Convergence of potential net ecosystem production in C_3 grasslands

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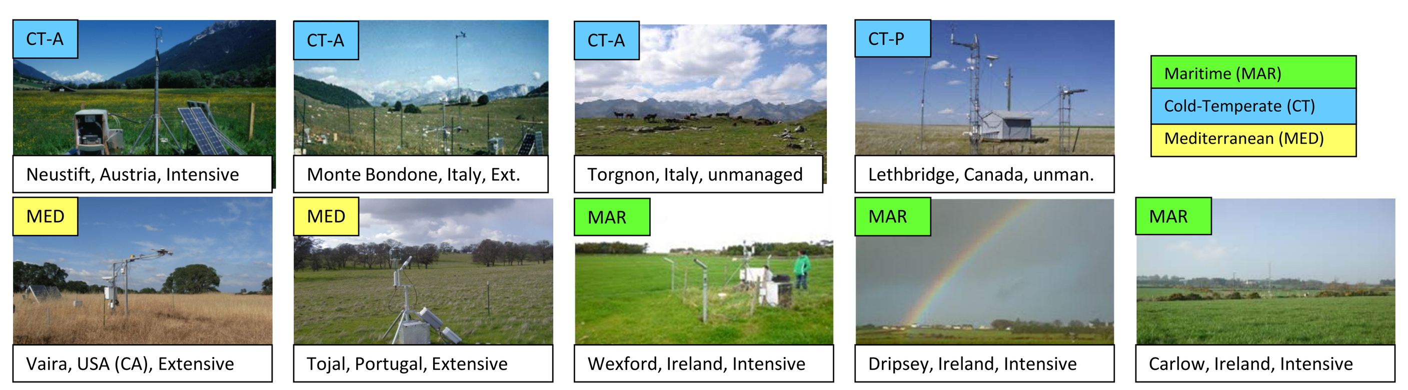
1. Background

Metabolic theory and body size constraints on biomass production and decomposition suggest that differences in the intrinsic potential net ecosystem production (NEP_{POT}) should be small among contrasting C_3 grasslands and therefore unable to explain the wide range in the annual apparent net ecosystem production (NEP_{APP}) reported by previous studies (e.g. Gilmanov et al. 2010). In a recent synthesis study (Peichl et al., 2013), we estimated NEP_{POT} for nine C_3 grasslands under contrasting climate and management regimes using multi-year eddy covariance data.

2. Study sites

Table 1: Site characteristics of the nine investigated grassland sites Neustift, N; Monte Bondone, MB; Torgnon, TN; Lethbridge, L; Vaira, V; Tojal, T; Dripsey, D; Wexford, W; and Carlow, CW.

Site	N	MB	TN	L	V	T	D	W	CW
Country	Austria	Italy	Italy	Canada (AB)	USA (CA)	Portugal	Ireland	Ireland	Ireland
Coordinates	47°07' N 11°19' E	46° 01' N 11° 2' E	45° 50' N 7° 34' E	49° 43' N 112° 56' W	38 °41' N 120° 95' W	38°28′ N 8°01′ W	51°59' N 8°45' W	52°30' N 6°40' W	52°52′ N 6°54′ W
Elevation (m a.s.l.)	970	1550	2160	951	129	190	195	57	56
Climate region	Cold-Temperate	Cold-Temperate	Cold-Temperate	Cold-Temperate	Mediterranean	Mediterranean	Maritime	Maritime	Maritime
Mean T_a (°C)	6.5	5.5	3.1	5.4	16.5	15.5	9.4	10.1	9.4
Mean PPT (mm)	852	1189	920	402	562	669	1207	877	824
Snow cover and/or T < 0°C	Nov - Apr	Nov - Apr	Nov - May	Oct - Apr	none	none	none	none	none
Management	intensive meadow	extensive meadow	abandoned pasture	unmanaged prairie	extensive pasture	extensive pasture	intensive meadow/ pasture	intensive meadow/ pasture	intensive meadow/ pasture
Nitrogen fertilizer application (kg N ha^{-1} y^{-1})	manure	low	none	none	none	none	~150-250 (inorganic, manure, slurry)	~200-300 (inorganic, manure, slurry)	~200 (inorganic, manure, slurry)
Soil type	Fluvisol	Typic Hapludalfs	Cambisol	Orthic chernozem	Lithic haploxerepts	Luvisol	Gleysol	(Gleyic) Cambisol	Calcic Luvisol
Soil texture	(sandy) loam	loam	loamy sand	clay loam	silt loam	sandy (clay) loam	loam	loam	sandy loam
Soil C (kg C m^{-2})	8.1 (0-30cm)	8.7 (0-20cm)	2.8 (0-20cm)	3.7 (0-10cm)	6.0 (0-30cm)	3.3 (0-30cm)	9.0 (0-30cm)	3.9 (0-10cm)	4.2 (0-10cm)
Soil N (kg N m^{-2})	n.a.	0.76 (0-20cm)	0.22 (0-20cm)	n.a.	0.60 (0-30cm)	n.a.	0.76 (0-30cm)	0.34 (0-10cm)	0.42 (0-10cm)
Max. LAI (m^2 m^{-2})	5.5	4.7	2.8	1.2	2.7	2.3	2.5	na	5.1
Dominant species	*Dactylis glomerata*	*Festuca rubra*	*Nardus stricta*	*Agropyron dasystachyun*	*Brachypodium distachyon*	*Avena barbata*	*Lolium perenne*	*Lolium perenne*	*Lolium perenne*
Data coverage	2001 - 2009	2003 - 2009	2009 - 2010	1999 - 2006	2001- 2007	2005 - 2008	2003-2006, 2008, 2009	2004-2006, 2008, 2009	2003, 2008
References	*Wohlfahrt et al.* (2008b)	*Marcolla et al.* (2011)	*Migliavacca et al.* (2011a)	*Flanagan & Adkinson* (2011)	*Ma et al.* (2007)	*Aires et al.* (2008)	*Peichl et al.* (2011)	*Peichl et al.* (2012)	*Flechard et al.* (2007)



3. Concept of potential NEP

The three main controls on NPP and R_h that subsequently determine NEP_{POT} include the stationary long-term effects from i) environmental conditions, ii) management practices and iii) ecosystem traits. NEP_{APP} then deviates from NEP_{POT} as a function (*f*) of seasonal and short-term constraints from environmental conditions (*e*) and management (*m*) events (Fig. 1).

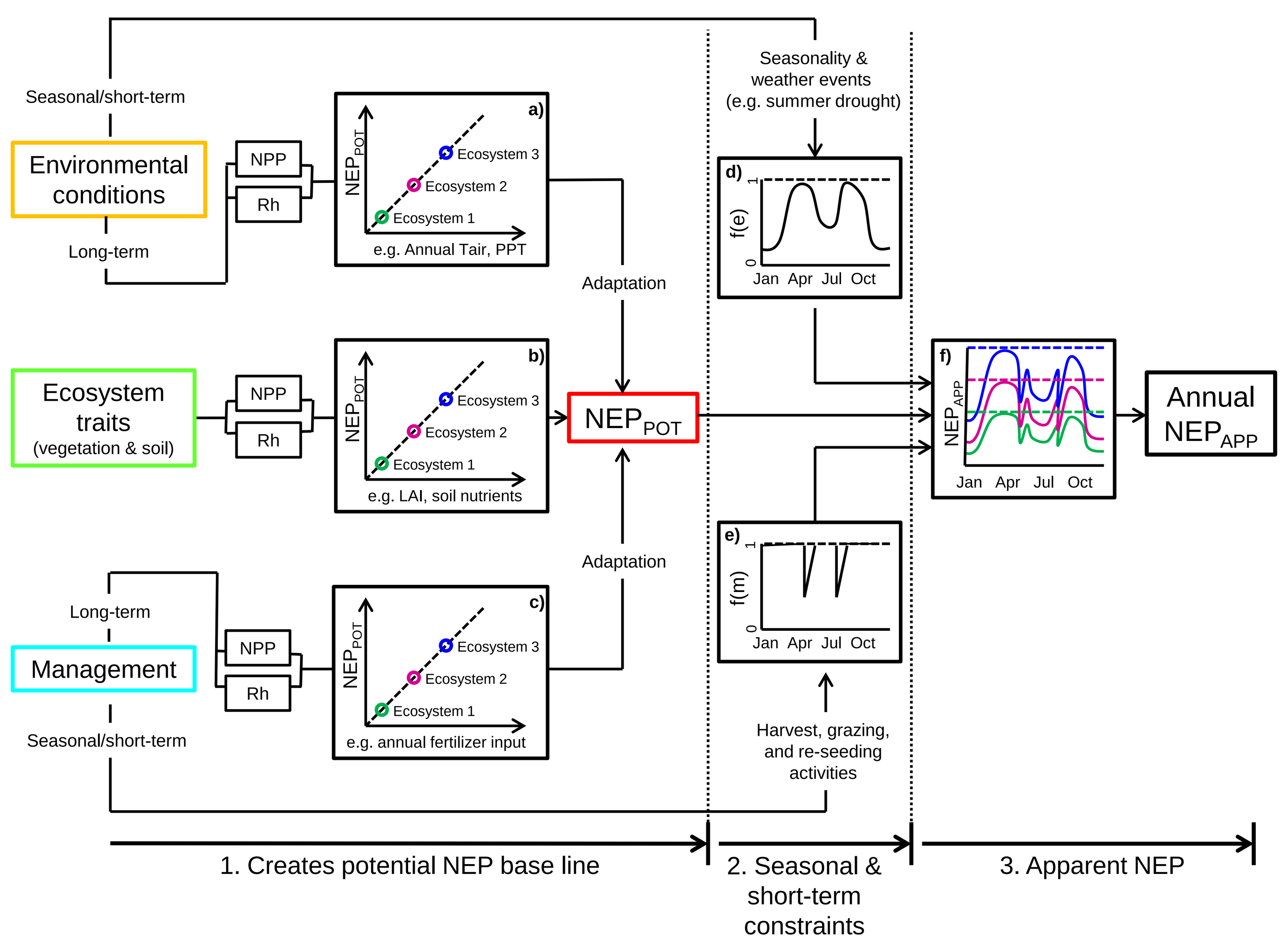


Figure 1: Conceptual diagram outlining the interactions between ecosystems traits, environmental conditions, management, net primary production (NPP), heterotrophic respiration (R_h), potential net ecosystem production (NEP_{POT}) and apparent NEP (NEP_{APP}).

NEP_{POT} was determined for each site as the maximum of all 30-day averages of NEP_{APP} across all years using a moving window. Thus, we assume that the maximum *apparent* rate occurring under optimum conditions within a multi-year time series should approach or ideally equal the *potential* rate. Furthermore, GEP_{APP} and ER_{APP} at the time of NEP_{POT} were denoted as GEP_{POT} and ER_{POT}, respectively.

4. Convergence of NEP_{POT}

NEP_{POT} was within a narrow range of 4.6 to 6.0 g C m^{-2} d^{-1} and not significantly different for six out of nine sites (Fig. 2).

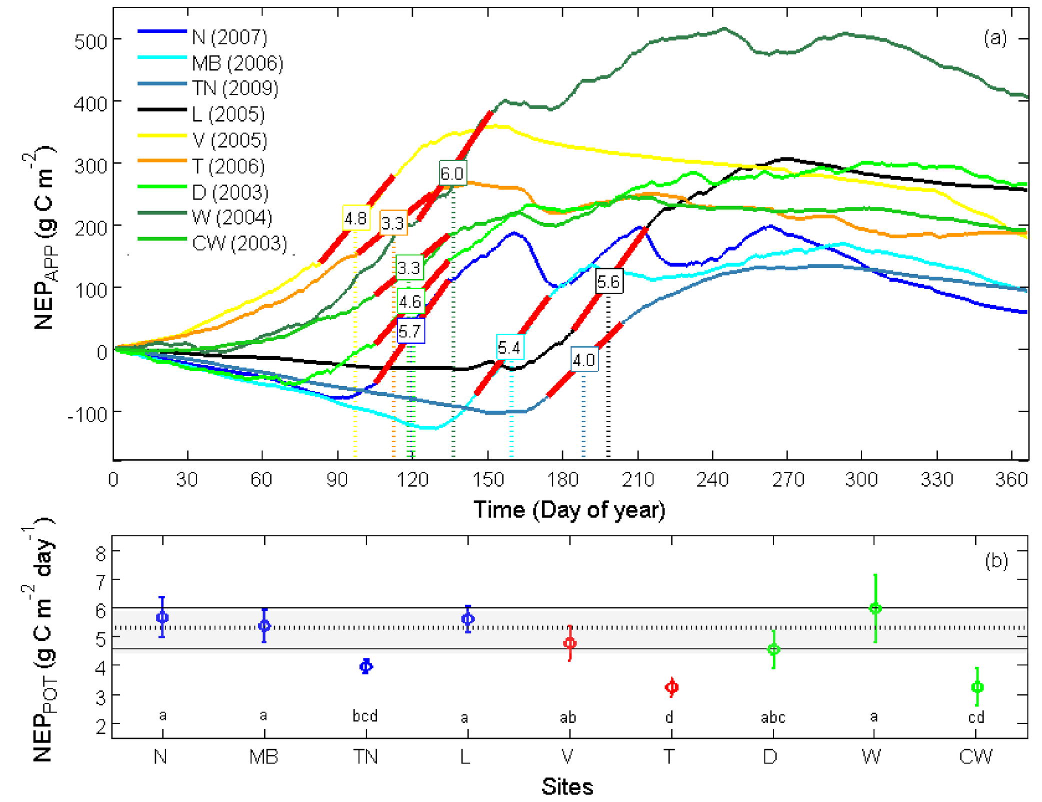


Figure 2: (a) Cumulative NEP_{APP} for years when NEP_{POT} occurred at the grasslands sites; (b) NEP_{POT} for grasslands in the cold-temperate (blue), Mediterranean (red), and maritime (green) regions; grey band indicates the convergence zone for NEP_{POT}.

NEP_{POT} occurred when the 30-day mean GEP_{APP} was equal or close to its maximum (Fig. 3). NEP_{POT} occurred close to the maximum 30-day mean ER_{APP} at the extensive sites, but preceded the peak of 30-day mean ER_{APP} at the meadows and intensively managed pastures.

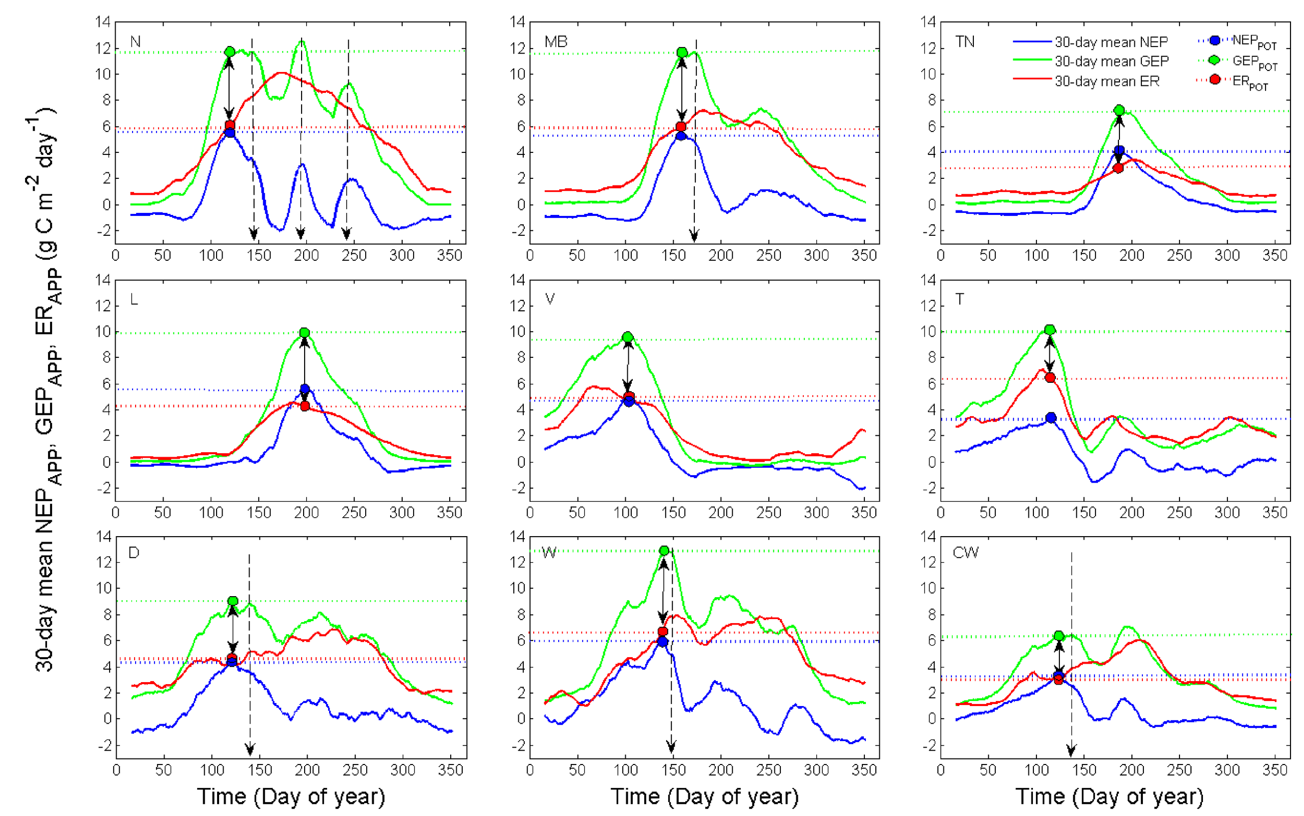


Figure 3: 30-day mean NEP_{APP}, gross ecosystem production (GEP_{APP}) and ecosystem respiration (ER_{APP}) at the nine sites (see Table 1) during the year in which NEP_{POT} occurred.

5. Link of metabolic pathways

Rapid C turnover and metabolic constraints on production and decomposition rates due to relatively small vegetation body size (Brown et al. 2004) may explain the convergence of NEP_{POT} in C_3 grasslands (Fig. 4). Moreover, ecosystem traits that are critical controls of NEP_{POT} vary much less widely in C_3 grasslands compared to other biomes, which may facilitate the convergence of NEP_{POT}.

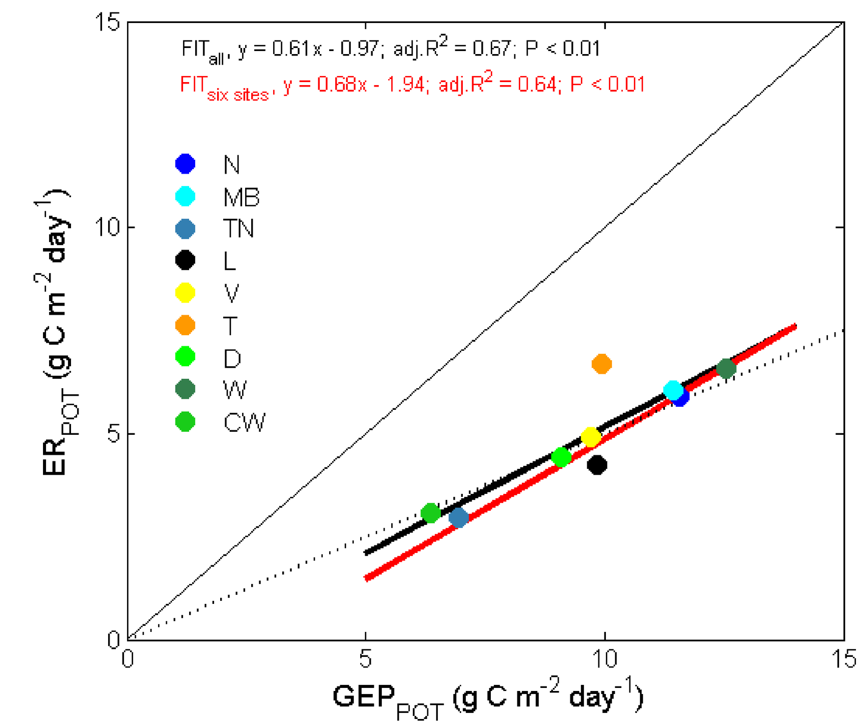


Figure 4: Regression between GEP_{POT} and ER_{POT}

6. Conclusions

NEP_{POT} converged within a narrow range suggesting little difference in the net carbon dioxide uptake capacity among C_3 grasslands. Our results indicate a unique feature of C_3 grasslands compared to other terrestrial ecosystems and suggest a state of stability in NEP_{POT} due to tightly coupled production and respiration processes. Consequently, the annual NEP_{APP} of C_3 grasslands is primarily a function of seasonal and short-term environmental and management constraints, and therefore especially susceptible to changes in future climate patterns and associated adaptation of management practices.

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