# Interacting controls on productivity in a northern Great Plains grassland and implications for response to ENSO events

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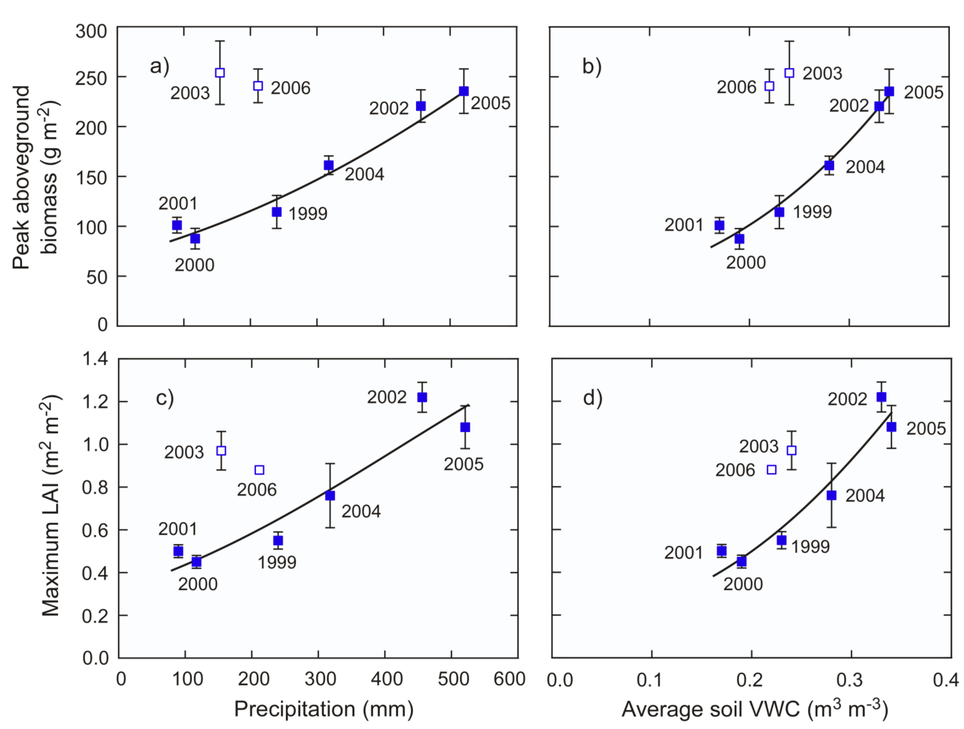
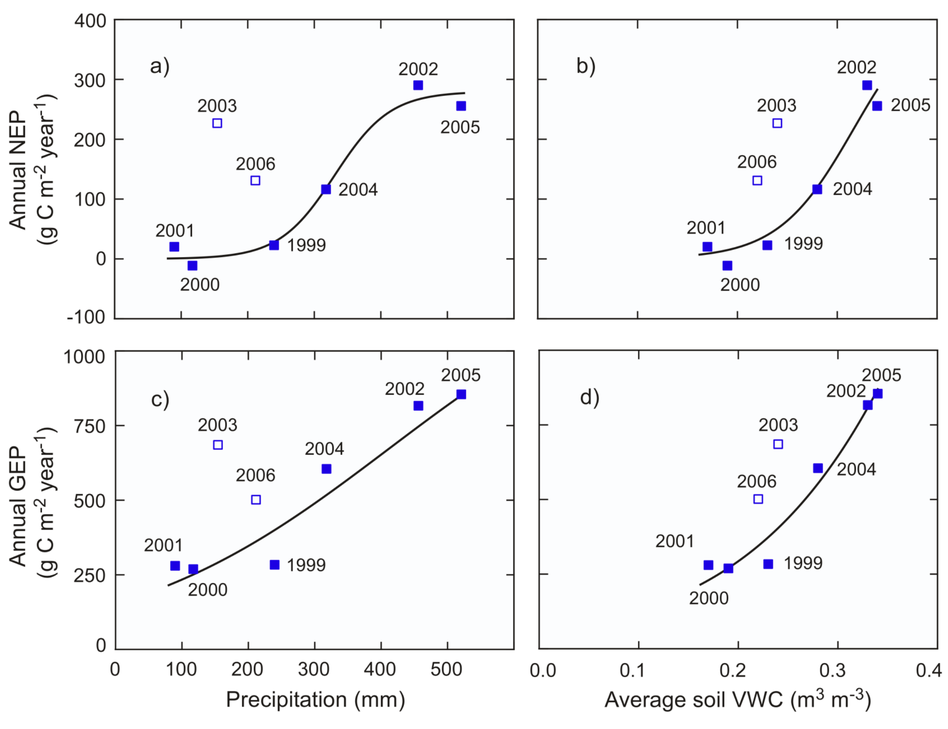
## Introduction

This study investigated the causes of annual variability in peak aboveground biomass, net ecosystem productivity (NEP) and gross ecosystem productivity (GEP) during an eight-year period (1999-2006) in a northern Great Plains mixed grassland near Lethbridge, Alberta. We tested for a relationship between growing season precipitation and productivity, determined whether soil moisture carry-over from the previous fall-winter could alter this relationship, and investigated the interaction between soil moisture and temperature controls on productivity. NEP, evapo-transpiration (ET) and meteorological variables were measured continuously at the site from 1999 to 2006. Live (green) aboveground biomass and leaf area index (LAI) were measured bi-weekly during the growing season, and subsamples of biomass were analyzed for total nitrogen and phosphorus contents. Precipitation data were measured nearby at the Lethbridge airport by Environment Canada. Bimonthly values of the Multivariate ENSO Index (MEI) for 1950 to 2007 were obtained from the National Oceanographic and Atmospheric Administration (NOAA).

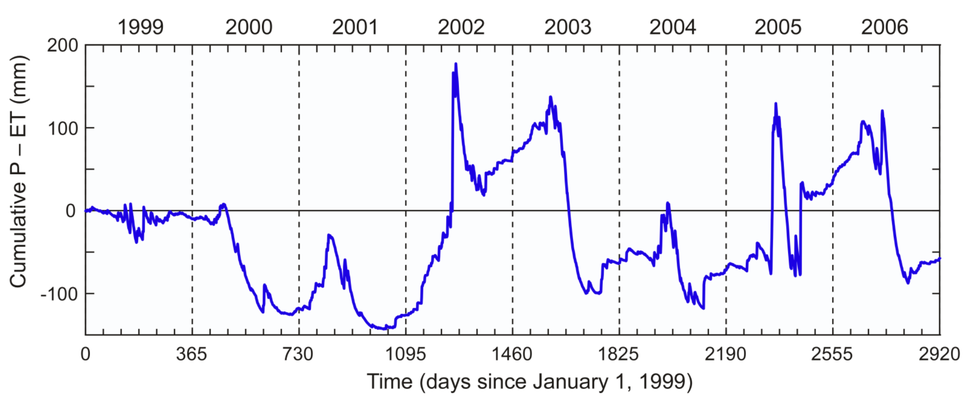
## Precipitation, soil moisture and productivity

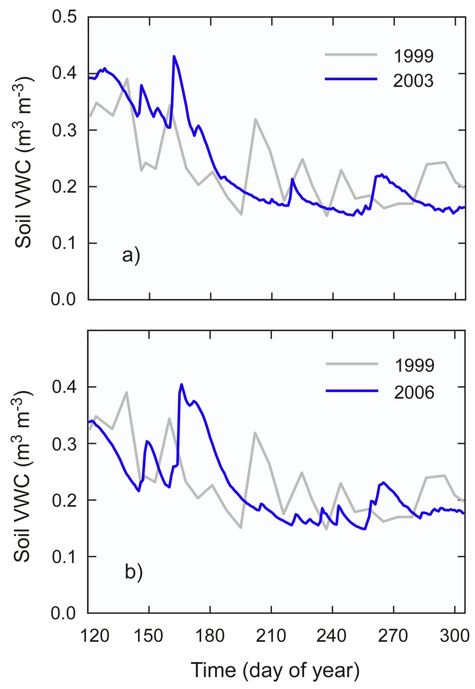
Aboveground biomass, NEP and GEP were strongly related to May-October precipitation, illustrating the basic summer precipitation control on grassland productivity.



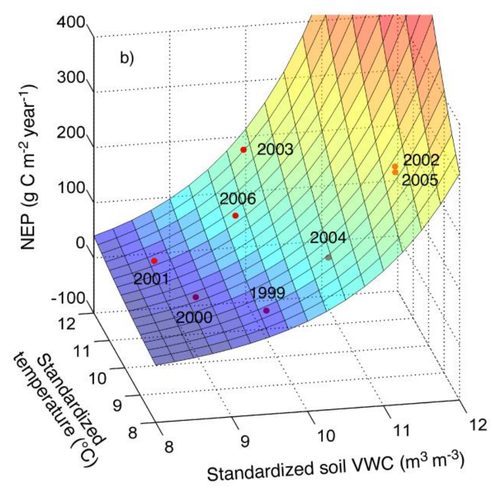



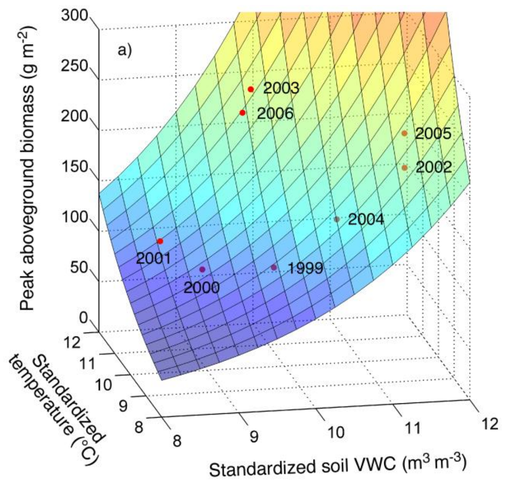

Soil moisture carried-over from the previous fall-winter also influenced productivity in 2003 and 2006. A positive difference between precipitation and evapo-transpiration (P – ET) allowed soil moisture to be carried-over, resulting in soil moisture in 2003 and 2006 that was similar to 1999 (a year with near-normal growing season precipitation), despite lower precipitation in these two years. As a result, 2003 and 2006 had higher productivity than predicted by the relationships observed between precipitation and productivity in other years.

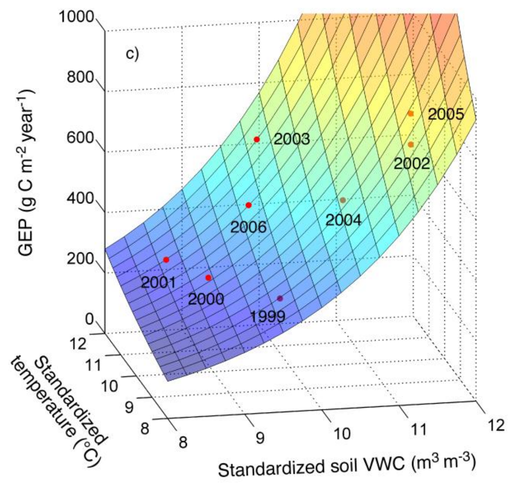



## Soil moisture-temperature interaction and productivity



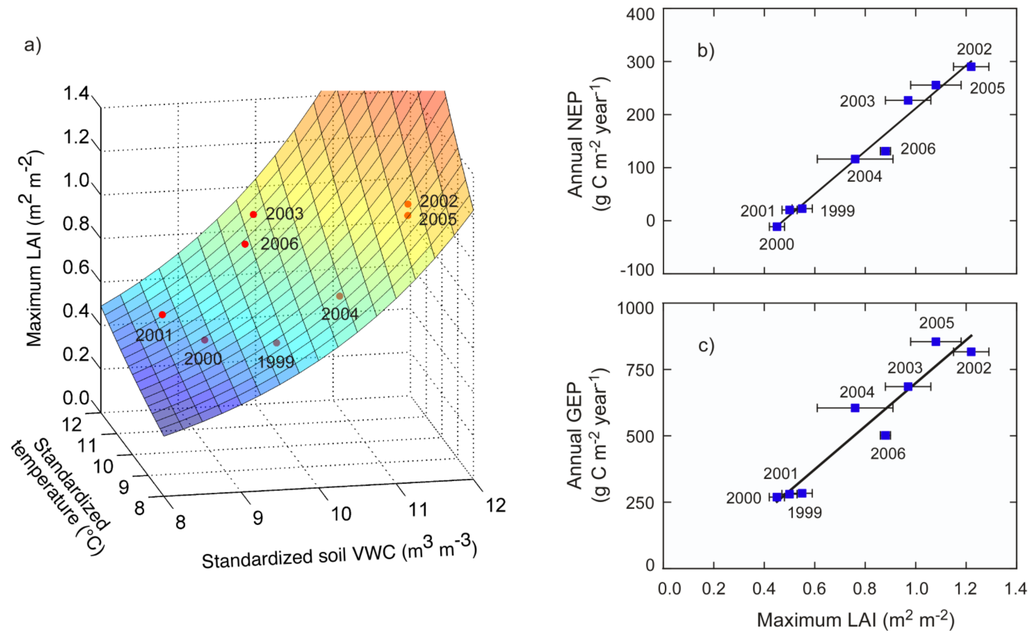




Annual productivity was influenced by a soil moisture-temperature interaction. Adequate soil water content, associated with moisture carried-over from previous years, in combination with higher than average temperatures, resulted in higher productivity in 2003 and 2006 than predicted by observed relationships between productivity and soil moisture alone in other years.

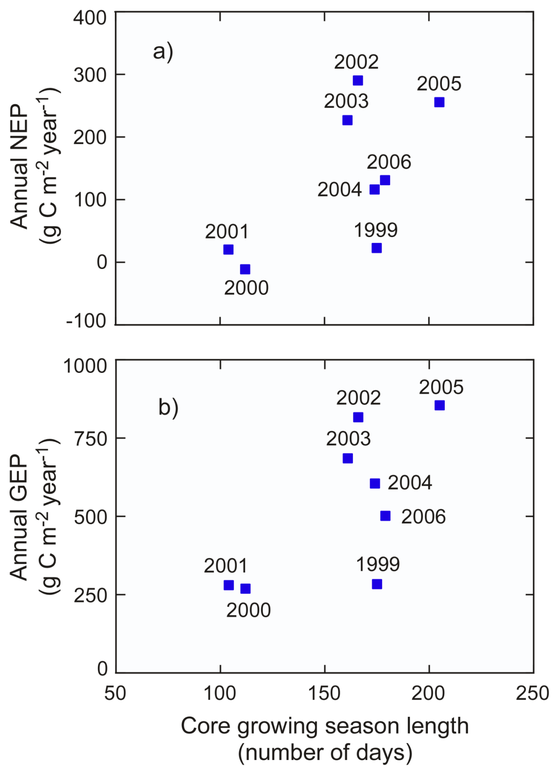
## Soil moisture-temperature interaction and LAI

In general, the interaction between soil moisture and temperature controlled the development of leaf area in the grassland. In turn, variation in peak LAI was strongly correlated with annual NEP and GEP.



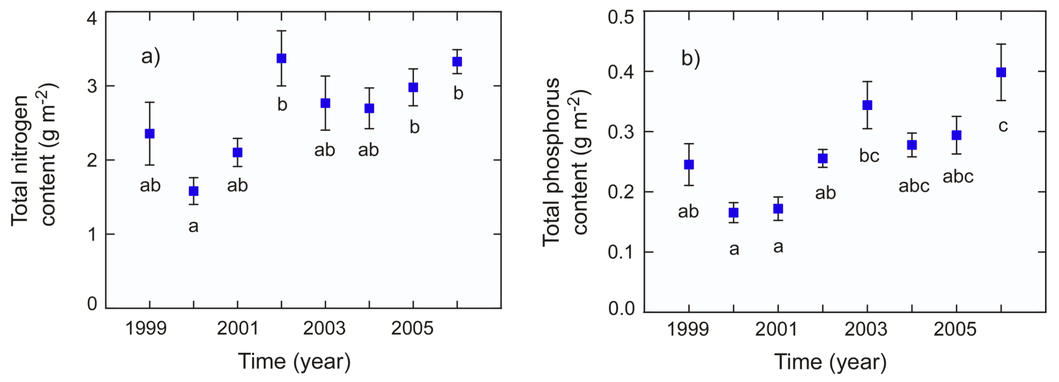

## Growing season length

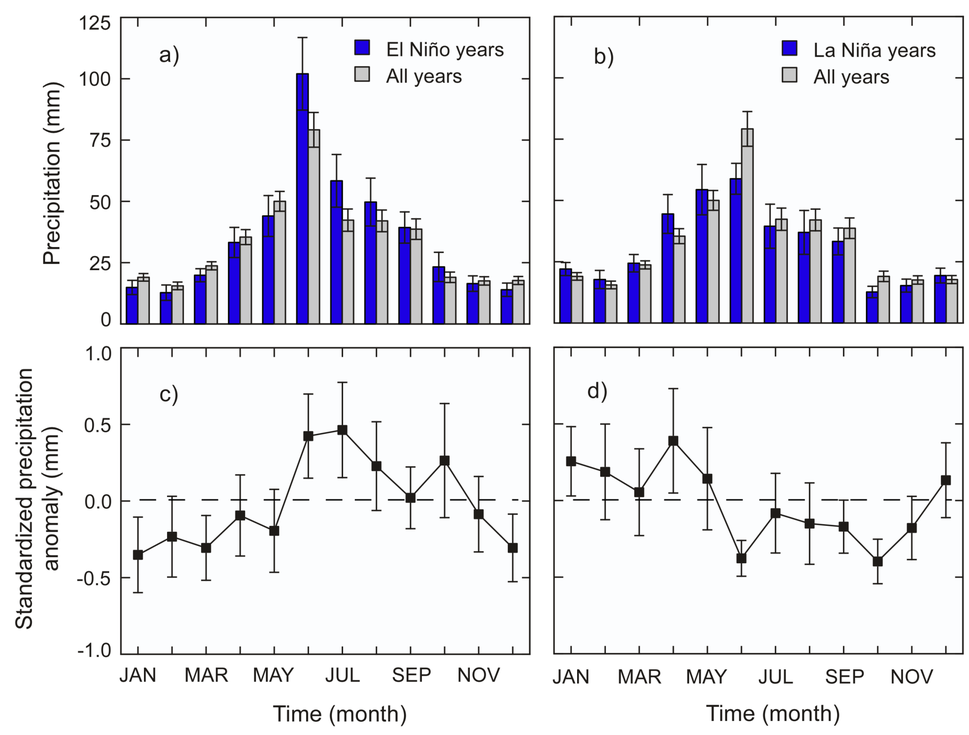
Among study years with average to high productivity, the length of the growing season did not vary by much However, in the two driest years (2000-2001), the drought reduced the length of the growing season by about 70 days.




## Nutrient availability

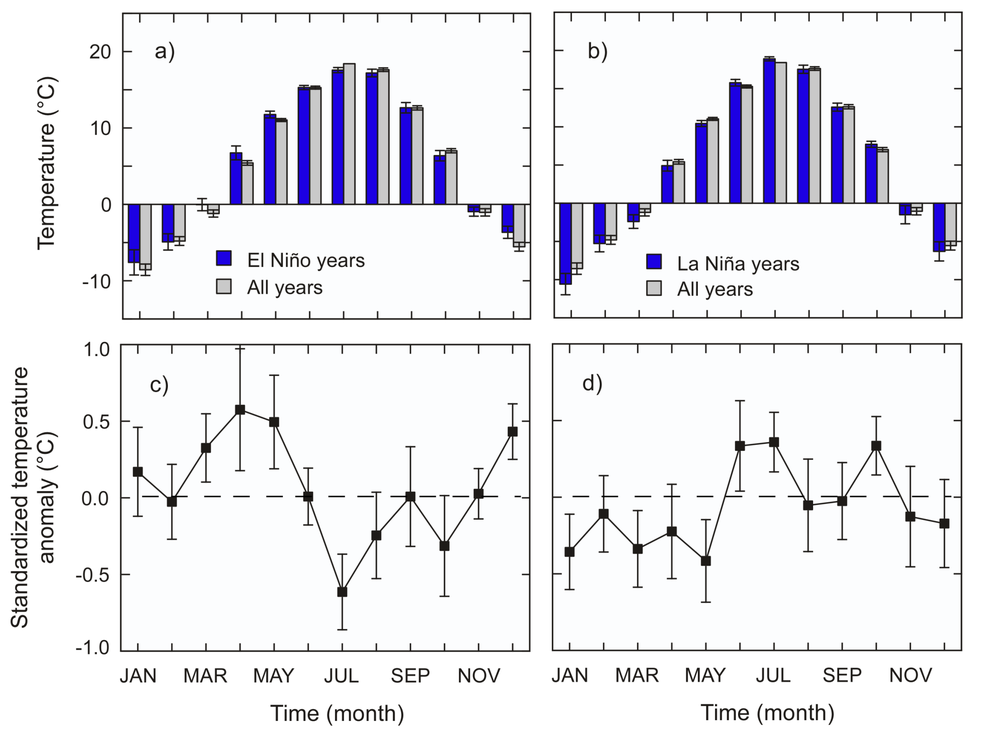
It is possible that relatively high soil moisture, along with warm soil temperatures, could stimulate nutrient cycling processes and contribute additional soil nutrients to the carry-over effect on productivity. However, our estimates of variation in nutrient availability among years (calculated from tissue nutrient content and biomass measurements) showed no significant difference in total nitrogen or phosphorus content between 2003 or 2006 and other study years with high productivity (2002, 2004, 2005).




## ENSO, environmental variation and productivity

Interacting effects of precipitation and temperature on productivity should result in ENSO having a significant influence on ecosystems in the northern Great Plains. We observed cooler and wetter summer months during El Niño conditions than the average for all years from 1950-2007. Summer months associated with La Niña conditions were generally warm and dry relative to the average for 1950-2007. In particular, this effect was observed in June and July, when grassland plants normally undergo their peak rates of growth and development.




Aboveground biomass and ecosystem $CO_2$ uptake were generally higher in years with an average MEI value for April/May to September/October that was greater than zero (i.e. more similar to El Niño conditions), and lower in years with an average MEI value near or below zero (i.e. neutral or more similar to La Niña conditions). However, the two driest years (2000 and 2001) had MEI values near zero, indicating that La Niña and the ENSO cycle were not the primary cause of the low precipitation and warm temperatures apparent in those particular years.