Long-term carbon accumulation in a cold desert: Role of shrub islands and soil moisture across a long chronosequence of shoreline dunes at Mono Lake, CA

M. I. Shuldman, J.H. Richards, Z.T. Aanderud
Department of Land, Air, and Water Resources
University of California, Davis

Introduction

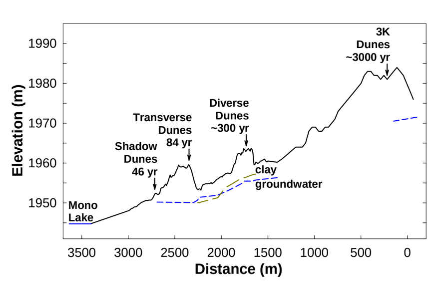
- Shrub island/interspace systems are widespread in arid and semi-arid ecosystems such as the Great Basin Desert.
- The amount and permanence of carbon (C) sequestered in cold deserts may be higher than normally appreciated. Long-term accumulation in shrub islands of soil organic C (SOC) and coarse woody litter could be the result of slow decomposition rates in dry soils.
- Late Holocene fluctuations in Mono Lake's level (40m in 3800 years) and recent fluctuations due to water removal for agricultural and urban uses have led to the formation of a series of shoreline dune systems in the Mono Basin.
- We inventoried C in soils along a chronosequence of *Sarcobatus vermiculatus* shrub islands and interspaces at the Mono Basin Ecosystem Research Site (MBERS).
- We performed a decomposition study of multiple litter types (woody roots, fine roots, woody stems, leaves) to determine if net C accumulation is due to slow decomposition rates.

Research Questions

- How much C is present across the landscape and in islands and interspaces?
- What percentage of soil C is organic versus inorganic? Coarse litter versus SOC?
- Are litter type decomposition rates consistent across the sites?
- Is the litter type with the slowest rate present in the largest amounts at older sites?

Site Characteristics

Description of Chronosequence Study Sites



	Shadow	Transverse	Diverse	3K
pH	9.8	9.8	8.4	8.3
EC soil (dSm^{-1})	13.4	8.8	1.7	2.2
EC gw (dSm^{-1})	16.1	5.4	1.5	--
Texture	sand	sand	sand	loamy sand
Depth gw (m)	2.2	7.4	9.4	~10

Figure 1. The four study sites and ages along a chronosequence at MBERS. MBERS is located on the north-eastern edge of Mono Lake (38° 5'N 118° 58' W; ~1970 m). Depth to groundwater (gw) and lacustrine clay are also shown (above). Pictures of each site and basic soil characteristics are also listed (below).

Chronosequence pH and Electrical Conductivity

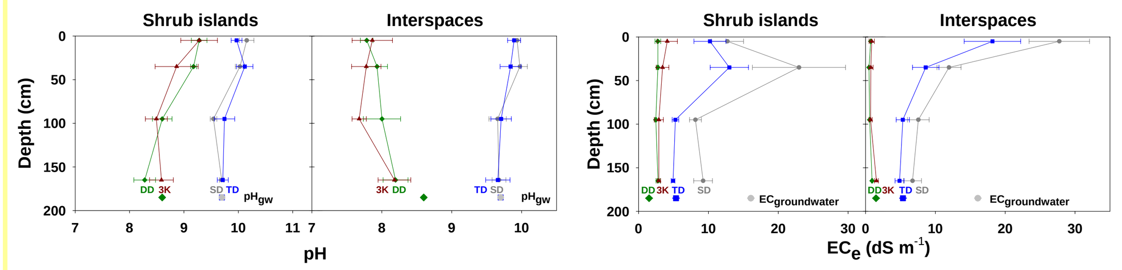


Figure 2. Soil EC and pH (± SE, n=8 samples at each depth) were determined using a saturated paste extract (SD = Shadow Dunes, TD = Transverse Dunes, DD = Diverse Dunes, 3K = 3K Dunes). Soil samples were taken during June 2004 using well mixed composited cores from 0-20, 20-60, 60-120, and 120-200 cm below the surface. As a comparison, groundwater EC and pH are shown for SD, TD, and DD (depth to groundwater varies with site as shown in the table in Figure 1).

Carbon Inventory

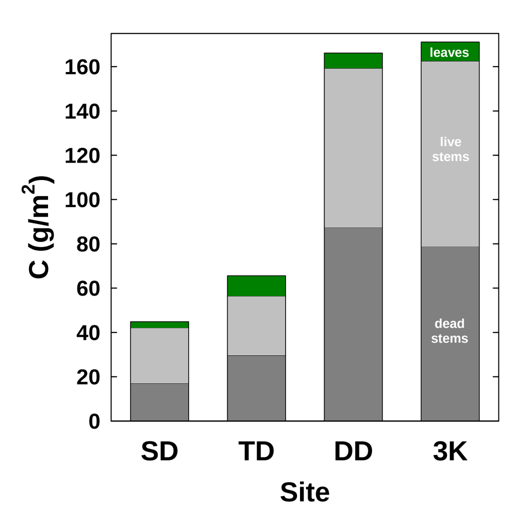
Methods

- Soil was collected under shrubs islands and interspaces at four depths (0-20cm, 20-60cm, 60-120cm, 120-200cm) and sieved to 2 mm. Soil was collected at 8 randomly chosen shrub islands and interspaces at each of four sites along the chronosequence.
- All litter was removed by sieving and hand-picking.
- Carbonates were removed by 12 M HCl fumigation.
- Aboveground biomass was estimated by harvesting quarter canopies of shrubs and separating by hand leaves, stems, and dead stems. Leaves, stems, and dead stems were dried to a constant mass and weighed.
- Subsamples of aboveground biomass pools (leaves, live stems, and dead stems) were ground for analyses of C, N, C:N, macronutrients, micronutrients, and stable isotopes.
- Analyses were performed on a CN analyzer and a continuous flow isotope ratio mass spectrometer.

Carbon Inventory - Results

Aboveground and Belowground Carbon Pools across the Chronosequence

Aboveground biomass across the chronosequence



Belowground biomass across the chronosequence

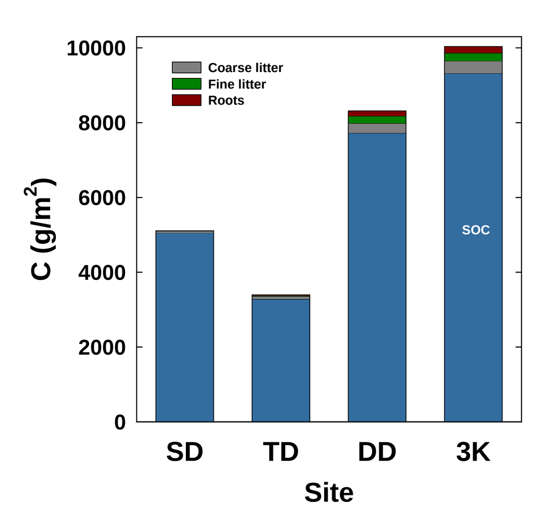
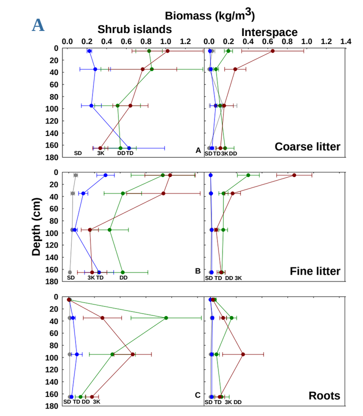


Figure 3. Aboveground biomass pools across the chronosequence (n=8). Quarter canopies of shrubs were removed and separated by hand into leaves, live stems, and dead stems. All plant material was cleaned, dried to constant mass, and weighed. Conversion of biomass to C was based on percent C for each pool estimated from previous data from MBERS. Values were also weighted by the ratio of total shrub cover to barren interspace at each of the four sites. (SD = Shadow Dunes, TD = Transverse Dunes, DD = Diverse Dunes, 3K = 3K Dunes)

Figure 4. Belowground biomass pools across the chronosequence in shrub islands and interspaces (n=16 at each depth). Soil samples were taken during June 2004 using well mixed composited cores from 0-20, 20-60, 60-120, and 120-200 cm below the surface. Litter was removed from soil by a combination of sieving and hand-picking. Conversion of biomass to C was based on percent C for each pool estimated from previous data from MBERS. Values were also weighted by the ratio of total shrub cover to barren interspace at each of the four sites. (SD = Shadow Dunes, TD = Transverse Dunes, DD = Diverse Dunes, 3K = 3K Dunes).

Organic Carbon Pools by Depth



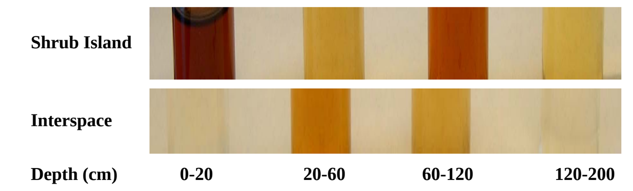


Figure 5. A) Biomass of litter and roots by depth across MBERS in shrub islands and in interspaces (± SE, n=8). B) Example of K_2SO_4 soil extracts showing substantial amounts of SOC are present in sandy soils at the older sites. For both A and B soil samples were taken during June 2004 using well mixed composited cores from 0-20, 20-60, 60-120, and 120-200 cm below the surface (SD=Shadow Dunes, TD=Transverse Dunes, DD=Diverse Dunes, and 3K=3K Dunes). Coarse litter (diameter > 2 mm), fine litter (diameter < 2 mm), and roots were separated from soil samples by a combination of sieving and hand-picking.

Decomposition Study

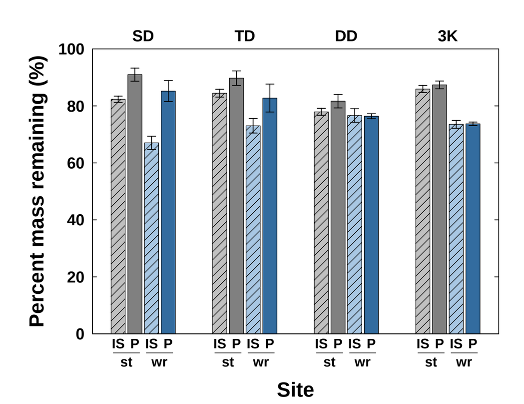
Methods

- Live woody roots, live woody stems, senesced leaves, and fine roots were collected from Transverse Dunes in Summer 2003
- Plant materials were washed, dried, put in 1mm mesh bags, and placed 25cm below the soil surface in Nov 2003. Litter bags were buried to simulate the burial by windblown sand that occurs normally in autumn, when soil surfaces are dry and weather fronts cause large wind and sand movement events.
- The first of three harvests was performed in Nov 2004. Litter will be analyzed for changes in mass, C, N, C:N, Na, cellulose, hemicellulose, and lignin.
- Soil moisture was measured in April, July, and October 2004 and April 2005 with a neutron probe. All sites and shrub/ interspace locations were measured to 1 m depth. The neutron probe was calibrated on site at locations artificially watered to field volumetric soil moisture content and at drier locations.

Decomposition Study– Results

Decomposition of Woody Litter and Soil Moisture

Percent mass remaining of woody litter after one year



Soil moisture along the chronosequence for 2004

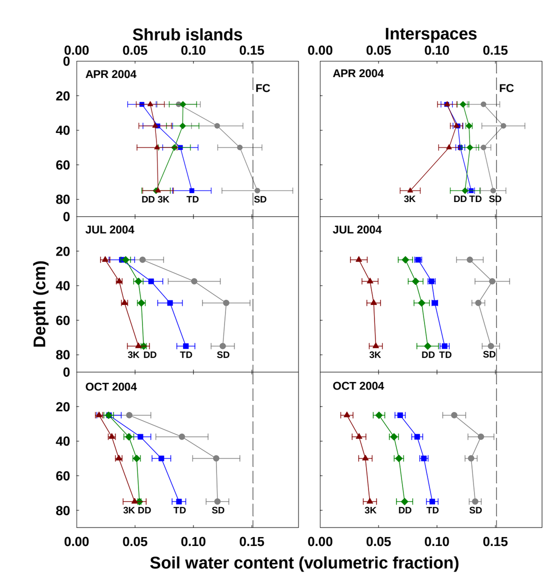


Figure 6. Percent of initial mass remaining (± SE) of woody stems (st = woody stems, grey bars) and woody roots (wr = woody roots, blue bars) after one year (Nov 2003 - Nov 2004). Stems and roots were buried in 1mm mesh litter bags 25-35cm below the surface of the ground under shrub islands (P = plant, solid bars, n=8) and barren interspace (IS = interspaces, dashed bars, n=5).

Figure 7. Soil moisture content (± SE, n=5) was determined using a neutron probe (SD = Shadow Dunes, TD = Transverse Dunes, DD = Diverse Dunes, 3K = 3K Dunes, FC = field capacity estimate). Measurements taken under shrub islands tend to have lower soil moisture than barren interspaces particularly in April, indicating poor recharge where most litter and organic matter is deposited. Older dune systems tend to be drier throughout the season than younger dunes systems.

Plant Influences on Litter Decomposition

Mass of fine roots that grew into litter bags (g)

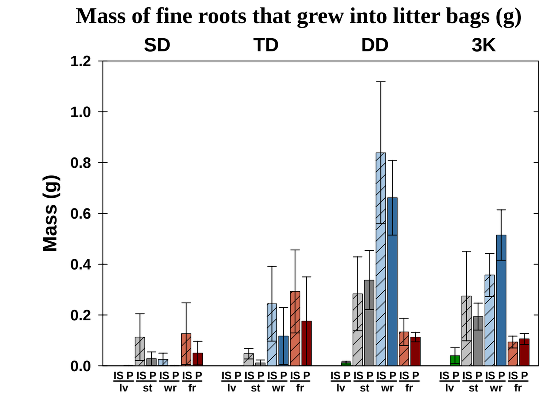


Figure 8. Mass of fine roots that grew into litter bags (± SE) of leaves (lv = leaves, green bars), woody stems (st = woody stems, grey bars), woody roots (wr = woody roots, blue bars), and fine roots (fr = fine roots, red bars) after one year (Nov 2003 - Nov 2004). Stems, roots, and leaves were buried in 1mm mesh litter bags 25-35cm below the surface of the ground under shrub islands (P = plant, solid bars, n=8) and barren interspaces (IS = interspaces, dashed bars, n=5).

Figure 9. Top left shows litter bags in field covered with roots and rhizoshpere soil, top right shows a litter bag just before being cleaned, bottom shows fine roots that were cleaned from the bag in top right.

Conclusions

- Most of the C stored in this ecosystem is in form of inorganic C.
- The largest pool of organic C is SOC, which increases with site age.
- Most of the coarse litter, fine litter and roots are found from 20-200 cm below the surface
- Interspaces were wetter than shrub islands at all sites, and younger dunes were wetter than older dunes.
- Decomposition rates of woody roots were twice that of woody stems and were not correlated with soil moisture differences between interspaces and shrub islands at the older sites.
- More fine roots grew into litter bags with woody material than litter bags with fine roots or leaves. For almost all litter types and sites more fine root growth occurred in the interspace than the shrub islands.

Ongoing Research

- Carbon, nitrogen, micronutrients, macronutrients, and isotope analyses on carbon inventory aboveground biomass.
- Microbial biomass carbon across the chronosequences at multiple depths.
- Second harvest for decomposition experiment in November 2005.
- C, N, Na, lignin, cellulose and hemicellulose analyses on decomposition experiment litter bags.
- Continuing soil moisture and temperature measurements.
- Sampling for coarse woody root biomass across the site (this component was not adequately characterized with our 2004 sampling).

Acknowledgments

UCDAVIS Kearney Foundation of Soil Science
JastroShields Research Grant