Multi-scale assessment of a grassland productivity model

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Supplementary Equations, Table S1, S2 & Image S1

The PhenoGrass model from Hufkens et al. 2016 has the following form:

$$W_{t+1} = W_t + P_t - (1 - V_t)/(D_t/(W_{cap} - W_p))^2 E_t - g b_3 D_t V_t \tag{1}$$

$$V_{t+1} = V_t + g S_t b_1 D_{t-L}(1 - V_t/V_{max}) - d b_2 (1 - V_t) V_t \tag{2}$$

$$D_t = max(0, W_t - W_p) \tag{3}$$

$$W_t = max(0, min(W_{cap}, W_t)) \tag{4}$$

$$V_t = max(0, min(V_{max}, V_t)) \tag{5}$$

$$\begin{cases} D_{t-L} > D_{t-L-1}; & d = 0 \\ D_{t-L} \leq D_{t-L-1}; & d = 1 \end{cases} \tag{6}$$

$$S_t = (TOA_t - Phmin)/(Phmax - Phmin) \tag{7}$$

$$\begin{cases} S_{t-1} > S_t; & d = 1 \\ S_{t-1} \leq S_t; & d = 0 \end{cases} \tag{8}$$

$$g = (\frac{T_{max} - T_m}{T_{max} - T_{opt}})(\frac{T_m}{T_{opt}})^{(\frac{T_{opt}}{T_{max} - T_{opt}})} \tag{9}$$

The vegetaion parameter V corresponds to the fCover, which is mapped to PhenoCam G_{cc} using the transfer function based on the relationship between annual precipitation and fractional vegetation cover (Donohue et al. 2013).:

$$S_c = MAP/(MAP + h) \tag{10}$$

where:

$$fCover = G_{cc} * S_c \tag{11}$$

MAP is the site level mean annual precipitation, and h is an estimated parameter. G_{cc} is a ratio of the green band within the daily image ROI:

$$G_{cc} = \frac{G_{dn}}{G_{dn} + R_{dn} + B_{dn}} \tag{12}$$

Where G_{dn}, R_{dn}, and B_{dn} are the mean digitial numbers for green, red, and blue channels, respectively. See Richardson et al. 2018 for further G_{cc} processing details.

	Parameter	Description
State Variables	W	Soil Water Content (mm)
	V	Fractional Cover (fCover)
	D	Plant available water (mm)
	g	Plant temperature response function
Input Variables	P	Precipitaiton (mm)
	MAP	Mean annual precipitation (mm)
	W_{cap}	Soil Field Capacity (mm)
	W_p	Soil Wilting Point (mm)
	V_{max}	Maximum vegetation cover (1.0)
	E	Evapotranspiration (mm)
	T_m	Running 15 day mean temperature (C)
	TOA	Top of atmosphere radiation
	T_{max}	Maximum temperature for growth (45 C)
	T_{min}	Minimum temperature for growth (0 C)
Estimated Parameters	b1	Vegetation growth parameter
	b2	Senescence parameter
	b3	Soil water extraction rate
	T_{opt}	Optimal vegetation growth temperature
	Phmin	Lower bound of optimal daily solar radiation
	Phmax	Upper bound of optimal daily solar radiation
	L	Lag (days)
	h	fCover Transfer function parameter

parameter	Great Plains Grasslands	E. Temperate Forests Grasslands
b1	0.0021756	0.0143214
b2	0.0607134	0.0269089
b3	0.2630305	9.8632117
Phmax	48.1106340	49.6940973
Phmin	25.5471298	33.1345876
Topt	29.7376494	35.6335041
L	3.0685254	3.1769617
h	10.3601586	949.5914722

Table S1. Final parameters for the two models which met the minimum NSE threshold.

name	lat	lon	vegetation	roi_id	first_date	last_date	site_years	ecoregion
ahwahnee	37.75	-119.58	GR	3000	2015-07-28	2020-03-05	4.6	NWForests
archboldavir	27.18	-81.22	AG	1000	2016-11-18	2020-03-05	3.1	ETempForests
archboldavirx	27.17	-81.22	AG	1000	2016-05-16	2020-03-05	3.6	ETempForests
archboldpnot	27.19	-81.20	AG	1000	2016-05-13	2020-03-05	3.6	ETempForests
archboldpnotx	27.18	-81.20	AG	1000	2016-05-16	2020-03-05	3.6	ETempForests
arsgacp1	31.51	-83.62	AG	1000	2016-05-10	2020-03-05	3.8	ETempForests
arsmnswanlake1	45.68	-95.80	AG	1000	2015-10-02	2020-03-05	4.4	GrPlains
bullshoals	36.56	-93.07	GR	1000	2013-11-19	2020-03-05	5.8	ETempForests
burnssagebrush	43.47	-119.69	SH	1000	2012-10-13	2020-03-05	7.3	NADeserts
butte*	45.95	-112.48	GR	1000	2009-01-11	2020-03-05	10.7	NWForests
cperagm	40.84	-104.77	AG	1000	2016-05-19	2020-03-05	3.8	GrPlains
cperagm	40.84	-104.77	GR	1000	2016-05-19	2020-03-05	3.8	GrPlains
cpertgm	40.83	-104.76	GR	1000	2016-05-04	2020-03-05	3.8	GrPlains
cperuvb	40.81	-104.76	GR	1000	2015-07-16	2020-03-05	4.7	GrPlains
gatesofthemountains	46.83	-111.71	GR	2000	2011-08-12	2019-02-01	7.1	NWForests
glacier	48.50	-113.99	GR	1000	2009-02-07	2020-03-05	11.0	NWForests
goodwater	39.23	-92.12	AG	1001	2015-09-26	2020-03-05	4.5	GrPlains
grandteton	43.92	-110.58	SH	1000	2015-07-28	2020-02-04	3.5	NWForests
harvardfarmnorth	42.52	-72.18	AG	1000	2015-11-07	2020-03-05	4.3	NForest
harvardfarmsouth	42.52	-72.18	AG	1000	2015-11-07	2020-03-05	4.3	NForest
harvardgarden	42.53	-72.19	AG	1000	2016-06-12	2020-03-05	3.7	NForest
hawbeckereddy	40.66	-77.85	AG	1000	2015-09-23	2019-05-14	3.4	ETempForests
humnokericea	34.59	-91.75	AG	1000	2015-06-25	2020-03-05	4.2	ETempForests
humnokericec	34.59	-91.75	AG	1000	2015-06-25	2020-03-05	4.5	ETempForests
ibp*	32.59	-106.85	GR	1000	2014-02-16	2020-03-05	6.0	NADeserts
ibp*	32.59	-106.85	SH	1001	2014-02-16	2020-03-02	6.0	NADeserts
jasperridge*	37.40	-122.22	GR	1000	2012-03-08	2017-03-09	5.0	MWCoastForests
jerbajada	32.58	-106.63	SH	1000	2014-04-20	2020-03-05	5.9	NADeserts
jernort	32.62	-106.79	SH	2000	2016-10-28	2020-03-05	3.3	NADeserts
jersand	32.52	-106.80	SH	1000	2014-02-28	2020-03-05	6.0	NADeserts
kansas*	39.06	-95.19	GR	1000	2012-12-03	2019-12-31	6.7	GrPlains
kaweah	36.44	-118.91	SH	1000	2011-07-13	2019-09-20	8.2	MedCA
kelloggcorn	42.44	-85.32	AG	1000	2014-05-23	2019-10-05	4.9	ETempForests

Table S2. Sites used in analysis. A * indicates the site was also used in Hufkins et al. 2016.

name	lat	lon	vegetation	roi id	first date	last date	site years	ecoregion
kelloggcorn2	42.40	-85.38	AG	1000	2015-07-16	2019-04-11	3.2	ETempForests
kelloggcorn3	42.40	-85.37	AG	1000	2015-07-16	2020-03-05	3.7	ETempForests
kelloggcornsoy2	42.40	-85.37	AG	1000	2015-07-16	2020-03-05	3.7	ETempForests
kelloggmiscanthus	42.40	-85.38	AG	1000	2015-07-16	2020-03-05	3.7	ETempForests
kelloggoldfield	42.40	-85.37	AG	1000	2015-07-16	2020-03-05	4.2	ETempForests
kendall*	31.74	-109.94	GR	1000	2012-07-06	2020-03-05	7.6	SouthAridHighliands
kendall*	31.74	-109.94	SH	1000	2012-08-08	2019-11-07	7.2	SouthAridHighliands
konza*	39.08	-96.56	GR	1000	2012-03-17	2019-12-19	6.2	GrPlains
lethbridge*	49.71	-112.94	GR	1000	2011-12-07	2020-03-05	8.3	GrPlains
luckyhills	31.74	-110.05	SH	2000	2015-01-26	2018-06-04	3.4	SouthAridHighliands
mandanh5	46.78	-100.95	AG	1000	2015-09-17	2020-03-05	4.5	GrPlains
mandani2	46.76	-100.93	AG	1000	2016-04-22	2020-03-05	3.7	GrPlains
manilacotton	35.89	-90.14	AG	1000	2016-06-21	2020-03-05	3.6	ETempForests
marena*	36.06	-97.21	GR	1000	2012-06-12	2018-06-19	5.8	GrPlains
mead1	41.17	-96.48	AG	1000	2016-07-12	2020-03-05	3.7	GrPlains
mead2	41.16	-96.47	AG	1000	2016-07-12	2020-03-05	3.6	GrPlains
mead3	41.18	-96.44	AG	1000	2016-07-12	2020-03-05	3.7	GrPlains
meadpasture	41.14	-96.46	AG	1000	2016-07-15	2020-03-05	3.7	GrPlains
monture*	47.02	-113.13	GR	2000	2010-11-04	2019-02-01	8.0	NWForests
mtrobson	53.03	-119.20	GR	1000	2015-02-16	2020-03-05	4.8	NWForests
nationalelkrefuge	43.49	-110.74	GR	1000	2015-08-12	2020-03-05	4.5	NWForests
NEON.D03.DSNY.	28.13	-81.44	GR	1000	2016-12-15	2020-03-05	3.2	ETempForests
NEON.D06.KONA.	39.11	-96.61	AG	1000	2016-05-07	2020-03-05	3.7	GrPlains
NEON.D06.KONZ.	39.10	-96.56	GR	1000	2017-02-25	2020-03-05	3.0	GrPlains
NEON.D09.WOOD.	47.13	-99.24	GR	1000	2016-12-18	2020-03-05	3.2	GrPlains
NEON.D10.ARIK.	39.76	-102.45	GR	1000	2016-12-18	2020-03-05	3.1	GrPlains
NEON.D10.CPER.	40.82	-104.75	GR	1000	2016-06-30	2020-03-05	3.7	GrPlains
NEON.D10.STER.	40.46	-103.03	AG	1000	2016-12-18	2020-03-05	3.2	GrPlains
NEON.D11.OAES.	35.41	-99.06	GR	1000	2017-02-28	2020-03-05	3.0	GrPlains
NEON.D13.MOAB.	38.25	-109.39	GR	1000	2017-02-25	2020-03-05	3.0	NADeserts
NEON.D14.JORN.	32.59	-106.84	GR	1000	2017-02-25	2020-03-05	3.0	NADeserts
NEON.D14.SRER.	31.91	-110.84	SH	1000	2017-02-25	2020-03-05	3.0	NADeserts
NEON.D15.ONAQ.	40.18	-112.45	GR	1000	2016-12-18	2020-03-05	3.2	NADeserts
NEON.D15.ONAQ.	40.18	-112.45	SH	1001	2016-12-18	2020-03-05	3.2	NADeserts
oakville	47.90	-97.32	GR	1000	2014-08-06	2020-03-05	4.6	GrPlains

name	lat	lon	vegetation	roi id	first date	last date	site years	ecoregion
rosemountnprs	44.68	-93.07	AG	1000	2015-10-29	2020-03-05	4.3	GrPlains
sevilletagrass	34.36	-106.70	GR	1000	2014-11-07	2020-03-05	5.1	NADeserts
sevilletashrub	34.33	-106.74	SH	1000	2014-10-29	2020-03-05	5.0	NADeserts
silverton	45.00	-122.69	AG	1000	2013-07-22	2020-02-10	5.9	NWForests
smokypurchase	35.59	-83.07	GR	2000	2016-01-02	2020-03-05	4.0	ETempForests
southerngreatplains	36.61	-97.49	AG	1000	2012-05-16	2020-03-05	7.5	GrPlains
spruceT6P16E	47.51	-93.45	SH	1000	2015-08-24	2020-03-05	4.6	NForest
stjones	39.09	-75.44	GR	1000	2015-09-20	2020-03-05	4.4	ETempForests
sweetbriargrass	37.56	-79.09	AG	1000	2016-03-23	2020-03-05	3.8	ETempForests
teddy	46.89	-103.38	GR	1000	2010-01-02	2019-03-27	8.5	GrPlains
teddy	46.89	-103.38	SH	1000	2003-05-11	2019-03-27	14.4	GrPlains
tonzi*	38.43	-120.97	GR	1000	2011-10-26	2020-02-13	7.3	MedCA
turkeypointenf02	42.66	-80.56	AG	1000	2012-05-01	2020-03-05	7.5	ETempForests
twitchell	38.11	-121.65	AG	1000	2011-11-16	2017-04-05	4.0	MedCA
uiefmaize	40.06	-88.20	AG	1000	2008-11-06	2020-03-02	11.3	ETempForests
uiefmiscanthus	40.06	-88.20	AG	1000	2008-11-12	2018-04-29	9.2	ETempForests
uiefprairie*	40.06	-88.20	GR	1000	2008-10-22	2020-03-02	11.3	ETempForests
uiefswitchgrass	40.06	-88.20	AG	1000	2008-10-22	2020-03-02	10.6	ETempForests
usgseros	43.73	-96.62	GR	1000	2014-09-11	2017-10-02	3.1	GrPlains
uwmfieldsta	43.39	-88.02	GR	1000	2013-03-15	2020-03-05	7.0	ETempForests
vaira*	38.41	-120.95	GR	1000	2011-10-17	2020-02-28	7.7	MedCA

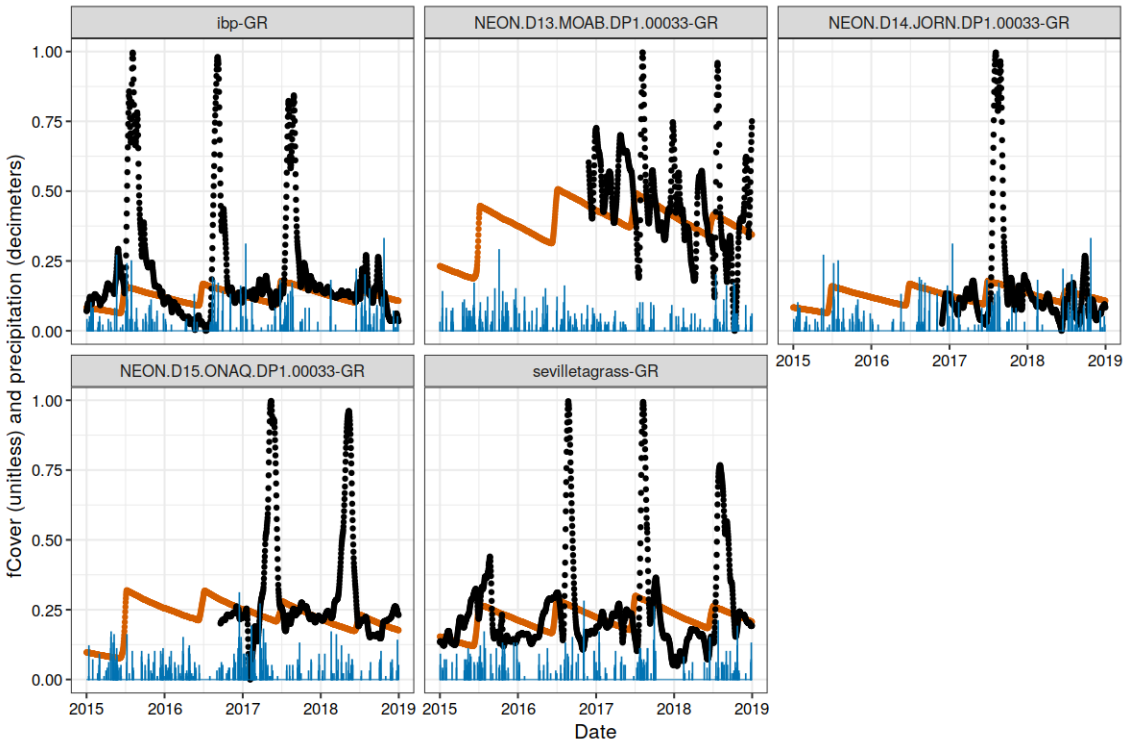

Figure S1. Predicted (red) and observed (black) fCover values at five grassland sites in the North American Deserts ecoregion for the years 2015-2018. Blue bars represent precipitation in decimeters.

References

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