 2015-2016 growing season for vegetation and soil sampling, and will carpool with the post-doctoral researcher to reduce costs. A vehicle for transportation will be reserved through the University of California Riverside Fleet Services. The final report including field, laboratory and data analyses will be completed in June 2016.

Literature Cited

Allen, M.F. & Kitajima, K., 2013. In situ high-frequency observations of mycorrhizas. *New Phytologist*, 200(1), pp.222–228.

Antonio, C.M.D. & Vitousek, P.M., 1992. Biological Invasions By Global Change. , pp.63–87.

Cleland, E.E. et al., 2007. Shifting plant phenology in response to global change. *Trends in Ecology and Evolution*, 22(7), pp.357–365.

De Deyn, G.B., Cornelissen, J.H.C. & Bardgett, R.D., 2008. Plant functional traits and soil carbon sequestration in contrasting biomes. *Ecology Letters*, 11(5), pp.516–531.

Dunn, P.H. et al., The San Dimas Experimental Forest : 50 Yearsof Research.

Granier, a, 1987. Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. *Tree physiology*, 3(4), pp.309–20. Available at: http://www.ncbi.nlm.nih.gov/pubmed/14975915.

Hernandez, R.R. & Allen, M.F., 2013. Diurnal patterns of productivity of arbuscular mycorrhizal fungi revealed with the Soil Ecosystem Observatory. *New Phytologist*, 200(2), pp.547–557.

Ihrmark, K. et al., 2012. New primers to amplify the fungal ITS2 region - evaluation by 454-sequencing of artificial and natural communities. *FEMS Microbiology Ecology*, 82(3), pp.666–677.

Orgiazzi, A. et al., 2015. Soil biodiversity and DNA barcodes: opportunities and challenges. *Soil Biology and Biochemistry*, 80, pp.244–250. Available at: http://dx.doi.org/10.1016/j.soilbio.2014.10.014.

De Vries, F.T. & Bardgett, R.D., 2012. Plant-microbial linkages and ecosystem nitrogen retention: Lessons for sustainable agriculture. *Frontiers in Ecology and the Environment*, 10, pp.425–432.

Willis, C.G. et al., 2010. Favorable climate change response explains non-native species' success in Thoreau's Woods. *PLoS ONE*, 5(1).

Wilson, S.D., 2014. Below-ground opportunities in vegetation science. *Journal of Vegetation Science*, 25, pp.1117–1125.