Critical Climate Period for Net Primary Production in Chihuahuan Desert Ecosystems

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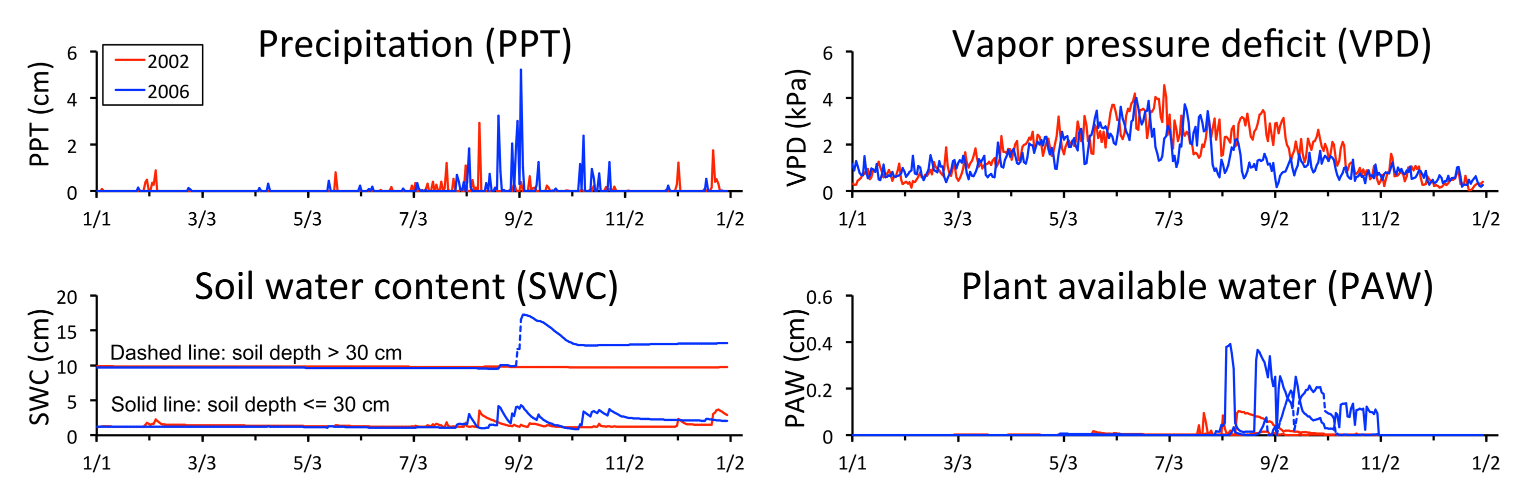
Introduction

In desert ecosystems where water is the main limiting factor, it is expected that net primary production (NPP) is largely determined by precipitation. However, precipitation alone often explains only a small portion of the variation in NPP. We examined the importance of four climate-related variables to patterns in NPP: precipitation (PPT), vapor pressure deficit (VPD), soil water content (SWC), and plant available water (PAW). Our goal was to identify the timing and duration of each variable (i.e., critical climate period) that correlates well to NPP, and to determine the variables that best explain variation in NPP for grasslands and shrublands in the Chihuahuan Desert.

The study site, Jornada Basin USDA-LTER site (32.5N, 106.45W) , is located in the northern Chihuahuan Desert, southern New Mexico, USA. Climate is arid to semiarid with a 96-year average of 25 cm of annual precipitation, of which 53% occurs during the monsoon season (Jul – Sep). Average monthly temperatures range from 6 °C in January to 26 °C in June.

Methods

Three major ecosystem types were examined: upland grasslands, mesquite shrublands, and creosotebush shrublands. Vegetation (aboveground biomass and NPP, 1992-2010), climate (precipitation, air temperature, relative humidity, 1992-2010), and soil texture (by depth) data were collected at three locations for each ecosystem type. VPD was calculated from daily mean temperature and daily mean relative humidity. SWC and PAW were simulated in the process-based SOILWAT model with inputs of daily precipitation, daily minimum and maximum air temperature, monthly herbaceous biomass, soil texture by depth, and other climate variables; and summed by two soil depths (0-30 cm, > 30 cm).



Methods - continued

A sliding-window method was used to delineate 861 climate periods in each growing season (Mar 1 – Oct 1), with window size varying from 15 to 215 days. Daily values of each variable were either accumulated (PPT, SWC, PAW) or averaged (VPD) within a period. The highest correlation coefficient calculated between a variable and perennial grass NPP (or shrub NPP) was used to identify the critical period and the best explanatory variable. A stepwise regression was used to determine the variables that best explain variation in NPP.

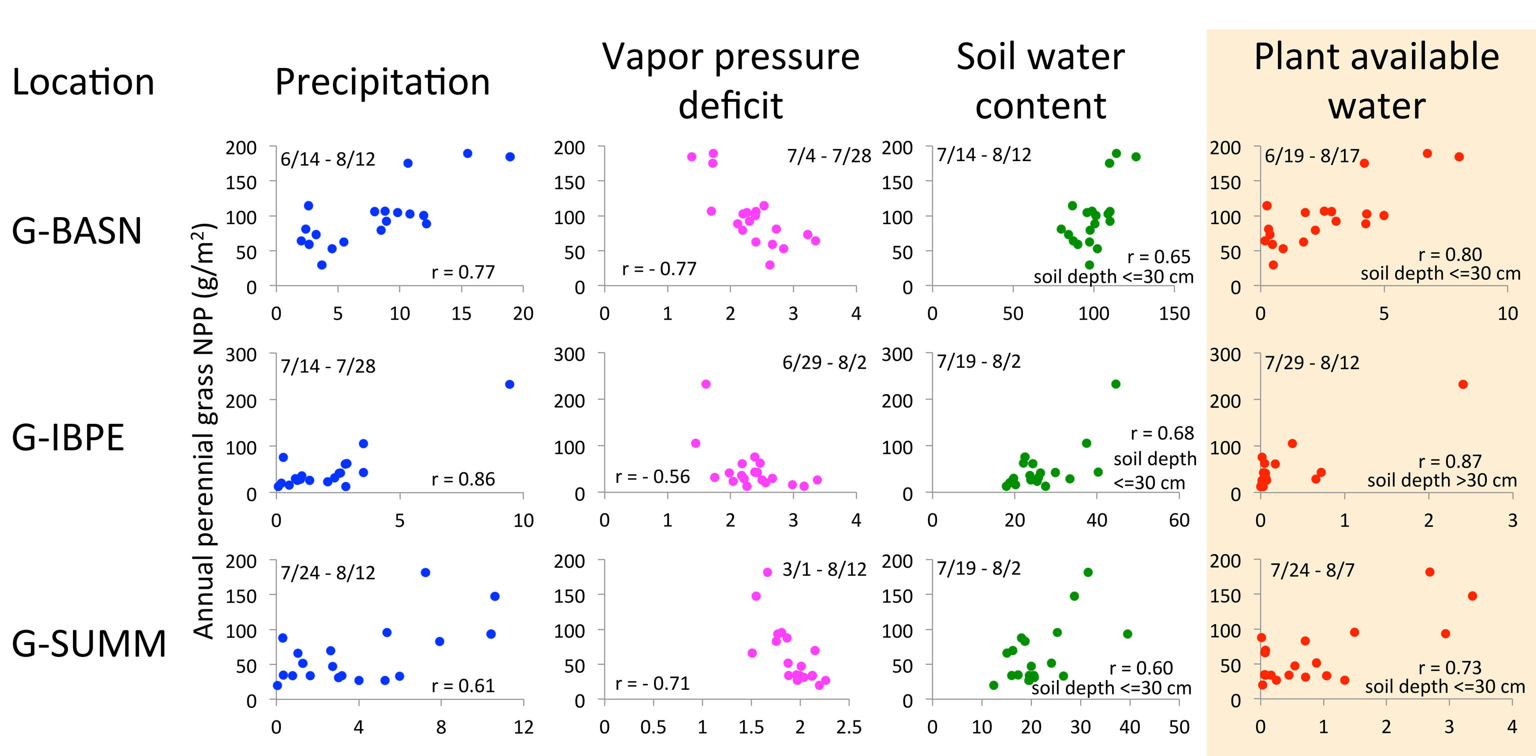
Results - perennial grass NPP, upland grasslands

Plant available water in the shallow soil depth (<= 30 cm) was the best explanatory variable for grass NPP at two locations, and in the deep soil depth (> 30 cm) for the 3rd location. Critical periods (Jul – Aug) fell in the early part of the monsoon season, and were shorter (average = 30 days) than those for shrubs. Including additional variables in the equation improved R^2 by 8 – 26%.

G-BASN: NPP = 58.5 + 15.1***PAW**, $R^2 = 0.63$, $p < 0.0001$

G-IBPE: NPP = 14.9 + 42.6***PAW** + 1.1*PPT, $R^2 = 0.81$, $p < 0.0001$

G-SUMM: NPP = 223.8 + 20.4***PAW** – 93.2*VPD, $R^2 = 0.68$, $p = 0.0001$



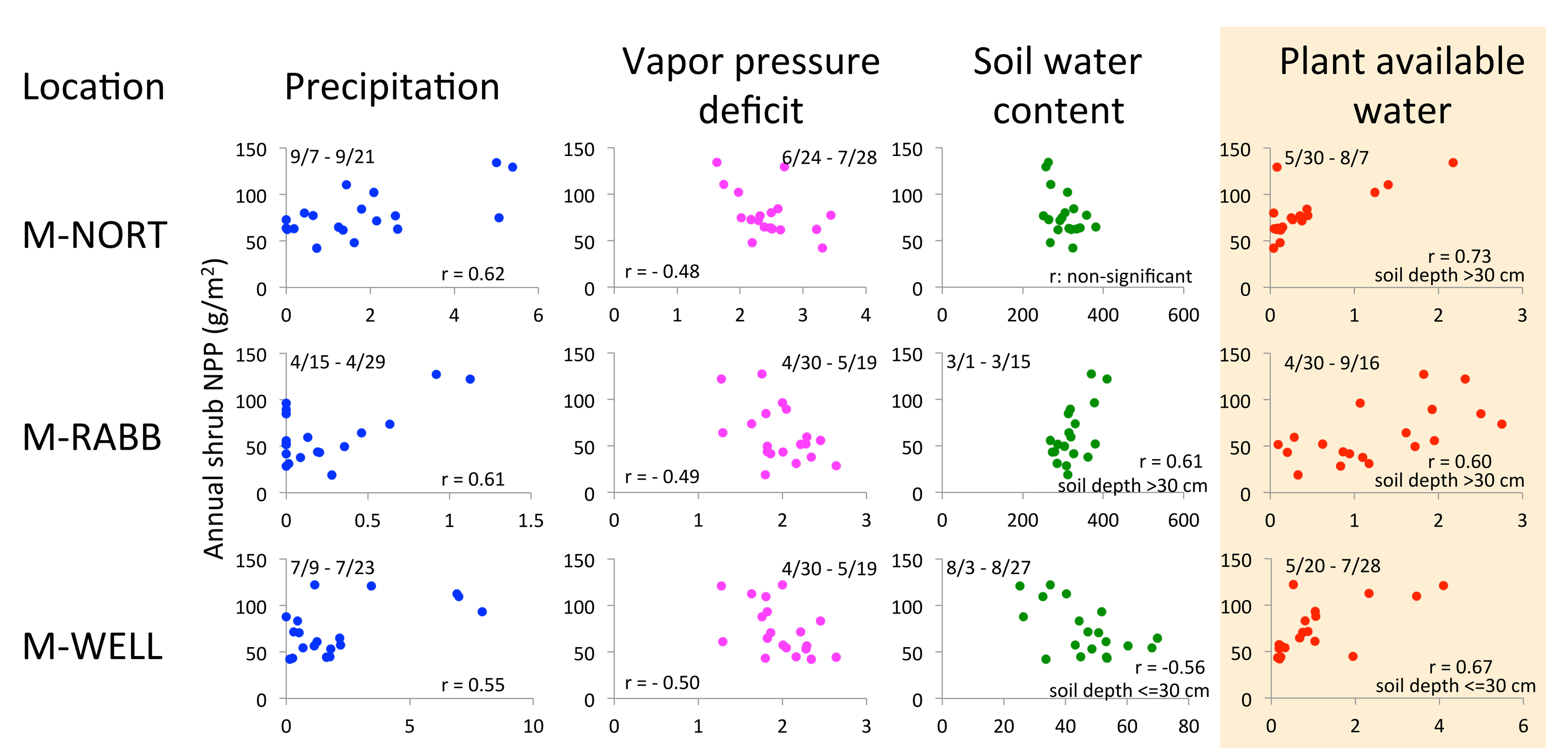
Results - shrub NPP, mesquite shrublands

Plant available water in the deep soil depth (>30 cm) was the best explanatory variable for mesquite NPP at two locations, and in the shallow soil depth (<= 30 cm) for the 3rd location. Critical periods started before the monsoon season, and were longer (average = 93 days) than those for grass NPP or creosotebush NPP . Including additional variables in the equation improved R^2 by 27 – 61%.

M-NORT: NPP = 57.1 + 24.8***PAW** + 0.6*PPT, $R^2 = 0.67$, $p = 0.0001$

M-RABB: NPP = -80.0 + 18.0***PAW** + 0.4*SWC, $R^2 = 0.58$, $p = 0.0009$

M-WELL: NPP = 56.4 + 16.0***PAW**, $R^2 = 0.45$, $p = 0.0018$



Scatterplots of annual perennial grass (or shrub) NPP vs. each variable aggregated during the critical period (N = 19).
The dates at the top of each plot are the beginning and ending dates for the critical period. At each location the variable with the highest correlation with NPP among the four variables is highlighted.

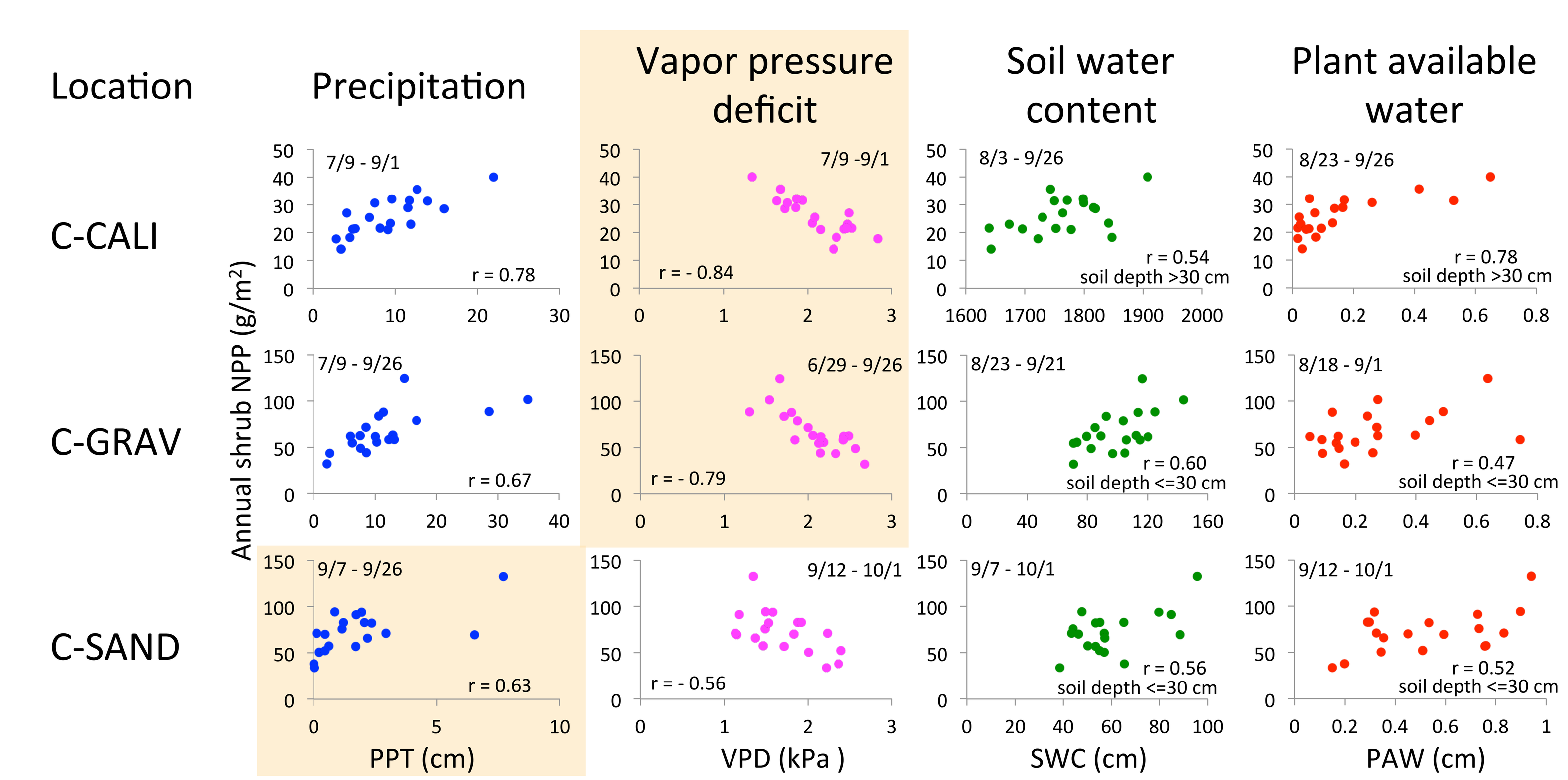
Results - shrub NPP, creosotebush shrublands

Vapor pressure deficit was the best explanatory variable for creosotebush NPP at two locations; PPT was the best variable at the other location. Critical periods fell in the monsoon season, and were longer (average = 55 days) than those for grass NPP but shorter than those for mesquite NPP. Including additional variables did not improve the variation explained.

C-CALI: NPP = 56.1 – 14.3***VPD**, $R^2 = 0.70$, $p < 0.0001$

C-GRAV: NPP = 165.8 – 47.4***VPD**, $R^2 = 0.62$, $p < 0.0001$

C-SAND: NPP = 59.7 + 0.7***PPT**, $R^2 = 0.40$, $p = 0.0039$



Conclusions

Timing and duration of critical climate periods reflect the photosynthetic pathway and growth form of the dominant plant functional group. In grasslands, shallow PAW during the summer monsoon explained variation in NPP whereas deep PAW from spring to fall provided the best explanation for mesquite. In creosotebush shrublands, temperature and relative humidity were better predictors of NPP than PAW. Identifying the critical climate period and the important variables will improve estimates of NPP in grasslands and shrublands.