Modeling the Climate and Hydrological Controls of the Expansion of an Invasive Grass Over Southern Arizona

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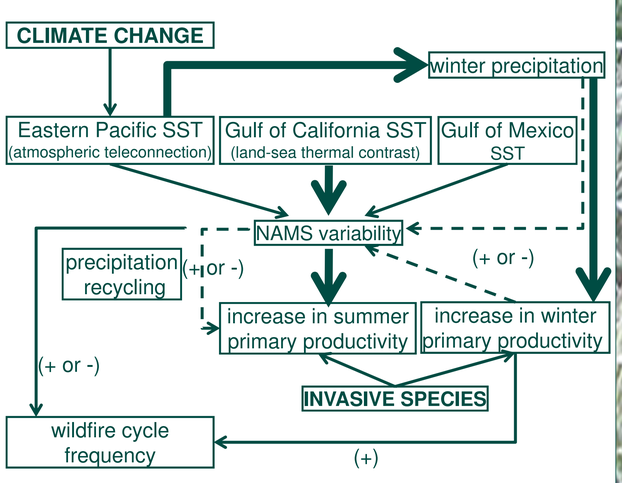
INTRODUCTION

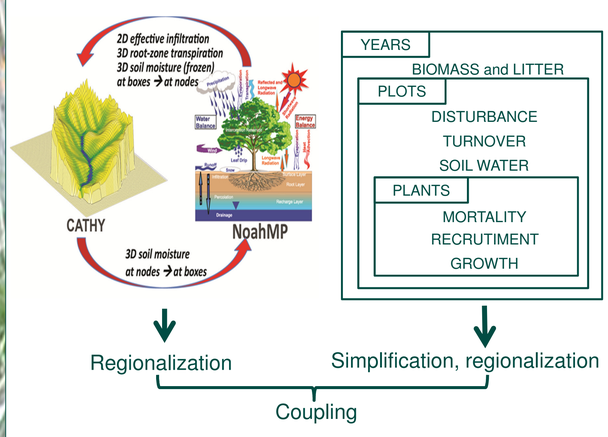
- Moisture source for the North American Monsoon (NOAA)

- Climate-biosphere interactions in the North American Monsoon System

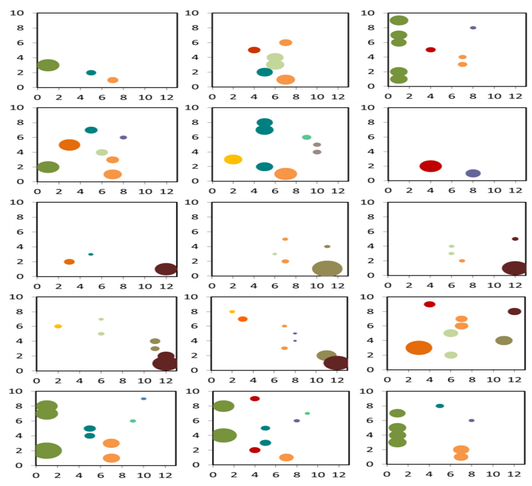


MODELS

- Coupled land surface and hydrology model
  NoahMP-CATHY (Niu et al. 2013)
- Vegetation model
  ECOTONE (Peters 2002)



- ECOTONE: an individual based dynamic vegetation model (Peters 2002)

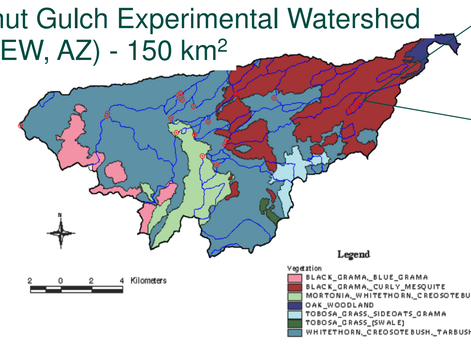


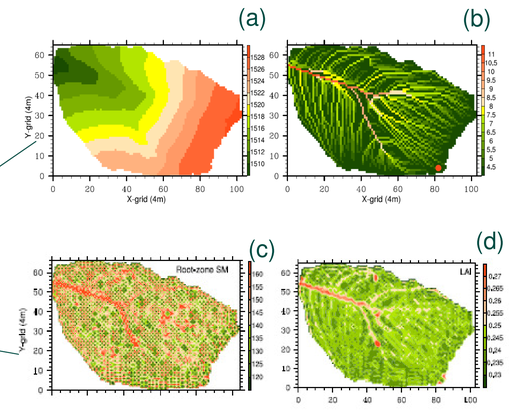
An example of landscape of 15 plots in ECOTONE. Horizontal axis: species index, vertical axis: individual plants' index. Marker size is proportional to biomass, colors indicate different species.

STUDY SITES IN THE SOUTHWEST

- Santa Rita Experimental Range (SRER, AZ) - 200 km²
- Jornada LTER (NM) - 800 km²
- Kendall catchment in WGEW (0.1 km²)

- Walnut Gulch Experimental Watershed (WGEW, AZ) - 150 km²





Elevation model (a), upstream area (b), soil moisture (c) and leaf area index (d) at 4 m resolution (Niu et al, 2013, Ecohydrology)

GOALS

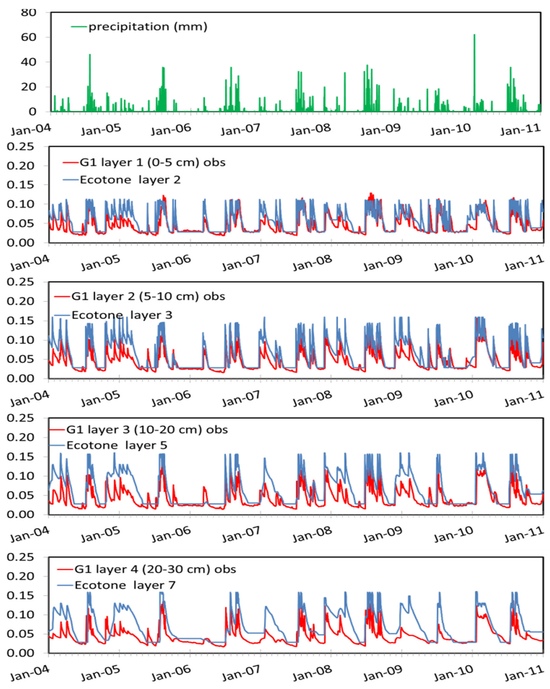
- Create a multi-level modeling framework for understanding the climate-biosphere interactions of North American Monsoon System
- Couple an individual based, dynamic vegetation model (ECOTONE) to a regional climate model to include vegetation feedbacks
- Modify and integrate climate, land surface and vegetation models to operate at 1 km scale
- Design the model to help with understanding the spread of invasive species and their effect on wildfire regimes

RESEARCH PLAN

- Model vegetation change at Kendall catchment (ECOTONE+NoahMP/CATHY) to understand the causes of vegetation change at the site
- Model spread of Lehmann lovegrass and buffelgrass at Santa Rita ER (ECOTONE+NoahMP) to invasion of non-native grasses at the site
- Compare the spread of Lehmann lovegrass at SRER and Jornada LTER (ECOTONE+NoahMP) to understand the causes of the differences in its distribution at the two sites

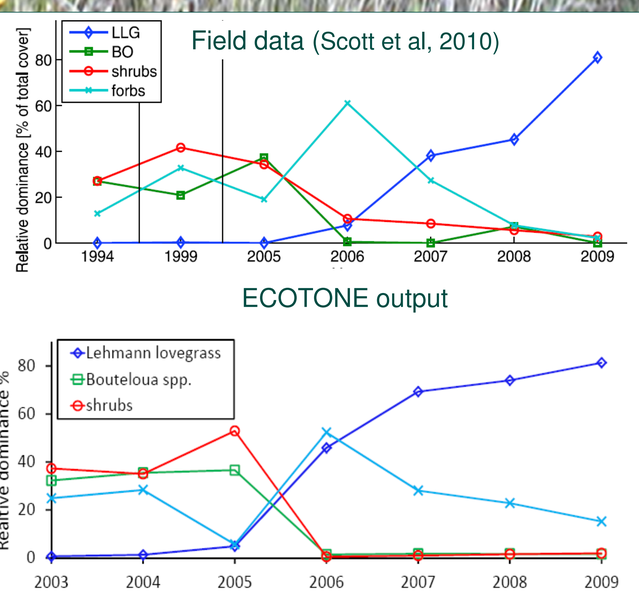
RESULTS AND PROGRESS

- Used site characteristics and weather data from the Santa Rita Experimental Range (SRER) to modify ECOTONE for SE Arizona
- Sensitivity tests indicate that on the plot scale, the biomass and species distribution are sensitive to initial conditions
- Found that the key parameters that influence the effects of climate change are water use efficiency, photosynthetic pathway type (C3/C4) and root distribution
- Comparison with measurements from SRER lead to the conclusion that ECOTONE's soil water sub-model has to be replaced with that of NoahMP-CATHY



Comparison of soil moisture outputs of AZ regional ECOTONE with measurements at the Santa Rita Experimental Range (SRER).

- Used site characteristics, vegetation, and weather data from the Kendall catchment site to simulate vegetation change (Scott et al, 2010) at the site
- Drought caused the decline of native vegetation and the spread of the invasive Lehmann lovegrass, which has higher seed survival and establishment rate in dry years
- Lovegrass-dominated ecosystems are less effective at using precipitation pulses than native species (Huxman et al., 2004)



COUPLED NoahMP-CATHY

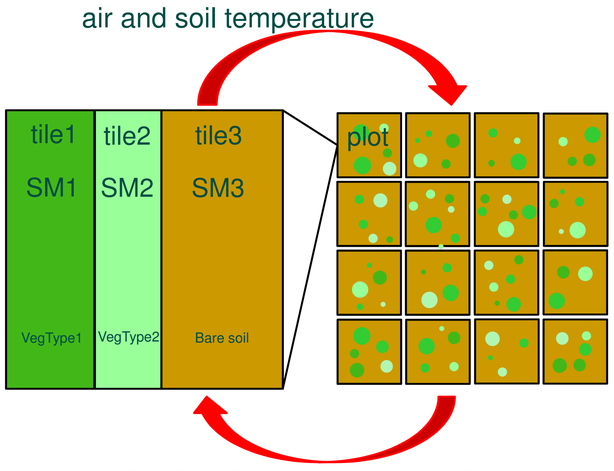
Abiotic environment: available soil moisture air and soil temperature

NoahMP-CATHY

Structure: Grid cells (1km²) / tiles

Input: vegetation type, soil type, climatic forcing

Output: Surface energy, water and carbon fluxes



ECOTONE

Structure: Landscape / plots (1-100m²)

Input: soil moisture, temperature, seed germination and establishment prob.

Output: biomass and species distribution

Vegetation feedbacks: Biomass, root distribution in soil layers, vegetation fraction and cover, litter, leaf area index

NEXT STEPS

- Complete coupling of ECOTONE with NoahMP-CATHY
- Perform additional sensitivity analysis with atmospheric forcing over the NAM region and improve the coupled models
- Study the effect of rainfall and soil moisture redistribution on the distribution of species and biomass
- Study the effect of wetter soil over lowland areas, which may buffer the impacts of climate change

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