Impacts of management and environmental conditions on the roles different plant species play in altering nitrogen inputs, recycling, and retention.

Final Report

Principal Investigator(s): *Please provide name and department, phone, e-mail*

Valerie Eviner

Dept Plant Sciences

530-752-8538

veviner@ucdavis.edu

Executive Summary:

Conventional agricultural practices have decoupled N supply from plant demand, and have compromised and/or overwhelmed many natural ecosystem services, including: nutrient provision and retention, erosion control, water infiltration and storage, soil carbon storage and maintenance of biodiversity. The most effective way to provide multiple services is to restore the plant-soil interactions that naturally provide and retain nutrients, particularly by: rebuilding soil organic matter, increasing plant cover, increasing the diversity of plants to ensure high plant uptake and root C inputs (to fuel microbial immobilization and nutrient turnover) across the growing season, and fostering key plants that play important roles in providing key services. This study will investigate the potential for different plant types to restore these services to agricultural soils. In particular, we will address:

- What are the effects of different plants, and mixtures of plants, on: the timing and quantity of N supply, N retention, sequestration of added N, soil organic matter build-up, water infiltration and storage, and erosion control?
- How do the effects of these vegetation treatments differ under varying conditions? (N supply, mowing, precipitation).

On a long-term agricultural research field at UCD, we have established plots containing a variety of California grassland species that are (or some of which can be) used as covercrops, green manures, buffer strips, or as fallow treatments to allow soils to recover before replanting of crops. These include 15 species of native and exotic grasses, forbs and legumes. These species are being grown in monocultures, and in mixtures of varying diversity (between 2 and 15 species).

These vegetation treatments are being exposed to a number of management and environmental conditions:

- N additions
    - Control
    - Addition of 45 kg N/ha/yr)
- Clipping (to simulate mowing or grazing)
    - None

    - Fall clipping
    - Spring clipping
- Altered precipitation
    - Control
    - Shorter drier growing seasons (achieved by rain-out shelters)
    - Longer wetter growing seasons (achieved by irrigating with rain collected from rainout shelters)

The vegetation treatments have been established for 4 years, the clipping and N additions for 3, and the precipitation treatments for 1 year. We assessed these plots for:

- soil organic matter buildup (changes from start of experiment)
- water infiltration (infiltrometer)
- water storage (water holding capacity)
- erosion control (soil cohesion with a torsional vein tester)
- net N mineralization rates (fall, winter, spring)
- the timing and quantity of N supply (resin bags collected every 6 weeks throughout the growing season)
- N retention (plant uptake, microbial biomass)
- Amount and method of sequestration of added fertilizer N (through comparing fertilized and unfertilized values for treatments using above measures)

This project so far has clearly demonstrated that:

- Plant species differ in their effects on multiple services. In particular, native grasses foster higher rates of N cycling, but lower erosion control Annual exotics enhance erosion control, decrease N cycling rates, and greatly increase water infiltration rates.
- The impacts of mixes of species or species groups (e.g. annuals + weeds) on ecosystem services cannot be predicted based on their component monocultures.
- Management (e.g. season of mowing) alters vegetation impacts on ecosystem services, such that a group of species that best provide a service in one season of mowing, will provide the lowest amount of that same service when mowed in another season.

Specific Results: *Please describe specific data results and outcomes for each objective (and any additional results that may not fit under a specific objective). Summarizing data in graphics and tables is encouraged, as appropriate.*

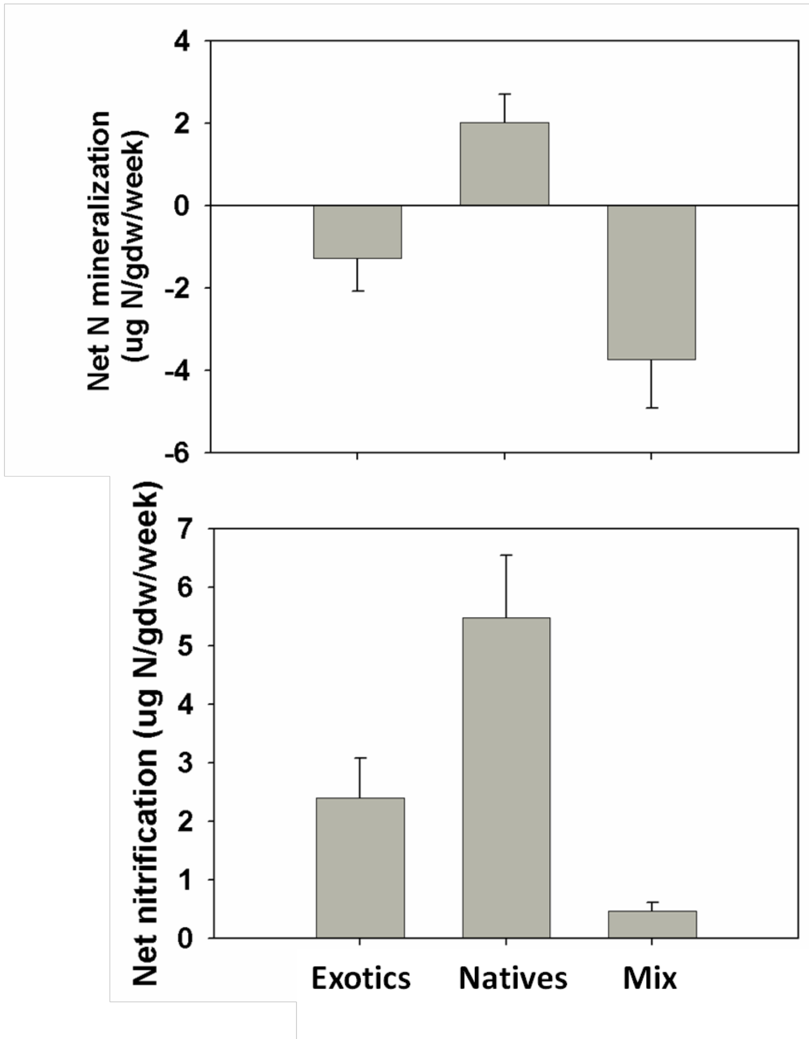
While all field samples have been taken, sample processing and analyses are still underway, particularly for plant and soil N and C data, which require extensive processing.

Current summary results are presented below, with some measures being presented for all species and mixes (e.g. water infiltration), and others for a subset of mixes (e.g. comparing rangeland exotic forage annuals that have been dominant for 200-300 years, native grassland species (mostly native perennial bunchgrasses), and new noxious weeds (e.g. medusahead and goatgrass).

Function	**Comparison**
N cycling	Natives > Annuals > > Mix In progress: surface resins, plant N, microbial N, deep resins
Soil C pools	Natives = Annuals Shallow C in annuals, deep in natives ** deeper samples in progress
Surface soil erosion resistance	Natives < Annuals
Water infiltration	Natives = Weeds < Annuals

Table 1- Data summary

Figure 1. Rates of net N mineralization and nitrification.



Comparing N cycling in soils associated with native vs. exotic grasses, net N mineralization and nitrification rates are greater in native than exotic soils (Figure 1). Natives had a particularly strong impact on enhancing net nitrification rates. Interestingly, the mix of native and exotic grasses was lower than either group alone, highlighting that N cycling in species mixtures are not predictable based on their component monocultures.

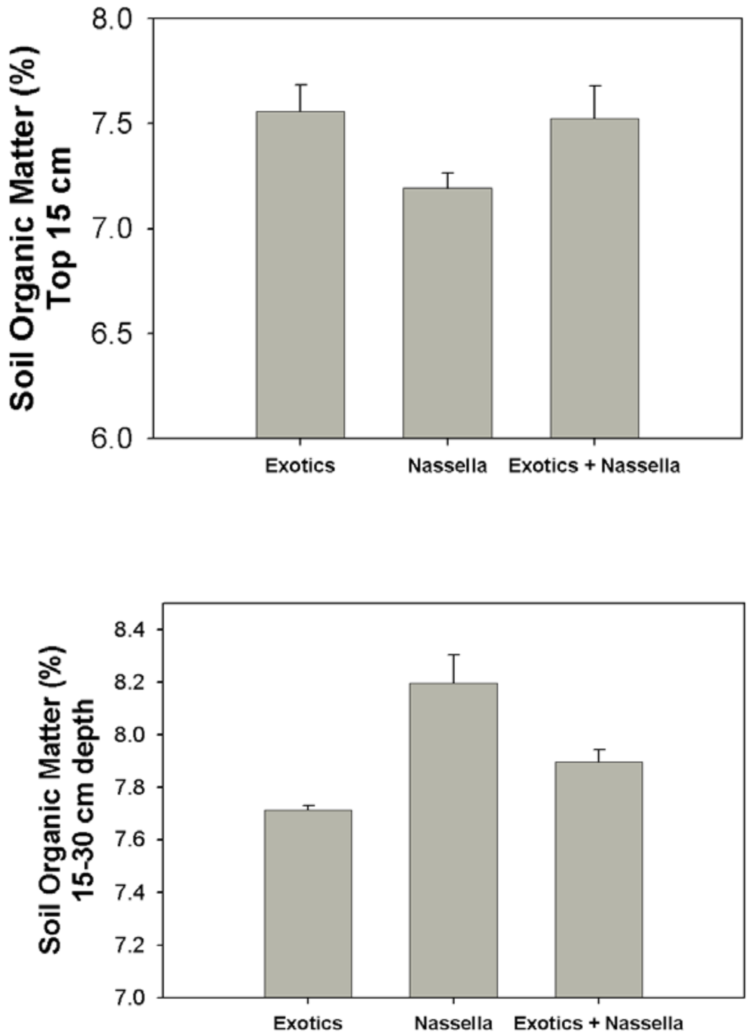


Figure 2: Effects of natives vs. exotics on soil organic matter.

Soil organic matter in the top 30 cm of soil did not differ between natives, exotics, and their mixes. However, the distribution of organic matter did differ by depth, with annuals and mixes having higher concentration of SOM in the top 15 cm of soil, and natives having more in the 15-30 cm depth.

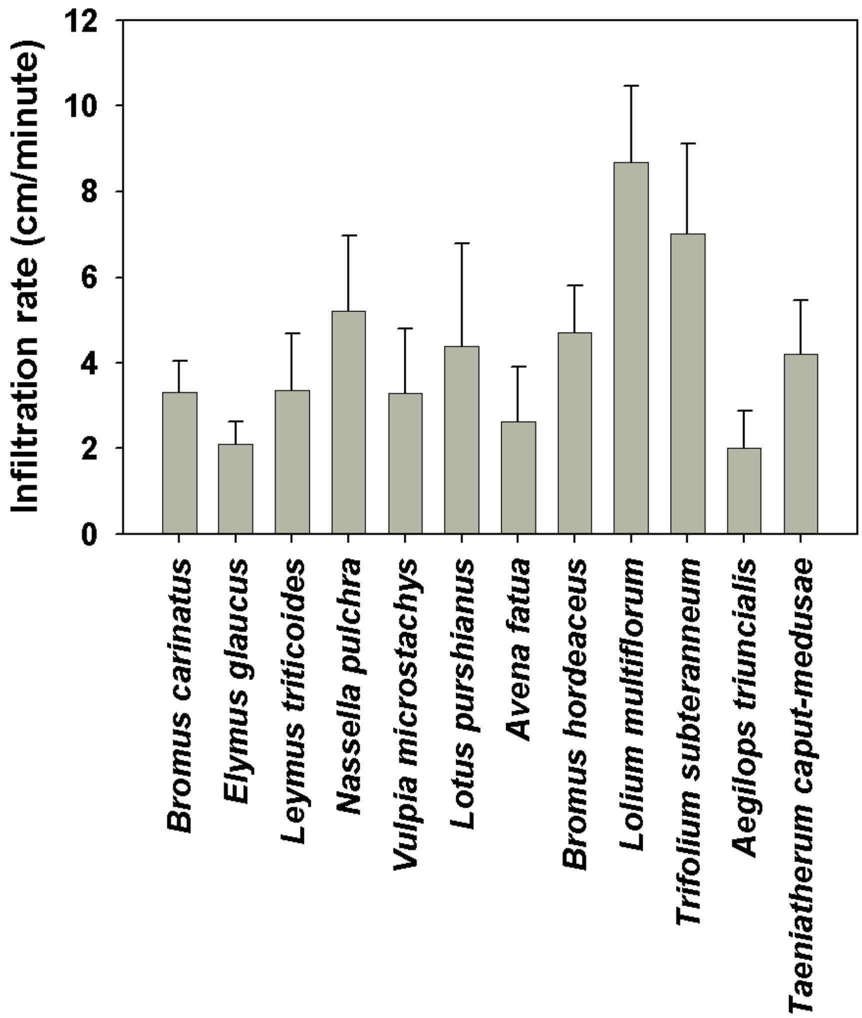


Figure 3: Impacts of species on water infiltration.

Water infiltration significantly varied by plant species (Figure 3), but these differences were not predictable based on plant traits such as rooting depth, or by native vs. invasive status.

When considering groups of species (Figure 4), annuals grown together had higher infiltration rates than mixes of natives or weeds, but when these groups were mixed, natives + weeds had high infiltration rates, similar to those of annuals alone, while all mixes with annuals had lower infiltration rates than annuals alone. Once again, it is clear that results in monocultures and mono-typic groups cannot predict results from mixed plantings.

When the monotypic exotic mixes and weed mixes were clipped in the spring and fall, this greatly altered their infiltration rates (Figure 5). In unclipped plots, infiltration was higher in exotics than in weeds. This same pattern held true for spring-clipped plots, but infiltration rates were much higher in both vegetation plantings, compared to unclipped controls. However, in fall clipped plots, the reverse pattern was found, where infiltration in weed plots was higher than exotic plots (Figure 5).

Figure 4. Impacts of mixed species groups on water infiltration rates.

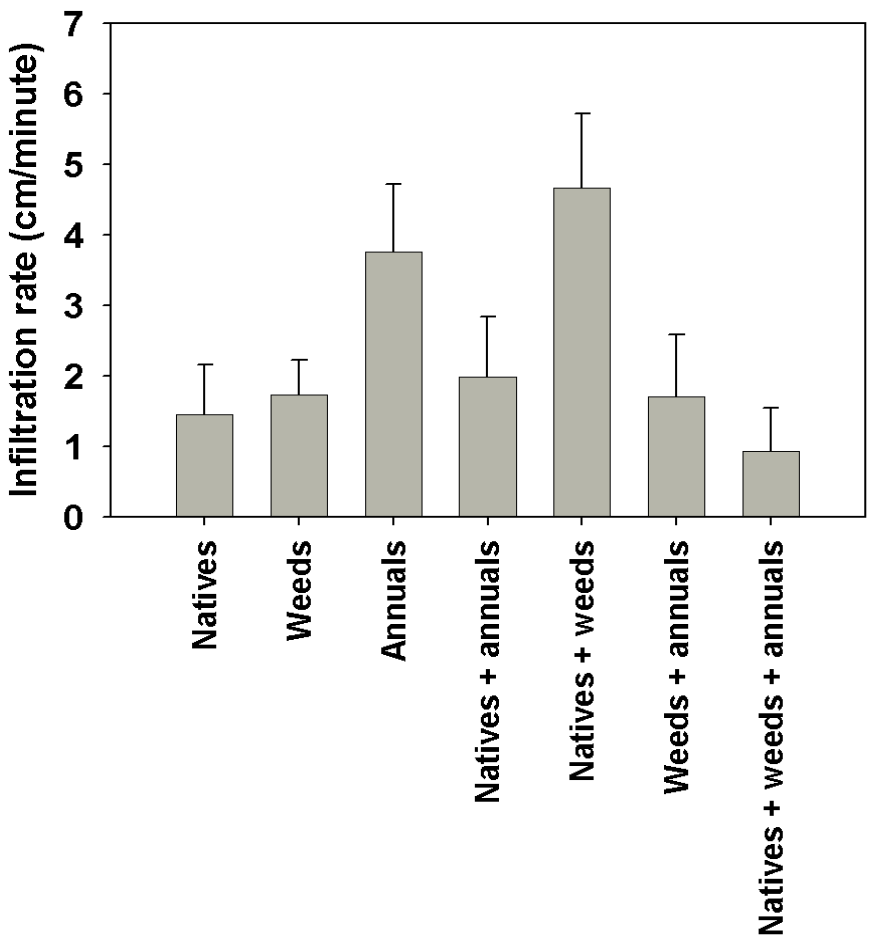
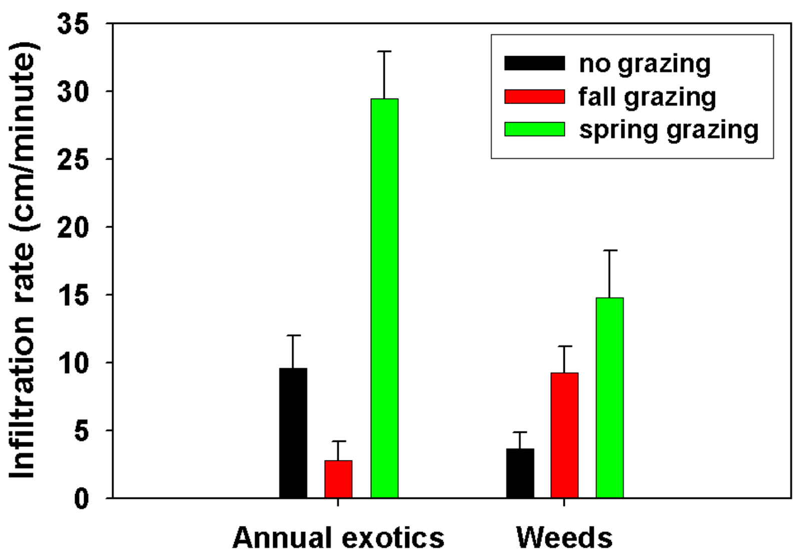
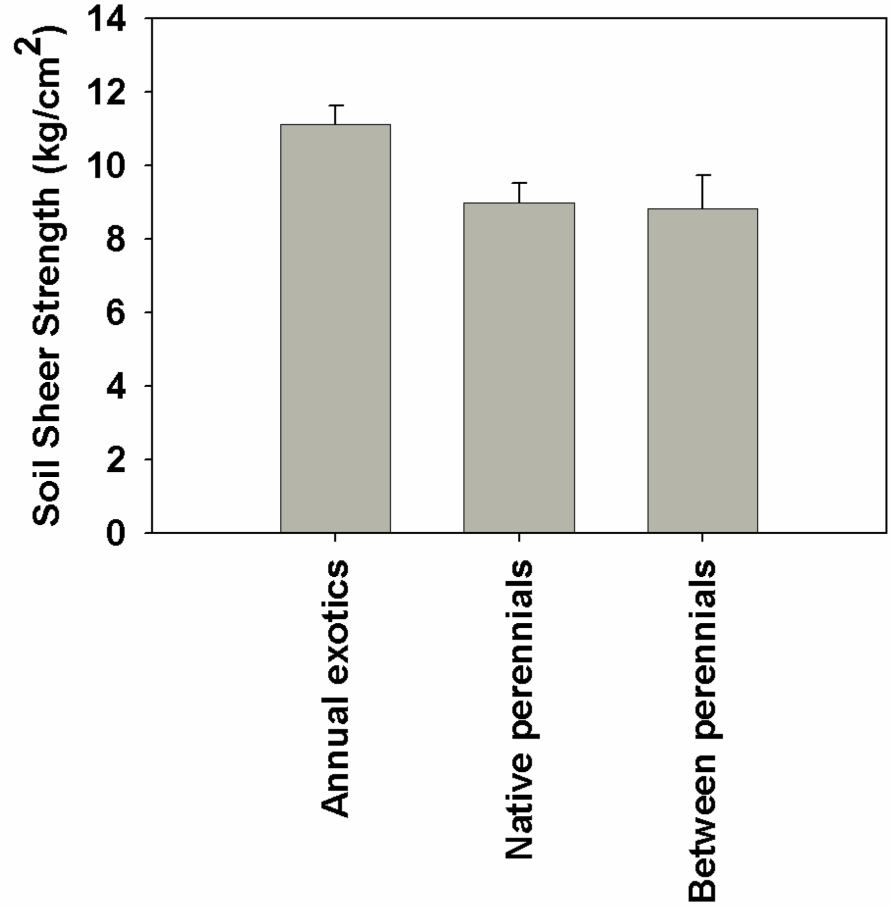


Figure 5. Infiltration rates in exotic vs. weed mixes exposed to no clipping, fall or spring clipping.



Soil erosion control potential (sheer stress) was greater in annual exotics than in soils associated with native perennials (either directly under the grasses or in their interspaces) (Figure 6).



Samples currently being processed:
There are many other samples that were collected as part of this project that are currently being processed and analyzed. All results discussed here will be available for all single species, as well as all mixes and treatments of the mixes (N fertilization, clipping, precipitation). In addition, the following measures are being assessed:

- Seasonal determination of soil available N (resins), plant N uptake, and microbial biomass N.
- Soil C and N storage at 15 cm intervals from 0-90 cm deep.
- Water holding capacity

Potential Impacts:

Impacts of this research will include:

- Recommendations on which plants and mixtures of plants can best perform specific roles in restoring N provision, retention, and sequestration of added N. And in providing multiple services (soil C storage, water infiltration and storage, erosion control)
- Site-specific recommendations for which species provide these functions best under certain management and environmental conditions.
- An improved understanding of the time and extent to which N cycling can be restored on agricultural land.

Stakeholders with most interest will include:

- Rangeland managers
- Agricultural managers who utilize cover crops, green manures, buffer zones, or who leave areas to naturally colonize at some point in time.
- Restoration practitioners.