The sensitivity of carbon exchanges in Great Plains grasslands to precipitation variability

Petrie, M.D. *et. al., J. Geophys Res Biogeosci* 121 (2016)
doi: 10.1002/2015JG003205

Objectives:

- Grasslands play a major role in the global carbon budget and in terrestrial carbon storage, sequestering approximately 0.5 Pg C yr−1 and accounting for as much as 10% of aboveground and 10–30% of below-ground terrestrial carbon storage.
- The Great Plains of North America encompasses approximately 2.9 million km^2 in the central United States and Canada, and is one of the most productive regions of rangeland globally, yet there is little information on how fine-scale relationships compare between them regionally.
- This study compared grassland carbon exchanges, energy partitioning, and precipitation variability in eight sites in the eastern and western Great Plains using eddy covariance and meteorological data.
- The analysis included eight grassland sites: three in the eastern grasslands, three in the western grasslands, and two ecological boundary sites. Daily precipitation data for the period 1980-2012 and available 30-minute eddy covariance data for each site were used in the analysis.

New Science:

- The study found generalizable differences in how western and eastern grasslands responded to precipitation, and that these differences may be muted locally by precipitation and temperature regimes, especially at ecotones.
- Eastern grasslands had a moderate vapor pressure deficit (VPD = 0.95 kPa) and high growing season gross primary productivity (GPP = 1010 ± 218 g C m^{-2} yr^{-1}).
- Western grasslands had a growing season with higher VPD (1.43 kPa) and lower GPP (360 ± 127 g C m^{-2} yr^{-1}).
- Western grasslands were sensitive to precipitation at daily timescales, whereas eastern grasslands were sensitive at monthly and seasonal timescales.
- At daily timescales, both western and eastern grasslands showed similar normalized increase in GPP after isolated rainfall pulses occurred, although western grasslands were more sensitive.
- Generally, eastern grasslands have greater productivity and carbon storage than western grasslands as a result of higher precipitation.
- Eastern and western grasslands were found to be a net sink in wet years and a net source in others, and many grasslands in this region remain carbon neutral on the order of years to decades, therefore fluctuations in precipitation around the annual means are likely the dominant control on carbon exchanges throughout the Great Plains, not just in the more arid west.
- Because eastern grasslands are less influenced by short-term variability in rainfall than western grasslands, the effects of precipitation change are likely to be more predictable in eastern grasslands as the timescales of variability that must be resolved are relatively longer.
- Variations at individual sites, such as a fire event in one year at one site, affected the carbon dynamics of the site in predictable ways; however, it was not possible to explain why one site, which had 28% higher than average annual precipitation and similar EF, VPD, and sensitivity to precipitation as other western grasslands was a net source of carbon during the study period.

- The findings support the authors’ postulation that regional heterogeneity will increase in grassland carbon exchanges in the Great Plains in coming decades.

Significance:

- Because many ecosystem processes in grasslands are driven by precipitation, the ecological viability of Great Plains grasslands and the carbon sequestration services they provide may be impacted by global climate change.
- There is growing scientific consensus on the importance of understanding how variability in temperature and precipitation regimes affects grassland ecosystem functioning, yet the majority of available information addresses different, often site-specific processes, limiting the generalizability of this information.
- The variability found at individual sites emphasizes the need to better explore demographic patterns in western grasslands as a potential ecosystem-scale response to climate variability.
- Because local processes may shape longer-term grassland dynamics and may mute or amplify the effects of climate variability, such processes should be included in future work.
- This study strengthens understanding of precipitation variability as a local driver of year to year variation in grassland processes and carbon sequestration and as a regional driver that, over longer timescales, interacts with temperature to shape differences in functioning between eastern and western Great Plains.

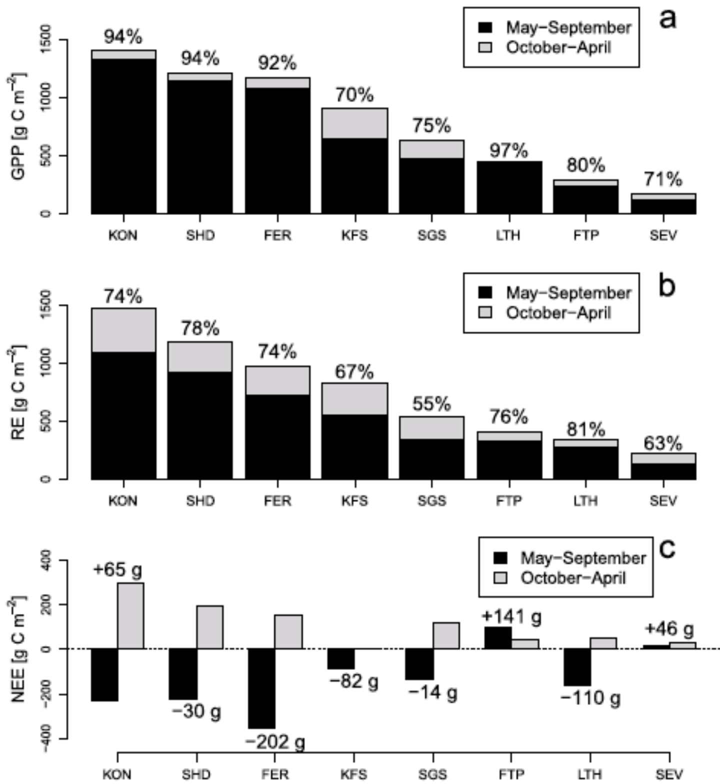

Figure 3. (a) Mean annual gross primary production (GPP: g C m^{-2} yr^{-1}), (b) ecosystem respiration (RE), and (c) net ecosystem exchange (NEE). For GPP and RE, the contribution of June–September fluxes to annual averages is shown as a percentage, and the total average carbon sink or source (as NEE) is shown in Figure 3c. Sites LTH, FTP, and SGS are western sites; KON, KFS and SHD are eastern sites. Ecosystem boundary sites are SEV (western) and FER (eastern).

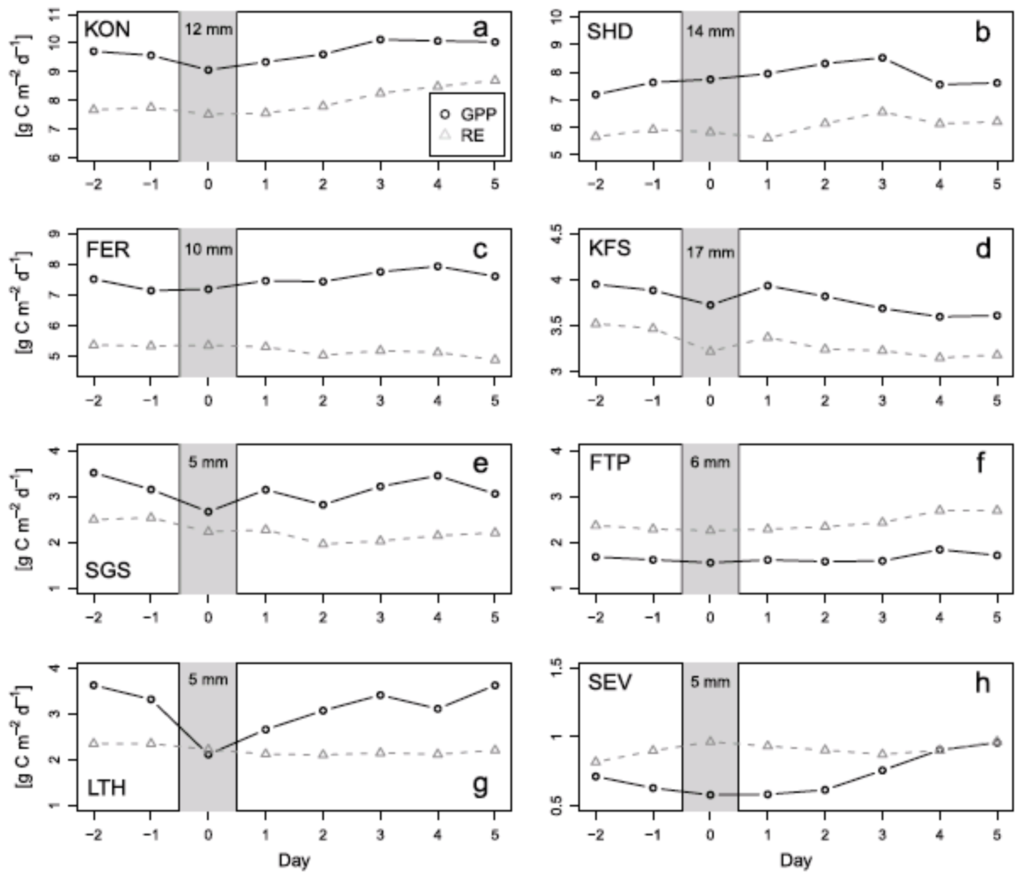

Figure 7. Response of daily gross primary production (GPP: g C m^{-2} d^{-1}) and ecosystem respiration (RE: g C m^{-2} d^{-1}) to isolated rainfall pulses occurring during each site's active growing season. Values correspond to rainfall events between the *x* and $x \pm 1/2\sigma^2$ of average precipitation event magnitude for each site. On the *x* axis, values correspond to days prior to (negative) or after (positive) the rainfall pulse. The *y* axis scale differs between panels.