Modeling Gross Primary Production in Semi-arid Inner Mongolia using MODIS Imagery and Eddy Covariance Data

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Introduction

Semi-arid Inner Mongolia, P.R.C, is experiencing climate change with associated land cover/use change that includes an increase in irrigated agriculture and population growth. We evaluate temporal scaling up of carbon fluxes from eddy covariance (EC) tower observations in different water-limited land cover/use and biome types.

Site	Vegetation	Location (decimal degrees)		Altitude (m)	Mean annual rainfall(mm)		Mean annual temperature (˚C)	
		Latitude	longitude		2006	2007	2006	2007
D01	Duolun steppe	42.046667	116.283610	1350	423	199	8.4	7.4
D02	Duolun cropland	42.045556	116.279722	1350	410	190	8.9	7.5
X03	Xilinhaote steppe	43.554444	116.671389	1250	152.9	170.4	7.2	7.7
K04	Kubuqi poplar stand	40.563333	108.745000	1020	227	180.4	12.3	11.5
K05	Kubuqi shrubland	40.451667	108.625000	1160	202.7	180.4	12.3	11

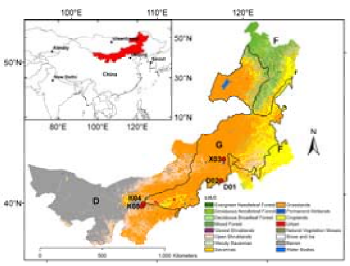


Fig 1. MODIS derived IGBP classification overlaid with EC flux tower sites and WWF terrestrial biome boundaries

Methods

The Vegetation Photosynthesis model (VPM) and modified VPM (MVPM), driven by Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) for 2006-2007, derived from the MODIS surface reflectance product (MOD09A1), was used to scale up and validate temporal changes in GPP using EC towers during 2006 & 2007 growing seasons.

While VPM needs just four parameters obtained from flux towers for each of the five ecosystem/LCLU types, the MVPM is independent of any ground measured meteorological data. Both models are based on simple equations that are not computationally intensive like most process-based models.

MVPM in particular, offers a cost effective solution in predicting GPP at remote study sites that lack infrastructure to set up ground based sensors.

$$GPP_{VPM} = \varepsilon_g \times fAPARchl \times PAR_i$$

$$\varepsilon_g = \varepsilon 0 \times Tscalar \times Pscalar \times Wscalar$$

$$GEP_{MVPM} = \alpha\, \frac{[\ln(GPP\ MODIS)^*(EVI^*LSWI^*LST)]}{fPAR\ MODIS}$$

(Fig. 2 and 3) Seasonal changes in observed GPP_{EC} and predicted GPP_{VPM} in 2006 & 2007. Linear regression between observed GPP_{EC} and predicted GPP_{VPM} in 2006 & 2007 (Fig. 4 & 5). Seasonal changes in observed GPP_{EC} as compared with GPP_{MVPM} (Fig. 7).

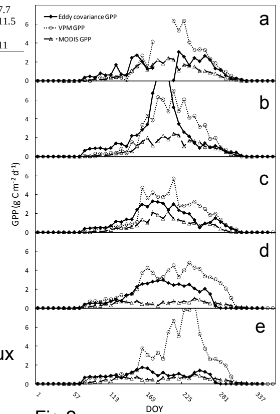


Fig 2.

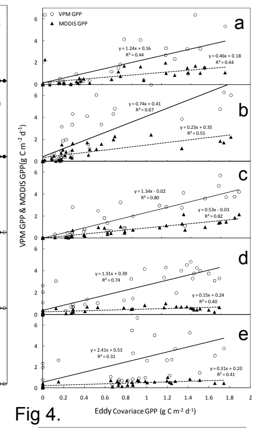
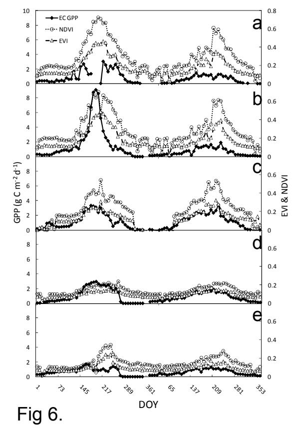


Fig 4.



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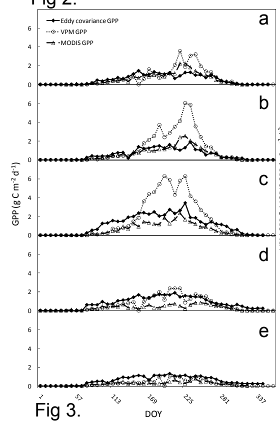

Fig 3.

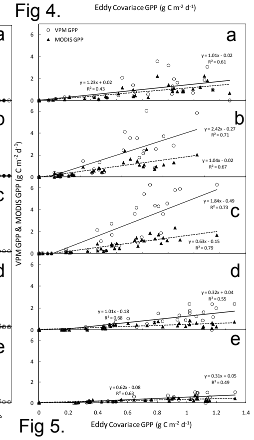

Fig 5.

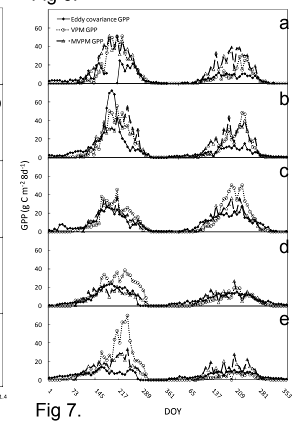

Fig 7.

EC flux towers, DO1, D02, X03, K04 & K05 are a, b, c, d, & e, in the figures above.

Site	Flux tower				VPM Model				MVPM			
	$GPP_{obs\,(1-12)}$		$GPP_{obs\,(5-10)}$		$GPP_{pre\,(1-12)}$		$GPP_{pre\,(5-10)}$		$GPP_{pre\,(1-12)}$		$GPP_{pre\,(5-10)}$	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
D01	40.00	24.00	33.20	21.41	69.42	29.43	68.00	28.40	78.90	62.41	79.08	61.58
D02	77.00	27.65	69.02	22.59	72.96	49.00	71.64	48.02	74.18	60.29	75.57	59.26
X03	49.62	50.14	42.18	43.67	59.36	70.20	57.72	68.86	49.50	54.51	49.64	53.33
K04	45.44	39.12	40.61	30.30	74.13	28.51	69.84	26.96	42.64	34.32	39.52	31.66
K05	30.24	25.40	21.43	21.50	86.28	19.31	81.76	18.13	53.20	35.95	49.21	34.62

Results

The VPM model predicted the annual GPP (GPP_{VPM}) reasonably well in 2006-2007 at the Duolun cropland (R^2 = 0.67 & 0.71) and Xilinhaote typical steppe (R^2 = 0.80 & 0.73). The predictive power of VPM varied in the desert steppe, at an irrigated poplar stand (R^2 = 0.74 & 0.68) and nearby shrubland in Kubuqi (R^2 = 0.31 & 0.49).

The comparison between GPP_{EC} and GPP_{MVPM} predicted GPP showed good agreement for the Xilinhaote typical steppe (R^2 = 0.84 & 0.70) in 2006-2007, Duolun typical steppe (R^2 = 0.63), and cropland (R^2 = 0.63) in 2007. The predictive power of MVPM decreased slightly in the desert steppe, at the irrigated poplar stand (R^2 = 0.55 & 0.47) and the shrubland (R^2 = 0.20 & 0.41). The results of this study demonstrate the feasibility of scaling up GPP from EC towers to the regional scale.

Site	year	significance	SE	R^2
D01	2006*	0.642	0.105	.008*
	2007	0.000	0.033	**.527**
D02	2006	0.014	0.222	.203
	2007	0.000	0.035	**.630**
X03	2006	0.000	0.540	**.844**
	2007	0.000	0.056	**.702**
K04	2006	0.000	0.197	**.553**
	2007	0.000	0.085	**.471**
K05	2006	0.013	0.076	.207
	2007	0.000	0.050	**.415**

Future Work

We are expanding our flux network in Inner and Outer Mongolia, thus increasing the number of measurements / tower-years. OM and IM have contrasting socio-economic and political systems and since, 1979 have divergent land use trajectories with environmental changes taking place more rapidly in IM than OM.

The regional atmospheric modeling system (RAMS), calibrated with the EC flux tower/climate station network & RS data is being used to forecast future climate change scenarios in the Mongolian plateau.

Acknowledgements:

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