Assessing seasonal greenhouse gas emissions and belowground C and N processes under different fire frequencies in soils of Sierra Nevada chaparral shrublands

Urszula Norton[1], William R. Horwath[1], Jay B. Norton[2] and Timothy A. Doane[1]

[1]University of California Davis, LAWR, [2]UCCE Tuolumne County, CA

Research Rationale

Photo: Ace Young

Fig.1: 2001 Creek Fire Study site

•Chaparral shrubland covers over 13 million acres in California, accounting for 13% of the total land area. It spans a wide geoclimatic range from the southern and central coast to the Sierra Nevada foothills. Carbon and nitrogen dynamics in this ecosystem are not well documented. Specifically, information on the contribution of greenhouse gases (GHG) to the atmosphere is lacking.

•Historically, fire played a critical role in shaping the autosuccession of fire-adapted chaparral ecosystems, returning every 20-30 years on average in the Sierra Nevada foothills.

•As this ecosystem undergoes rapid human population growth and increasing commercial and residential development, often coupled with strict fire suppression policies, there is need for better understanding of how resulting ecological changes impact chaparral ecosystem resiliency and sustainability. Reintroduction of fire into fire-suppressed chaparral can provide opportunities for rapid, large-scale vegetation manipulation for range management and fire hazard reduction.

•We hypothesize that fire-induced type conversion from dense brush to grass-shrub mosaic caused by repetitive short-recurrence-interval fires (every 4 years) in high fire hazard zones provides ecological benefits, such as improved soil quality, which in turn, reduces flux of GHG to the atmosphere.

•The purpose of this research was to define the effects of 3 different fire return intervals in two predominant soil types on soil C and N dynamics and GHG flux.

Materials and Methods

Location: West slope of the central Sierra Nevada Range near Moccasin, CA (120°15" LAT and 37°45" LONG), 600m elev., MAT: 14.4°C, MAP: 600mm (Figs. 1 and 2).

Landscape Position: Shoulders and upper backslopes, 8 to 25 percent slopes

Soils:

1. Fine-loamy, mixed, superactive, thermic Mollic Haploxeralfs of the Stonyford and Rescue series formed in colluvium and residuum of **metabasic igneous or sedimentary rocks**. Loam texture
2. Fine-loamy, mixed, semiactive, thermic Ultic Haploxeralfs of the Auberry series formed in colluvium and residuum of **granitic rocks**. Sandy loam texture.

Fire History:

FS Fire-suppressed: **No recorded fires** in last ~100 years. Dense overstory of live and dead chamise (*Adenostoma fasciculatum*) and manzanita (*Arctostaphylos* spp.) and other shrubs 3 to 5 m in height. Very sparse ground cover of annual grasses and forbs (Fig.3);

20-y 20-year frequency: **Fires in 1950, 1972, and 1992**. Dense growth of chamise and other shrubs less than 2 meters in height regrowing in tall burned stems from 1992 fire (Fig. 4);

4-y 4-year frequency: **Fires in 1997 and 2001**. Dense annual grass ground cover with sparse, chamise 1 to 2 m in height and numerous burned shrubs from the 2001 fire (Fig. 5);

Measurements

Measurements were taken in spring and summer for 5 rain-free days:

•GHG flux (three air samples drawn during 30 minutes) were obtained using static chambers deployed on soil surface;

•Soil samples (0-10 cm depth) were obtained every time air samples were taken from nearby locations;

•Air samples were analyzed for: CO_2, N_2O and CH_4;

•Soil samples were analyzed for: water content, 0.5M K_2SO_4-extractable inorganic N, dissolved organic C(DOC) and dissolved organic nitrogen (DON);

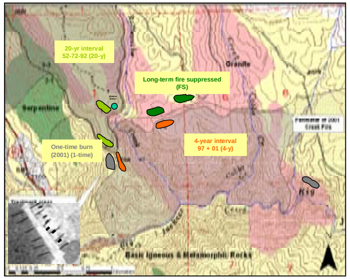


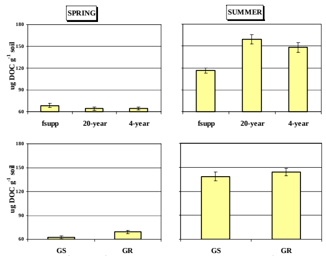
Fig.2: Study location map

Fig.3: Fire Suppressed

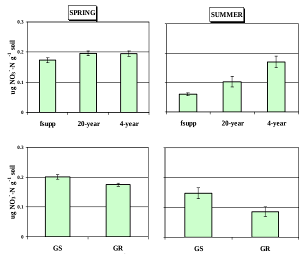
Fig 4: 20-year: '50,'72,'92

Fig 5: 4-year: '97, '01

Soil DOC



Soil NO_3^-



Legend: fsupp **(**fire suppressed); 20-year (three fires every 20 years); 4-year (two fires every 4 years); GS (Greenstone -Metabasic); GR (Granitic)

4-year fire treatment has:

•The lowest soil DOC and the highest CO_2 flux in spring, but the lowest CO_2 flux and high soil DOC during hot and dry season that lasts approx. 180 days.

•The highest levels of soil NO_3^-, but the lowest N_2O fluxes both in spring and summer;

Compared to granitic soils, metabasic soils have:

• Lower summer CO_2 flux and soil DOC in spring and summer;

• Higher soil NO_3^-, but lower N_2O fluxes both in spring and summer;

•The highest CH_4 consumption;

Soil C and N (soil x fire history)

	SWC (%)	error	NH_4-N	error	NO_3-N	error	DON	error	DOC	error	pH (H_2O)	error
			μg g⁻¹ soil									
spring												
soil x fire history (N=25)	0.25	0.01	3.41	0.23	0.18	0.01	2.36	0.13	61.87	3.18	6.34	0.03
Metabasic fire suppressed	0.24	0.01	3.56	0.21	0.17	0.01	3.89	0.27	75.26	3.83	6.15	0.04
Granitic fire suppressed	0.25	0.01	4.09	0.29	0.22	0.01	3.73	0.24	62.27	2.77	6.46	0.02
Metabasic 20-year fire return	0.22	0.00	3.41	0.28	0.18	0.01	3.78	0.33	66.46	3.66	6.28	0.03
Granitic 20-year fire return	0.23	0.01	3.59	0.33	0.21	0.01	2.84	0.32	62.67	2.51	6.31	0.04
Metabasic 4-year fire return	0.21	0.01	3.56	0.28	0.18	0.01	3.72	0.26	66.13	2.89	6.00	0.03
Granitic 4-year fire return												
summer												
soil x fire history (N=25)												
Metabasic fire suppressed	0.03	0.001	2.62	0.27	0.06	0.01	7.55	0.25	105.61	4.86	6.32	0.03
Granitic fire suppressed	0.03	0.002	2.86	0.36	0.06	0.01	8.35	0.28	126.96	4.06	6.01	0.04
Metabasic 20-year fire return	0.03	0.001	2.47	0.30	0.13	0.03	10.83	0.46	163.28	9.41	6.47	0.04
Granitic 20-year fire return	0.02	0.001	3.27	0.39	0.07	0.01	10.16	0.52	155.25	8.38	6.14	0.05
Metabasic 4-year fire return	0.02	0.001	2.98	0.44	0.26	0.03	10.22	0.52	146.07	9.54	6.29	0.04
Granitic 4-year fire return	0.02	0.001	2.98	0.31	0.07	0.01	9.79	0.55	149.81	9.74	5.92	0.04

4-year fire treatment on metabasic soils has:

•The highest CO_2 flux in spring and the lowest CO_2 flux in summer;

•The highest soil NO_3^- in summer, but the lowest N_2O fluxes both in spring and summer;

•The highest summer CH_4 consumption;

GHG flux

	CO_2 (kg CO_2-C ha⁻¹ d⁻¹)	(P<0.5)	CH_4 (g CH_4-C ha⁻¹ d⁻¹)	(P<0.5)	N_2O (g N_2O-N ha⁻¹ d⁻¹)	(P<0.5)
spring						
fire history (N=50)						
fire suppressed	14.3 (0.6)	c	-0.43 (0.04)	c	0.36 (0.04)	b
20-year fire return ('50, '72, and '92)	17.4 (0.7)	b	-0.79 (0.08)	a	0.54 (0.05)	a
4-year fire return ('97 and '01)	25.8 (1.0)	a	-0.60 (0.05)	b	0.16 (0.02)	c
soil (N=75)						
Metabasic	19.0 (0.9)	ns	-0.72 (0.06)	a	0.29 (0.03)	b
Granitic	19.3 (0.8)	ns	-0.48 (0.03)	b	0.42 (0.04)	a
soil x fire history (N=25)						
Metabasic fire suppressed	14.7 (0.9)		-0.41 (0.04)		0.29 (0.05)	
Granitic fire suppressed	13.9 (0.7)		-0.45 (0.06)		0.43 (0.06)	
Metabasic 20-year fire return	14.7 (0.9)		-1.04 (0.14)		0.41 (0.06)	
Granitic 20-year fire return	20.0 (0.9)		-0.52 (0.05)		0.67 (0.07)	
Metabasic 4-year fire return	27.6 (1.0)		-0.71 (0.07)		0.16 (0.02)	
Granitic 4-year fire return	23.9 (1.6)		-0.48 (0.06)		0.17 (0.02)	
summer						
fire history (N=50)						
fire suppressed	6.9 (0.6)	a	-1.61 (0.08)	ns	0.23 (0.02)	a
20-year fire return ('50, '72, and '92)	4.6 (0.3)	b	-1.51 (0.11)	ns	0.25 (0.02)	a
4-year fire return ('97 and '01)	2.9 (0.1)	c	-1.69 (0.09)	ns	0.12 (0.02)	b
soil (N=75)						
Metabasic	4.3 (0.2)	b	-1.77 (0.07)	a	0.19 (0.02)	ns
Granitic	5.4 (0.5)	a	-1.43 (0.07)	b	0.21 (0.02)	ns
soil x fire history (N=25)						
Metabasic fire suppressed	5.6 (0.2)		-1.60 (0.09)		0.25 (0.03)	
Granitic fire suppressed	8.4 (1.0)		-1.62 (0.13)		0.20 (0.03)	
Metabasic 20-year fire return	4.5 (0.4)		-1.83 (0.15)		0.22 (0.03)	
Granitic 20-year fire return	4.7 (0.5)		-1.19 (0.12)		0.29 (0.03)	
Metabasic 4-year fire return	2.6 (0.2)		-1.88 (0.12)		0.10 (0.02)	
Granitic 4-year fire return	3.1 (0.2)		-1.50 (0.12)		0.15 (0.03)	

GWP* estimates

	GWP cumulative spring (60 days) g CO_2 m⁻² x days	GWP cumulative summer (180 days) g CO_2 m⁻² x days	GWP fall (45 days)	GWP winter (80 days)	cumulative GWP spring and summer only g CO_2 m⁻² x days
fire history					
fire suppressed	4.3	4.9			9.2
20-year fire return ('50, '72, and '92)	5.4	3.4			8.9
4-year fire return ('97 and '01)	6.6	0.9			7.5
soil					
Metabasic	5.2	2.3			7.5
Granitic	5.7	3.8			9.5
soil x fire history					
Metabasic fire suppressed	4.2	4.1			8.3
Granitic fire suppressed	4.4	5.7			10.1
Metabasic 20-year fire return	4.3	2.7			7.0
Granitic 20-year fire return	6.5	4.2			10.7
Metabasic 4-year fire return	7.0	0.2			7.2
Granitic 4-year fire return	6.2	1.5			7.8

* GWP stands for Global Warming Potential and is calculated based on 20-year projections.

Conclusions

- **Frequent, low-intensity prescribed burns may not only reduce fire hazard but also lower the estimates of spring and summer GHG contributions to GWP regardless of the soil type.**
- **Extending the fire frequency to 20-years may not generate desirable effects on soil.**
- **Any fire re-occurrence on metabasic soils does reduce overall estimates of spring and summer GWP.**
- **Soils under chaparral at least double their capacity to consume CH_4 during hot and dry season.**
- **More on C and N pools in chaparral soils can be found on poster #1433 presented by J. Norton on Wednesday pm.**

Acknowledgments

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