Supporting Information

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SI Materials and Methods

We compared the past 27 y of climate data collected at Konza with a nearby long-running climate station in Manhattan, KS. Adjusted for average differences in temperature and precipitation observed from 1984–2010, over the past 100 y the mean maximum daily temperatures from day of year (DOY) 190–214 varied from 26.1–41.5 °C, with 95% of the years falling within 29.1–38.7 °C.

Grass aboveground net primary productivity ($ANPP_G$) was measured in both lowland and upland positions, but the response of production to climate variability did not differ in the two positions. Lowlands produced 58% more biomass than uplands on average (517 vs. 328 $g \cdot m^{-2}$, respectively), but there was no difference between the two topographic positions in relationships between $ANPP_G$ and precipitation or residual stream discharge from DOY 105–214 (P = 0.82, 0.96 respectively). There was only a nonsignificant trend for a greater reduction in $ANPP_G$ with higher temperatures in the lowlands than in the uplands (13.7 vs. 31.1 $g \cdot m^{-2} \cdot °C^{-1}$; P = 0.1).Therefore $ANPP_G$ data for the two positions were averaged for each year and used as the index of $ANPP_G$.

Discharge for King's Creek for any year was a function of the amount of precipitation and air temperature, and residual variation in discharge was determined after adjusting for differences in climate among years. From 1984–2010, discharge during DOY 105–214 varied from 0 m^3 in 1989 to 7,050 × 10^6 m^3 in 1993. Discharge increased with increasing precipitation (partial r^2 = 0.82, P < 0.001) over this period and was lower in years with higher maximum temperatures in April (partial r^2 = 0.05, P < 0.001):

$$\begin{aligned}\text{Discharge}_{105-214} = & -1723.11 + 7.06 * \text{Precip}_{105-214} \\ & + (0.016 * \text{Precip}_{105-214})^2 \\ & + (1.26\text{e}-5 * \text{Precip}_{105-214})^3 \\ & - 103.10 * \text{MaxTemp}_{95-114}).\end{aligned}$$

Part of the variation in residual discharge seemed to be associated with event size. For example, 2000 and 2007 had similar precipitation but the 2007 discharge was 17 × 10^6 m^3 higher. Peak flow in 2007 was associated with a 92-mm event, whereas peak flow in 2000 was associated with a 59-mm event. Despite this case example, there was no relationship between residual discharge during the critical precipitation period and the fraction of precipitation that came in events > 40, 50, or 60 mm (P > 0.65 for all) or the fraction of precipitation that came in events < 5 or 10 mm (P > 0.85 for both).

On average, soil moisture was consistently high in April and declined throughout the year until reaching a minimum in early August (Fig. 2). However, there was high variation in soil moisture at any one point in time among years. As an example of how high temperatures reduce soil moisture, the critical climate period approach shows that soils were drier in early August in years with higher temperatures before and during early August (Fig. S3). Early August soil moisture at 25 cm [average date measured = DOY 222 (August 10)] declined linearly with decreasing precipitation (DOY 185–219, partial r^2 = 0.66) and increasing mean daily maximum temperatures (DOY 160–184, partial r^2 = 0.14; or DOY = 165–219, partial r^2 = 0.11) before early August (Fig. S3).

Observations of land−atmosphere exchange were made using eddy covariance from the KZU Ameriflux site located at the Konza Prairie Long-Term Ecological Research (LTER) site on an annually burned watershed (watershed 1D) for the period from 2006–2010. Wind speed and temperature data were collected using a CSAT-3 sonic anemometer (Campbell Scientific), and the water and carbon fluxes were collected using a Li-Cor 7500 open path gas analyzer inclined into the mean wind at an angle of 15°. Several post-data collection processing methods were used on the 20-Hz data from each site. This methodology closely follows the data processing outlined by Baum et al. (1) and Brunsell et al. (2). All data collected from the eddy covariance tower were processed with the EdiRE software package (www.geos.ed.ac.uk/abs/research/micromet/EdiRe/). Corrections on the data included despiking, lag removal, planar-fit rotation, frequency-response corrections, sonic temperature sensible heat flux corrections, and density corrections for carbon and water fluxes. Quality-control filtering methodologies, including an integral turbulence test and a stationarity test, were conducted on the 20-Hz data collected. Filtered and missing data were gap-filled for continuous sets of data following Reichstein et al. (3). Net ecosystem exchange (NEE) was decomposed into gross primary production (GPP) and ecosystem respiration following Reichstein et al. (3) and summed for the month of August in each year.

We tested the roles of the two critical climate periods important for August ANPP for the August ecosystem carbon-exchange data. Mean daily maximum temperatures from DOY 190–214 explained almost all the variation in August NEE (r^2 = 0.96, P = 0.004), and precipitation from DOY 105–214 explained almost all the variation in August ecosystem respiration (r^2 = 0.92, P = 0.01). Together, the combination of temperature and precipitation over these two periods explained almost all the variation in August GPP (r^2 = 0.99, P = 0.02 for both). Critical climate periods involving August climate explained lower proportions of the variation in August ecosystem carbon exchange.

1. Baum K, Ham J, Brunsell N, Coyne P (2008) Surface boundary layer of cattle feedlots: Implications for air emissions measurement. *Agric For Meteorol* 148:1882–1893, 10.1016/j.agrformet.2008.06.017.
2. Brunsell NA, Schymanski SJ, Kleidon A (2011) Quantifying the thermodynamic entropy budget of the land surface: Is this useful? *Earth System Dynamics* 2:87–103, 10.5194/esd-2-87-2011.
3. Reichstein M, et al. (2005) On the separation of net ecosystem exchange into assimilation and ecosystem respiration: Review and improved algorithm. *Glob Change Biol* 11:1424–1439, 10.1111/j.1365-2486.2005.001002.x.

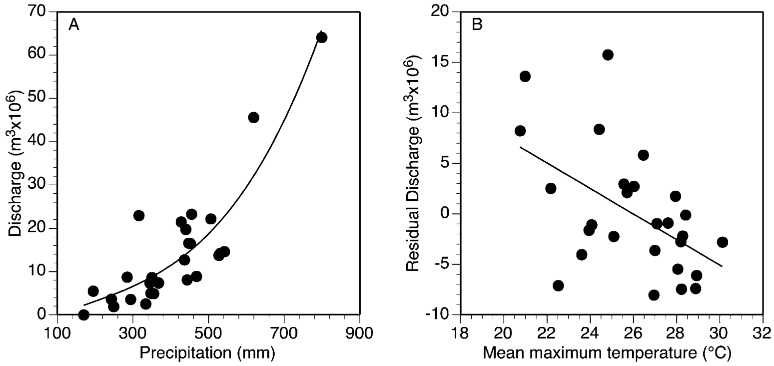

Fig. S1. (*A*) Relationship between stream discharge from King's Creek on Konza from DOY 105–214 and precipitation over the same date range from 1984–2010. (*B*) Partial residuals between maximum temperature from DOY 95–114 and stream discharge from DOY 105–214 after taking into account variation in precipitation from DOY 105–214.

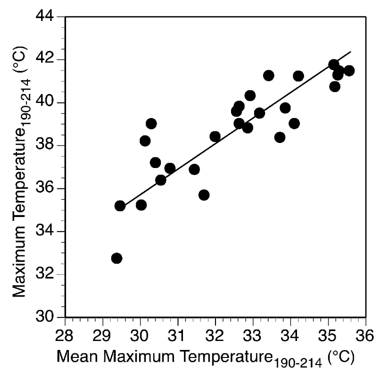

Fig. S2. Relationship between mean daily maximum air temperatures from DOY 190–214 and the maximum air temperatures recorded during that period (y = 0.04 + 0.93×, *r* = 0.86, *P* < 0.001). Date range spans 1984–2010.

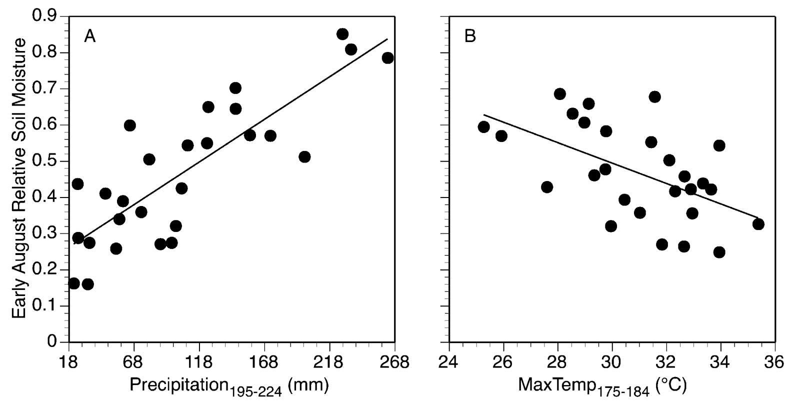

Fig. S3. Partial residual relationships between soil moisture at 25 cm in early August from 1984–2010 and (*A*) precipitation and (*B*) temperature during critical climate periods (r^2 = 0.73, *P* < 0.001 and *P* = 0.002, respectively).

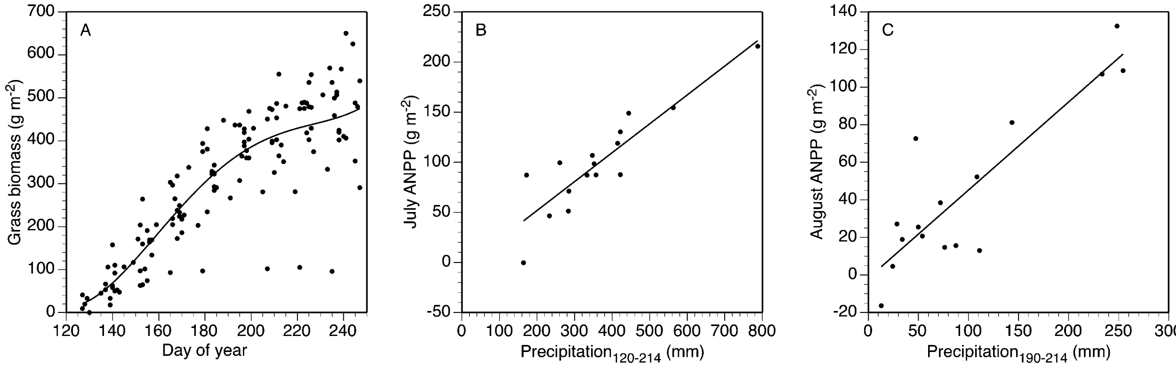

Fig. S4. Pattern of grass biomass over time and relationships between precipitation and July and August $ANPP_G$ vs. during critical climate periods. (*A*) Grass biomass measured biweekly from 1984–1999 and fit with a spline ($\lambda = 10^4$). (*B*) Relationship between July $ANPP_G$ and precipitation from DOY 120–214 ($r^2 = 0.80$). (*C*) Relationship between August $ANPP_G$ and precipitation from DOY 190–214 ($r^2 = 0.77$).

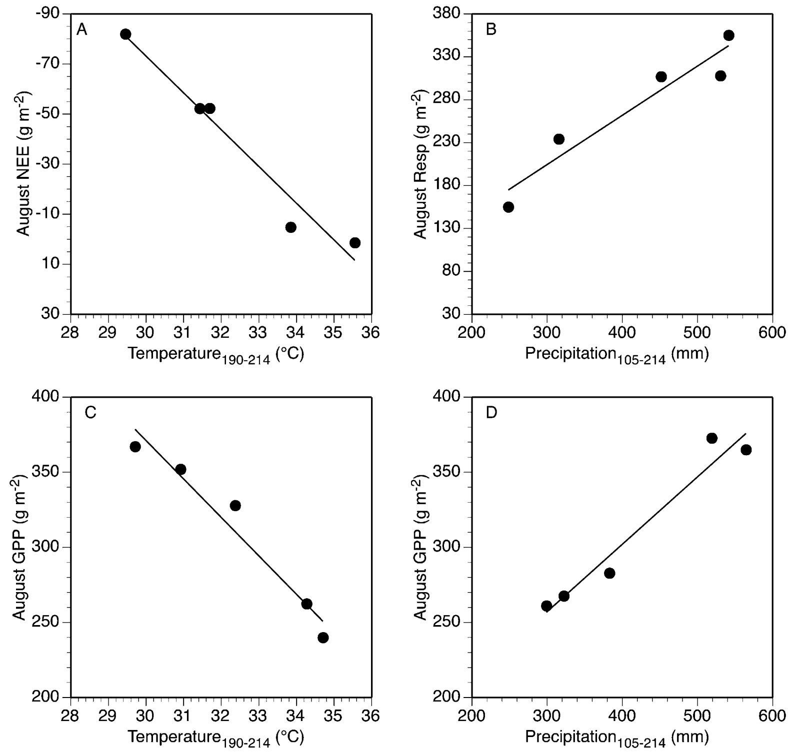

Fig. S5. (*A*) Relationship between August net ecosystem carbon exchange (grams of carbon per square meter) and mean daily maximum air temperature from DOY 190–214. Positive values represent a net efflux of carbon from the ecosystem. (*B*) Relationship between total precipitation from DOY 105–214 and August ecosystem respiration. (*C* and *D*) Partialled relationships between the two critical climate periods and August gross primary production. Data shown are for 2006–2010.

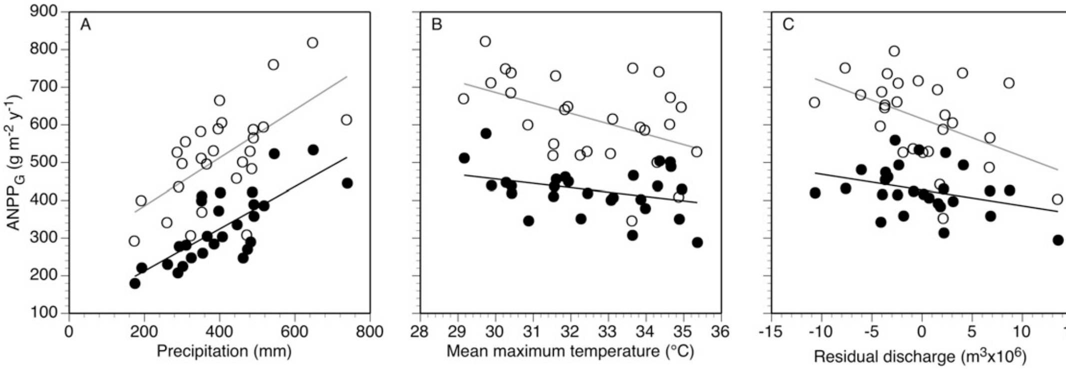

Fig. S6. Partial residual plots over 27 y of ANPP$_G$ and climate indices for uplands (filled circles, black line) and lowlands (open circles, gray line). (*A*) Precipitation from DOY105–214 ($P < 0.001$). (*B*) Mean daily maximum air temperatures from DOY 190–214 ($P = 0.004$). (*C*) Residual discharge after accounting for total precipitation and air temperature during critical periods ($P = 0.003$). Differences between the two landscape positions in the slopes of the relationships between climate and ANPP$_G$ were not significant ($P > 0.2$ for all three climate indices). Model $r^2 = 0.77$.