Spatially Explicit Modeling of Grazing Effect on Soil Organic Carbon Change in the Green River Basin, Wyoming

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Introduction

The Green River Basin (GRB) in Wyoming is managed primarily by the Bureau of Land Management (BLM). Little research has been done in this area to investigate impacts of range management and climate change on carbon dynamics. Using remotely sensed data and a biogeochemical model Erosion- Deposition-Carbon-Model (EDCM) [1], we estimated the soil organic carbon dynamics in the area and the grazing effect on the ecosystem.

Site Description

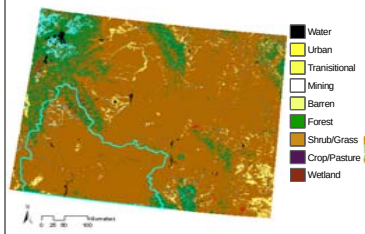

Figure. 1. Wyoming National Land Cover Data (NLCD) 2001 map

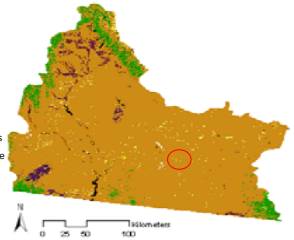

Figure 2. GRB NLCD 2001 and research area (red circle)

GRB is located in southwestern Wyoming. Most of the area is sagebrush grassland (> 80%). The dominant vegetation is Wyoming big sagebrush. Annual precipitation ranges from 150 to 500 mm. Mean monthly temperature varies from -8 to 17°C. The growing season starts in April and ends in October.

Methods

~ Moderate Resolution Imaging Spectroradiometer (MODIS) Net Primary Productivity (NPP) 2000 – 2004 average [1] was used for constraining the NPP of grass and sagebrush in the model.

~ Parameterization of grassland was from literature [3], and parameterization of sagebrush was based on local observation from University of Wyoming [4].

~ Spinning-up model runs of 200 years were used to get the initial conditions.

~ Two grazing scenarios were simulated:

Scenario I: 10 percent removal of aboveground live biomass (grass), 3 percent removal of leaves and fine branches (sagebrush).

Scenario II: 30 percent removal of aboveground live biomass (grass), 5 percent removal of leaves, fine branches (sagebrush).

Grazing intensity was derived from USDA livestock statistics from 1975 to 2006 in five counties inside the GRB [5].

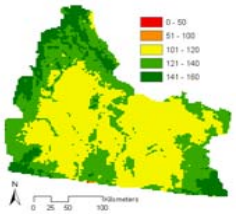

Figure. 3. MODIS NPP average 2001-2004 in GRB

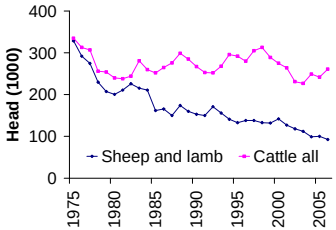

Figure. 4. GRB live stock change from 1975 to 2003 (USDA NASS)

Model Simulation and Results

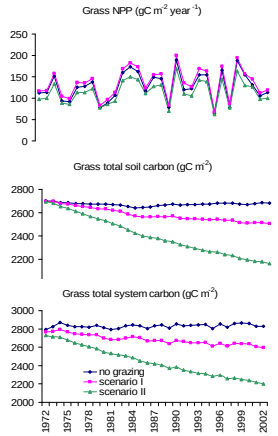

Figure 5. Simulation on NPP, total soil organic carbon and total ecosystem carbon change of grass under different grazing treatment

Grassland is carbon neutral under the no grazing condition. Production increases under grazing Scenario I but decreases under grazing Scenario II.

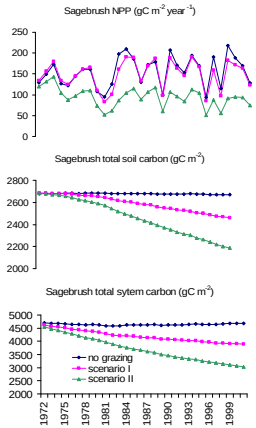

Figure 6. Simulation on NPP, total soil organic carbon and total ecosystem carbon change of sagebrush under different grazing treatment

Sagebrush also is carbon neutral under the no grazing condition. Sagebrush carbon stock decreases faster under Scenario I than grass.

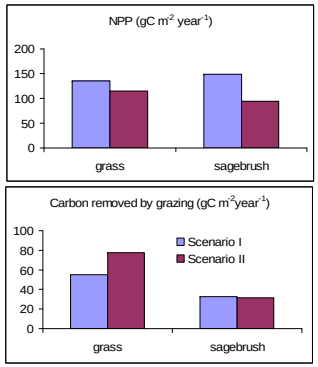

Figure 7. Comparison of NPP and grazing removed carbon under Scenarios I and II on grass and sagebrush

Sagebrush had less carbon removed than grass with similar NPP. Grass production is less effected by grazing than sagebrush.

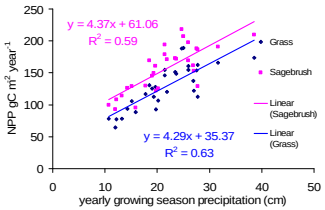

Figure 8. Correlation between simulated yearly NPP and growing season precipitation

The yearly NPP for both sagebrush and grass are highly correlated with growing season precipitation ($p < 0.05$).

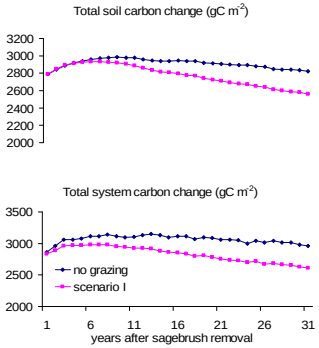

Figure 9. Simulated impacts of grazing on soil carbon and total system carbon change after conversion of sagebrush to grass

Simulated soil carbon and ecosystem carbon increase for about 6-7 years after shrub removal but decrease in the long term. Grazing will enhance soil carbon loss.

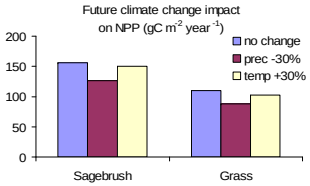

Figure 10. Simulated NPP change of sagebrush and grass response to future climate change

Both sagebrush and grass production are more sensitive to precipitation than temperature change in the future. Sagebrush is more temperature tolerant than grass.

Conclusions

~ No grazing led to little change in ecosystem carbon stock under both sagebrush and grass. Grazing had a larger impact on a sagebrush system than on a grass system, and Scenario II turned both systems from carbon neutral to carbon sources.

~ The carbon cycling is water limited. Projected decrease of precipitation in the future may alter the system from carbon neutral (natural systems) to a carbon source.

~ Transforming shrub to grassland may enhance the soil carbon sequestration in about 6 -7 years but will likely lose carbon in the long run, consistent with other studies [6][7].

Reference:

[1] Liu, S., N. Bliss, E. Sundquist and T.G. Huntington, 2003. Modeling carbon dynamics in vegetation and soil under the impact of soil erosion and deposition. *Global Biogeochemical Cycles*, Vol. 17, No. 2, 1074, doi:10.1029/2002GB002010.

[2] University of Montana, MODIS NPP mean 2001 to 2004.

[3] CENTURY Soil Organic Matter Model Technical Documentation.

[4] Elise Pendall, Department of Botany, University of Wyoming (Unpublished data).

[5] USDA, National Agricultural Statistics Service, http://www.nass.usda.gov/Statistics_by_State.

[6] Bechtold, H.A. Inouye, R.S., Distribution of carbon and nitrogen in sagebrush steppe after six years of nitrogen addition and shrub removal, Journal of Arid Envrionments, 71 (2007) 122-132.

[7] Norton, J.B., Monaco, T.A., Norton, J.M., Johnson, D.A., Jones, T.A., 2004. Soil morphology and organic matter dynamics under cheatgrass and sagebrush-steppe plant communities. Journal of Arid Environments 57, 445–466.