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

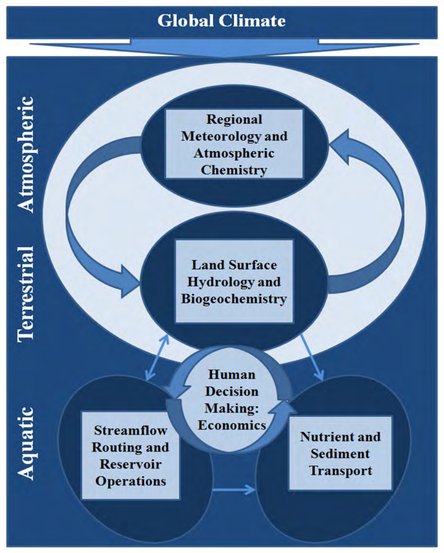
J.J. Reyes[1], M. Liu[1], C.L. Tague[2], J.S. Choate[2], R.D. Evans[3], K.A. Johnson[4], J.C. Adam[1]

(1) Department of Civil and Environmental Engineering, Washington State University, Pullman, WA
(2) Bren School of Environmental Science and Management, UC Santa Barbara, Santa Barbara, CA
(3) School of Biological Sciences, Washington State University, Pullman, WA
(4) Department of Animal Sciences, Washington State University, Pullman, WA

Introduction

Grasslands, managed and unmanaged, provide us an opportunity to investigate the coupled feedbacks between human activities and natural ecosystems. These areas comprise at least one-third of the Earth's surface and provide support for livestock (White et al., 2000). Capturing the interactions among water, carbon, and nitrogen cycling within the context of regional-scale patterns of climate and management is important to understand interactions 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 impacts of human activities and climate change on the structure and function of grassland ecosystems by incorporating management into an eco-hydrologic model. The *specific objectives* of this study are to: (1) determine biomass lost due to grazing, (2) determine an allocation strategy of carbon for grasses, and (3) explore impacts of grazing on biomass.



BioEarth

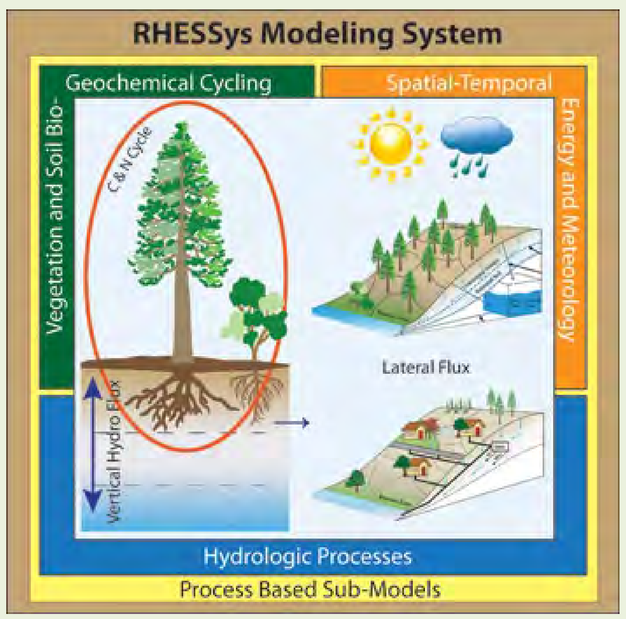
- BioEarth is a regional Earth systems modeling framework that couples carbon, nitrogen, and water.
- The regional scale is relevant for better informing stakeholders on management of agricultural and natural resources.
- This research supports the terrestrial component of BioEarth and looks at forage quality and quantity over rangelands.
- Other terrestrial landscapes include forests and croplands.

http://www.cereo.wsu.edu/bioearth

Model Description

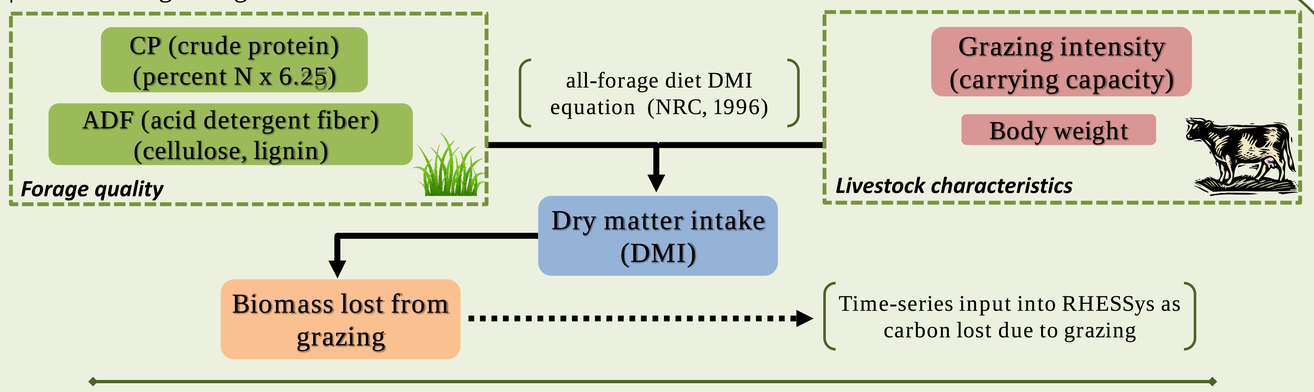
- RHESSys is a process-based model that simulates hydrology and biogeochemical cycling at the catchment/watershed scale (Tague and Band, 2004)
- RHESSys fully couples a spatially distributed hydrology model and dynamic soil and vegetation model with carbon and nutrient cycling.
- A unique feature of RHESSys is the hierarchical landscape representation. Climate, soil, vegetation, and management can be represented as different layers each with different spatial patterns.
- Spatial heterogeneity is represented by inter-linked "patches" and there is lateral transport of water and nutrients among them.

Regional Hydro-Ecologic Simulation System | RHESSys

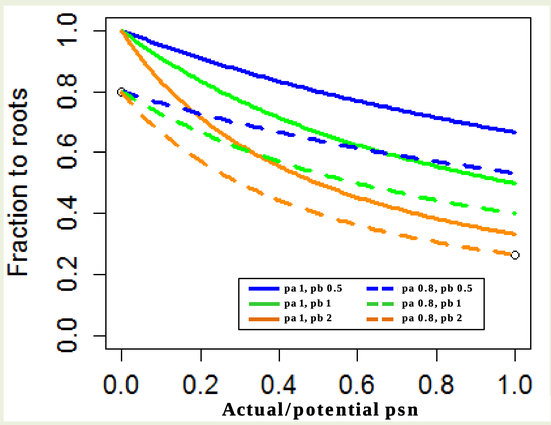


Results and Discussion

1 | Determine grazing losses



2 | Carbon allocation strategy



- Allocation of net primary productivity (NPP) to leaves and roots is determined after respiration costs, storage pool allocation, and turnover rates.
- Allocation of NPP to leaf C and root C is determined with the following:

$$\text{Fraction to root} = \frac{pa}{1+pb*\frac{actual}{potential}}$$

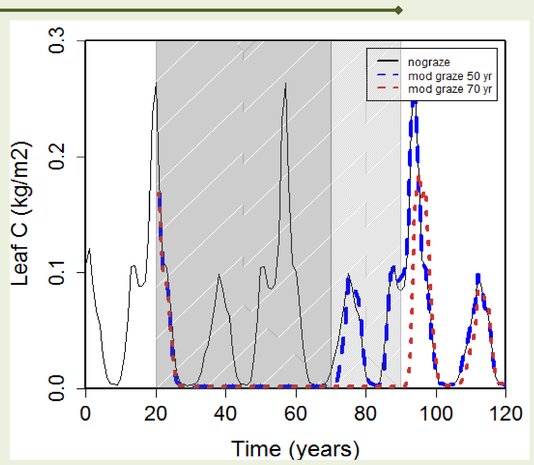
where actual and potential refer to photosynthesis by the plant (Landsberg and Waring, 1997). Fraction to leafC is (1-frootC).

- Parameter **pa** controls the maximum amount allocated to roots if the plant is completely resource limited, while **pb** controls the eccentricity of the hyperbolic function.

3 | Effects of grazing on biomass


Curlew Valley, Utah

- Grazing intensity (# animals/acre) can be simulated.
- Time to recovery for 50-yr and 75-yr dependent on biomass if no grazing were occurring.
- Biomass recovery for longer grazing periods does not reach previous peaks in short-run.



Conclusions

- Vegetation type and availability determine the DMI (kg/day/cow). Along with the grazing intensity, both will influence the grazing carbon lost each day.
- Analysis of the Waring allocation scheme for grasses will be performed by comparing observed and modeled NPP and biomass values.
- After longer periods of grazing, biomass may not reach previous peaks until a later time. However, better simulation of grass re-growth after defoliation must be included in RHESSys.

References

Adam et al. 2013. (In review). BioEarth: A regional biosphere-relevant Earth system model to inform agricultural and natural resource management decisions. *Climatic Change*.

Landsberg, J.J. & Waring, R.H. 1997. A generalised model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance and partitioning. *Forest Ecology and Management*, 95.

National Research Council (U.S.). 1996. *Nutrient requirements of beef cattle*. Washington, DC: National Academy Press.

Tague , C.L. & Band, L.E. 2004. RHESSys: Regional hydro-ecologic simulation system: An object-oriented approach to spatially distributed modeling of carbon, water, and nutrient cycling. *Earth Interactions*, 8.

White, R., Murray, S., & Rohweder, M. 2000. *Pilot analysis of global ecosystems: Grassland ecosystems*. World Resources Institute, Washington, DC.

Acknowledgements

This research is made possible by funding from the US Department of Agriculture, National Institute of Food and Agriculture (BioEarth; grant #2011-67003-30346), the National Science Foundation (IGERT NSPIRE; grant#0903714), NSF Graduate Research Fellowship Program.