Incorporating grazing into an eco-hydrologic model: Simulating coupled human and natural systems in rangelands

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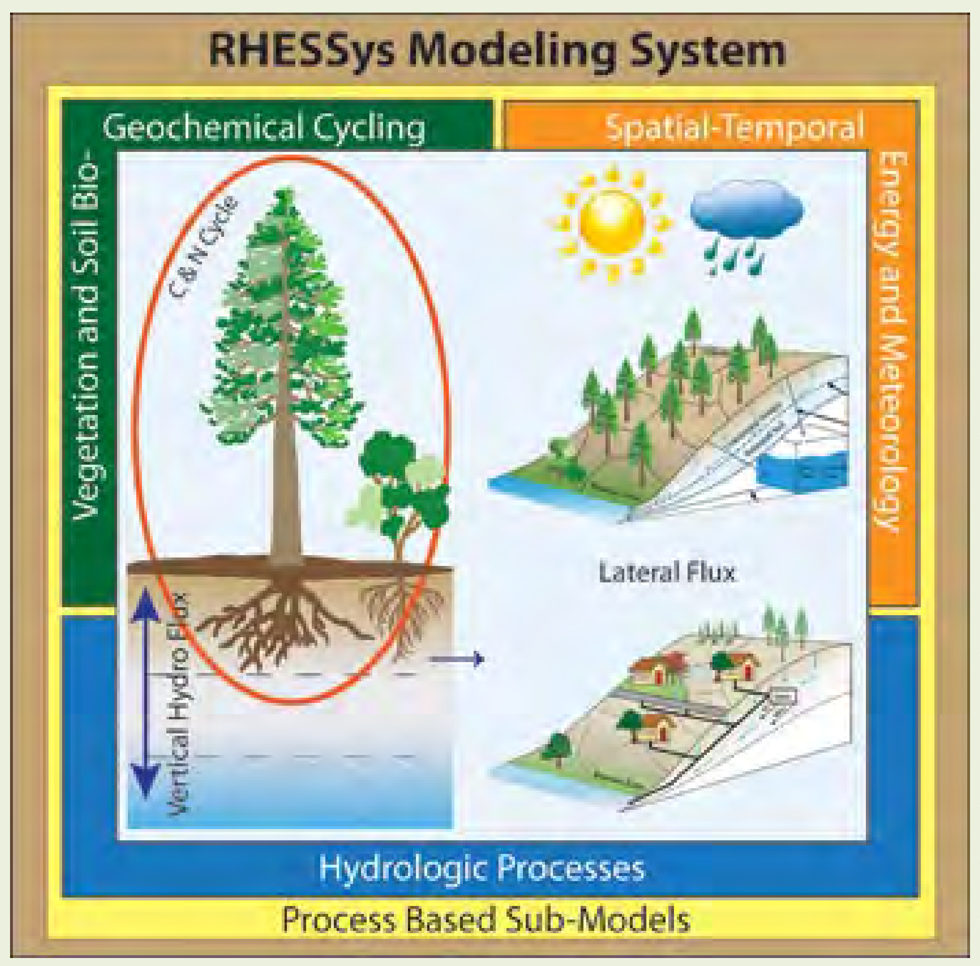
Introduction

Rangelands comprise at least one-third of the Earth's land surface and provide myriad of ecosystem services (e.g. biodiversity conservation, soil carbon (C) storage), and support for livestock (White et al., 2000). Capturing the interactions among water, C, and nitrogen (N) cycles within the context of regional-scale patterns of climate and management is important to understand feedbacks between human and natural systems, as well as provide relevant information to stakeholders and policymakers (Adam et al., 2013).

The *overarching objective* of this research is to investigate the coupled feedbacks between human activities and climate change on the structure and function of rangeland ecosystems by incorporating management into an eco-hydrologic model. The *specific objectives* of this study are to: **(1) develop methods for determining grazing losses, (2) implement an allocation strategy of carbon for grasses, and (3) explore sensitivity of grazing effects on biomass.**

Model Description

Regional Hydro-Ecologic Simulation System | RHESSys



RHESSys is a process-based model that simulates hydrology and biogeochemical cycling at the catchment/watershed scale (Tague and Band, 2004).

A spatially distributed hydrology model is fully coupled with dynamic soil and vegetation models with C and N cycling.

- ❖ A unique feature of RHESSys is its hierarchical landscape representation. Climate, soil, vegetation, and management can each be represented as distinct spatial patterns at different levels.
- ❖ Spatial heterogeneity is represented by inter-linked "patches" and there is lateral transport of water and nutrients among them.
- ❖ The following model parameters are used our evaluation of grazing impacts on biomass:

Model parameter	Description
pa and pb	Controls decay constant and froot, f(LAI)
% to storage (non-structural carbohydrates)	Allocates certain amount of new NPP to storage for current year (i.e. available reserves).
% allocated daily	Allocates certain percentage to daily growth instead of saving for next year's growth.

Methods

1 | Grazing intensity

CP (crude protein)

ADF (acid detergent fiber) (cellulose, lignin)

Forage quality

Grazing intensity (ha/AUM)

Body weight

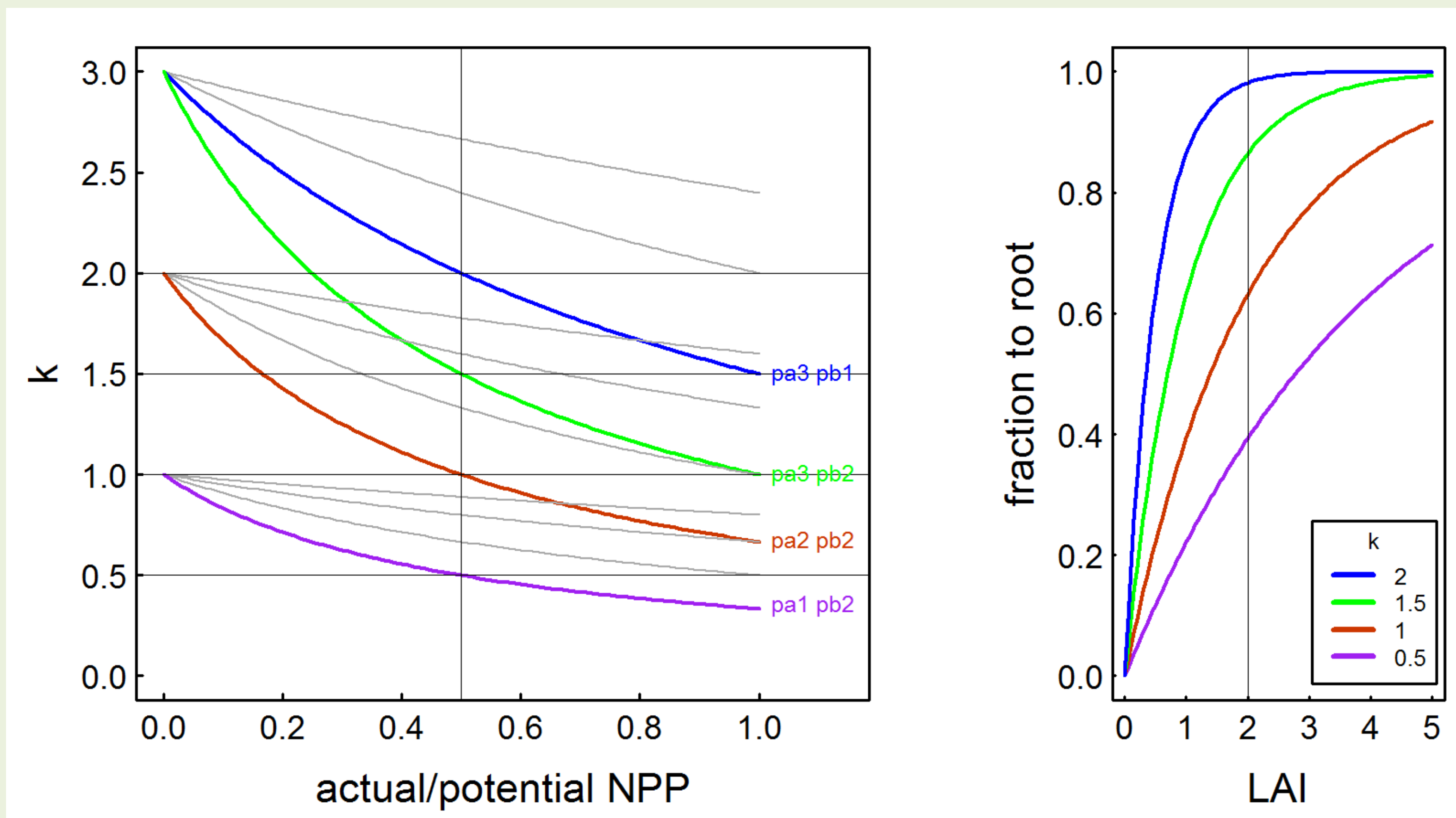
Livestock characteristics

Dry matter intake (kg/cow/day);
all-forage diet equation (NRC, 1996)
Total biomass lost due to grazing

Time series of daily biomass C removed (kg C/m2/ha)

2 | Carbon allocation

- ❖ We developed an allocation scheme based on resource limitation and and growth using net primary production (NPP) and leaf area index (LAI) as proxies, respectively.
- ❖ Grasses that are completely stressed (actual/potential NPP=0) have larger k values and allocate more to roots. Ecophysiologically, plants will allocate resources most efficiently when resource-limited.

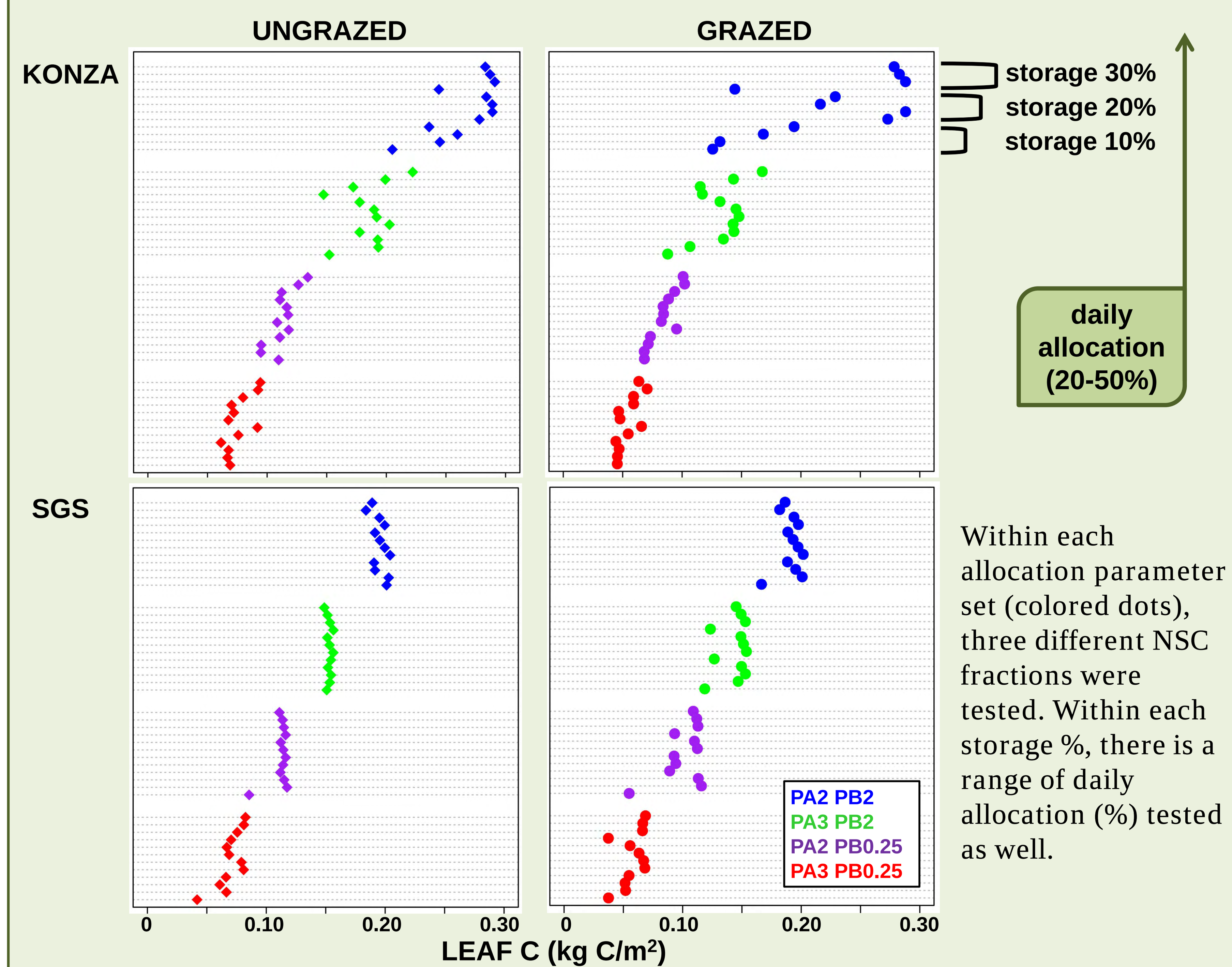


Site description

	Konza (Kansas)	Shortgrass Steppe (SGS)
Location	Kansas, USA	Colorado, USA
Elevation	1660m	4oom
Climate	Humid temperate	Dry temperate
Mean annual precipitation	332 mm	859 mm
Vegetation	Tallgrass prairie (C4) *Andropogon gerardii*	Shortgrass steppe *Bouteloua gracilis*
Management	Variable burning and grazing treatmings at sub-watershed scale	Grazing

Results

Dot plots were created showing sensitivity analyses of mean aboveground biomass for two different sites, Konza and SGS, both grazed and ungrazed. The following parameters were evaluated: *fraction of NPP allocated daily, fraction allocated to non-structural carbohydrate (NSC) pool, and allocation equation coefficients.*



Within each allocation parameter set (colored dots), three different NSC fractions were tested. Within each storage %, there is a range of daily allocation (%) tested as well.

- ❖ Allocation equation coefficients (colored dots) partition ungrazed and grazed leafC similarly.
- ❖ LeafC values are more sensitive to changes in fraction daily allocated in all but the SGS ungrazed site.
- ❖ For both sites, grazed conditions typically increased the range of leafC for a given set of parameters.

Conclusions

- ❖ For both ungrazed and grazed situations, parameters pa and pb can be used to calibrate the model to match general aboveground biomass observations.
- ❖ Differences in vegetation and climate may explain the more pronounced sensitivity of biomass to different parameters.
- ❖ From an ecophysiological standpoint, the aforementioned parameters mimic plants' response to defoliation by allocating more daily due to environmental or physical stresses (like grazing).
- ❖ Based on the environment and species, these can act as a "buffer" to grazing in simulations.

References

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