PRICKLY PEAR (*Opuntia engelmannii)* CARBON POOLS IN A DESERT GRASSLAND

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Figure 1. Vegetation change on the Santa Rita Experimental Range documented with repeat photography

Source: http://www.ag.arizona.edu/SRER/photos.html

ABSTRACT

Woody plant proliferation in global dry lands may have significant consequences for the global carbon cycle. However, estimates of the effects of this vegetation change on carbon pools are highly uncertain. Remote sensing approaches for assessing changes in aboveground carbon pools accompanying woody plant expansion do not currently account for the contribution of cacti. In addition, the carbon mass contained in *Opuntia* patches is not well documented. The objectives of this study were to (a) develop algorithms to predict *Opuntia engelmannii* biomass from non-destructive dimensional measurements of patch geometry; (b) apply these algorithms in field surveys to estimate biomass of *O. engelmannii* on landscapes with contrasting land use histories; and (c) quantify *O. engelmannii* carbon density and estimate patch and landscape-scale carbon mass. A volume algorithm based on patch height and diameter best predicted biomass of all patch sizes ($R^2 = 0.95$). Field surveys of management units with contrasting land use histories revealed large variation in *O. engelmannii* biomass (0 to 5094±1663 kg ha^{-1}). Data indicate prickly pear can contribute significantly to aboveground carbon pools in areas where little or no woody vegetation is detected by remote sensing. Failure to account for prickly pear biomass in stands of true shrubs (e.g. mesquite) may significantly underestimate aboveground carbon stocks.

Figure 9. Comparison of aerial and ground photos from SRER. The highlighted portion of the aerial photo appears to have very little woody vegetation, but a ground photo of the same location shows a very high abundance of ***O. engelmannii.*** *(Aerial photo courtesy Dawn Browning, 2002; Ground photo by A. Vogl, 2004)*

INTRODUCTION

- Woody plant abundance has increased in drylands worldwide over the past 100+ y
- The Santa Rita Experimental Range has a well-documented history of woody plant encroachment through the use of repeat photography and long-term transect monitoring (Figure 1, 2)
- Prickly pear cover has increased on the Santa Rita by ~400% from 1960 – 2000 (Figure 2)

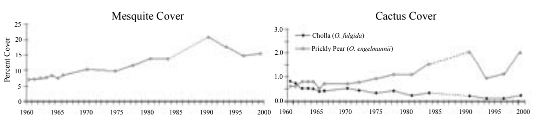


Figure 2. Data from 74 permanent transects located between 950- and 1,250-m elevation show an increase in mesquite and cactus cover on the Santa Rita Experimental Range from 1960 to 2000. (Dashed lines indicate years for which data is unavailable) *adapted from McClaran 2002*

- Prickly pear's long life, increasing abundance, and the size it can attain (>2 m tall) indicate it may contribute significantly to aboveground carbon pools in some areas.
- Current remote sensing and carbon accounting inventories for desert grasslands do not account for the contribution of cacti to aboveground carbon pools.

OBJECTIVES

- Develop algorithms to predict *Opuntia engelmannii* biomass from non-destructive dimensional measurements of patch geometry
- Apply these algorithms in field surveys to estimate biomass of *O. engelmannii* on landscapes with contrasting land use histories
- Quantify *O. engelmannii* carbon density and estimate patch and landscape-scale carbon mass

PATCH ALLOMETRY

METHODS

- Sampled 26 *Opuntia* patches ranging from small to large (0.23 to 3.20 m maximum diameter)
- Measured circumference, radial lengths, diameters, various heights
- Harvested entire patch; recorded fresh biomass by tissue class (cladodes, woody 'trunks', dessicated tissue)
- Dried subsample of each tissue class; converted field weights to total dry biomass
- Used regression techniques to find best relationship between dimensional variable(s) and total patch dry biomass

RESULTS

- Circumference was single factor that explained most variation in the total dry biomass (91%); however in patches ≥ 5.4 m circumference, biomass was increasingly underestimated (Figure 3)
- Best overall predictor of biomass was an oblate ellipsoid volume algorithm based on height at center and length of maximum diameter (Figure 4)

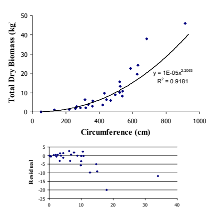


Figure 3. Top – Relationship of Circumference to Total Dry Biomass. Bottom – Residual values for predicted biomass using circumference.

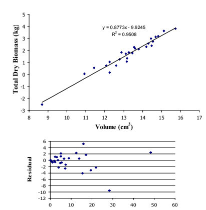


Figure 4. Top - Relationship of Log Volume to Log Total Dry Biomass. Bottom – Residual values for predicted biomass using oblate ellipsoid volume algorithm.

CARBON CONCENTRATIONS AND MASS

METHODS

- Sampled 6 *Opuntia* patches for tissue carbon content
- Collected terminal cladode, intermediate cladode, and woody tissue samples from each patch
- Quantified carbon concentrations (g C / g biomass) in each tissue type using gas chromatography (Costech ESC 4010 elemental analyzer)

RESULTS

- No significant differences in terminal and intermediate cladode carbon concentration (p>0.05)
- Mean carbon concentration for all tissue types = 0.40
- *Opuntia* patch carbon mass scaled directly with *Opuntia* patch volume (Figure 5)

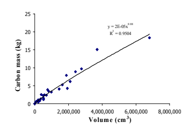
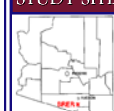


Figure 5. Relationship of *Opuntia* volume to Carbon mass

STUDY SITE



- Data are from the Santa Rita Experimental Range in Southeastern Arizona, ~80 km south of Tucson
- The SRER is the oldest active rangeland research facility in the United States
- Climate is semi-arid desert grassland with biannual rainfall (mean annual rainfall 325 mm)
- Sampling for patch allometry was conducted on five sites with varying abundances of *O. engelmannii* located ~980 m elevation.
- Biomass estimates were conducted on six sites with contrasting land use histories, between 900 and 1100 m elevation.

STAND BIOMASS/ CARBON MASS ESTIMATES

METHODS

- Established 30 X 30 m plots in areas with contrasting land use histories
- Surveyed four 15 x 4 m belt transects per plot
- Measured height and long axis of all *O. engelmannii* patches encountered in transects
- Used allometric function in Fig. 4 to predict total dry biomass (kg/ha)
- Multiplied patch biomass values (Table 1) by carbon concentration to estimate stand-level aboveground carbon mass

RESULTS

- Variation in patch size and biomass was substantial, both within and between plots (Table 1, Figure 7)

Table 1. Summary of transect data by site.

Site	n	Height (cm)			Max Diameter (cm)			Total Biomass (kg)	Total Biomass (kg/ha)
		Mean	Min	Max	Mean	Min	Max		
C-CUT	4	46±5	33	53	89±6	79	103	6.7	69±36
D-60	0							0	0
D-62	7	61±12	23	105	94±29	29	205	39	409±178
D-CONT	14	51±9	7	107	58±13	2	153	35	360±247
E-CONT	48	61±5	5	148	111±11	3	271	337	3509±1878
E-CUT	68	61±3	11	132	120±8	16	335	489	5094±1663

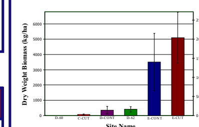


Figure 7. Total biomass and carbon mass by site

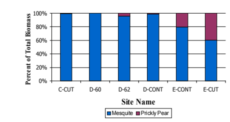


Figure 8. Comparison of prickly pear and mesquite biomass by site.

CONCLUSIONS

- *O. englemannii* cover has increased significantly on the Santa Rita Experimental Range over the past ~40 y
- Data indicate a direct relationship between *Opuntia* patch geometry and biomass/carbon mass
- The size and abundance of *Opuntia* patches varies greatly across the landscape (0 to 5094 kg ha^{-1})
- *O. engelmannii* can represent a large percentage of total aboveground woody biomass in some areas (Figure 8)
- Estimates of aboveground carbon pools based on remote sensing techniques may greatly underestimate carbon in areas where *Opuntia* is abundant (Figure 9)

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