Atmospheric-Ecosystem CO_2 Exchange in Sparse Arid Shrublands Across the Great Basin USA Over Multiple Years: Identifying Patterns and Mechanisms

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Introduction

Why should we care about deserts?

- Cover >30% of Earth's land surface; expanding because of desertification (**Fig. 1**)
- Existing deserts and semi-arid ecosystems may become more "woody"
- Responsive to global change
- New data suggests net CO_2 uptake may be higher than expected
- 37% of the world's population lives near deserts
- Contains 8% of the world's C stores – biomass = 8 Gt, soils = 191 Gt
- Only a few flux sites in arid regions (**Fig. 2**)

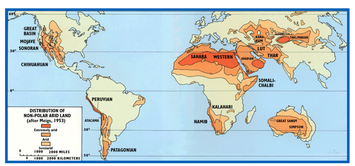

Figure 1. Distribution of non-polar arid land.

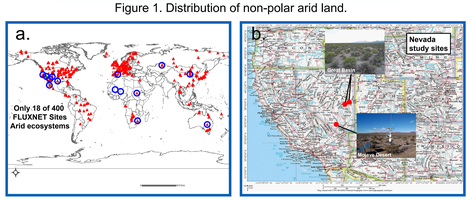

Figure 2. World-wide FLUXNET (a) and Nevada (b) arid ecosystem study sites.

Objectives

- To explore new empirical evidence on net ecosystem CO_2 exchange that suggests deserts of the world may be important sinks for CO_2 (using the available annual & multi-year data set)
- To evaluate evidence on modulating role of precipitation
- To look at potential effects of global change factors ([CO_2], invasive spp., precipitation)

Methods

Eddy covariance

- CSAT3 sonic anemometer
- LI-7500 open path infrared gas analyzer
- CR5000 data logger

EC data processing

- Raw data (10 Hz) were post-processed using the software EdiRe (University of Edinburgh, UK) and all standard corrections made according to Wohlfahrt et al. 2008

Dominant Shrub Species

Mojave	Great Basin
Larrea tridentate	*Artemisia tridentate*
Lycium andersonii	*Sarcobatus vermiculatus*
Ambrosia dumosa	*Chrysothamnus nauseosus*

Results

Great Basin, Eastern Nevada

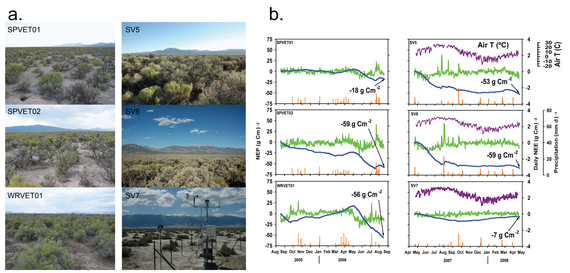

Figure 3. Photographs of study site vegetation (**a**) and cumulative NEP (blue line), daily NEE (green line), air temperature (purple line), and daily precipitation (orange bars) (**b**) from six eastern Nevada (Great Basin) ecosystems.

Mojave Desert

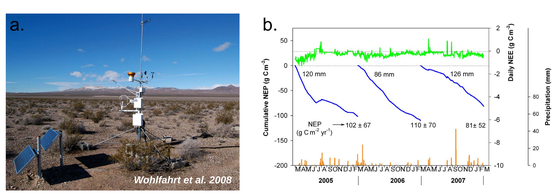

Figure 4. Photograph of study site vegetation and eddy covariance instrumentation (**a**) and cumulative NEP (blue line), daily NEE (green line), and daily precipitation (orange bars) (**b**) for three years of data collection from a Mojave Desert ecosystem.

Table 1. NEP from two Mojave Desert, six Great Basin and one Sonoran Desert study site.

Desert	Location	Year	NEP (g C m^{-2} yr^{-1})	Notes	Reference
Mojave Desert	S. Nevada*	2004	-127	FACE Amb CO_2 - dome	Jasoni et al. 2005
			-90	FACE Elev CO_2 - dome	
		2005	-180	FACE Amb CO_2 - dome	
			-93	FACE Elev CO_2 - dome	
		2005	-102	MGCF- EC	Wohlfahrt et al. 2008
		2006	-110	MGCF- EC	
		2007	-81	MGCF- EC	
Great Basin	E. Nevada*	2006	-18	SPVET01 - EC	Unpublished
			-59	SPVET02 - EC	(Arnone/Jasoni)
			-56	WRVET01 - EC	
		2007	-53	SV5 - EC	
			-59	SV6 - EC	
			-7	SV7 - EC	
	N. Nevada	2001	-33	Post-fire - dome	Obrist et al. 2003
			20	Shrub - dome	
		2004	49	Post-fire - dome	Unpublished
			56	Shrub - dome	(Jasoni/Arnone)
Sonoran	Baja California*	2002	-39	EC	Hastings et al. 2005
	Mexico	2003	-52	EC	

Discussion

Where is the C going?

Vascular plant NPP

Woody shrub NPP Grass and forb NPP

Figure 5. Photographs of woody shrub, grass, and forb vegetation in a Mojave Desert ecosystem.

Cryptobiotic soil crust NPP

- cyanobacteria
- mosses
- lichens

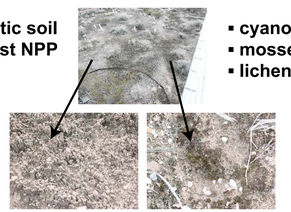

Figure 6. Photographs of cryptobiotic soil crusts (cyanobacteria, mosses, and lichens) in a Mojave Desert ecosystem.

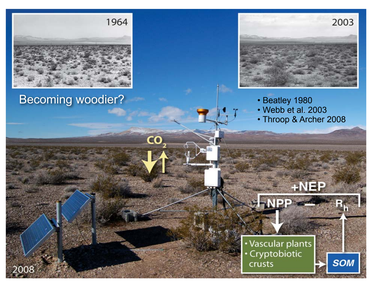

Figure 7. Schematic of carbon fluxes in a Mojave Desert ecosystem and photographs (insets) of woody biomass increase between 1964 and 2003.

Ecological feedbacks to desert C balance

Growth of invasive grass stimulated in wetter year under future CO_2 levels

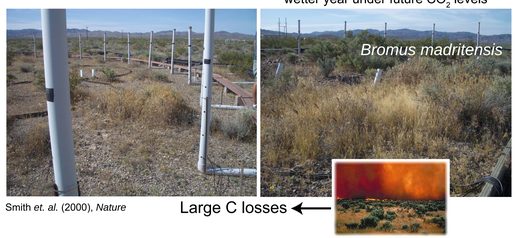

Figure 8. Photographs of invasive grass species (*Bromus madritensis)* during a dry (left panel) and wet (right panel) year in a Mojave Desert ecosystem. Inset indicates large C losses from increased fire potential with increased invasive grass species growth.

How much might deserts contribute to global NEP?

• Average NEP of these sites in Table 1 = -54 g C m^{-2} yr^{-1}
= -54,000,000 g C km^{-2} yr^{-1}
• Arid shrublands = 20% of Earth's land surface
20% of 148,939,100 km^2
= 29,787,280 km^2 x -54,000,000 g C km^{-2} yr^{-1}
= 1.61 Gt C yr^{-1}
= 22% of anthropogenic CO_2 emissions

How much might deserts contribute to global NEP?

• Average NEP of these sites (*) in Table 1 = -75 g C m^{-2} yr^{-1}
= -75,000,000 g C km^{-2} yr^{-1}
• Arid & semi-arid ecosystems ca. 30% of Earth's land surface
30% of 148,939,100 km^2
= 44,681,730 km^2 x -75,000,000 g C km^{-2} yr^{-1}
= 3.35 Gt C yr^{-1}
= 47% of anthropogenic CO_2 emissions

Summary and Conclusions

1. Deserts may be playing a much larger role in modulating global atmospheric CO_2
2. Must still determine where the NEP carbon is going in the ecosystem (NPP – vascular plants, autotrophic cryptobiotic crusts)

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