Assessing the dynamics of the sagebrush ecosystem under different conditions of vegetation, ambient CO_2, and fire

Karun Pandit[a], Hamid Dashti[a], Nancy Glenn[a], Alejandro N. Flores[a], Douglas J. Shinneman[b], and Andrew T. Hudak[c]

a. Department of Geosciences, Boise State University, Boise, ID; contact: karunpandit@boisestate.edu, b. U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID., c. U.S. Forest Service, Moscow, ID.

Introduction

- The sagebrush-steppe ecosystem in the Western U.S. has been reduced to half of its original range (Schroeder et al., 2004). Non-native species like cheatgrass coupled with climate change have altered vegetation composition, hydrological function, and wildfire frequency (Connelly et al., 2004; McArthur and Plummer, 1978; Schlaepfer et al., 2014).
- Restoration activities like reducing flammable vegetation and seeding native species are ongoing (Chambers et al., 2014; McIver & Brunson, 2014), but the impact of these programs are not explored at regional scales.

Image credit: Anna Roser

- Ecosystem Dynamic Models are widely used to estimate terrestrial vegetation dynamics, because of their applicability over broad spatial scales (Dietze et al., 2014; Fisher et al., 2017).
- In this study, we modeled Gross Primary Production (GPP) of the sagebrush ecosystem under different vegetation conditions, ambient CO_2, and fire, using the Ecosystem Demography (EDv2.2) model.

Study area and Data

- Study was carried out at Reynold Creek Experimental Watershed (RCEW) in the Great Basin.
- 20 * 40 grids with 1 km resolution.
- Field inventory data (Glenn et al., 2014) for vegetation initialization.
- Meteorological data from 1988 to 1998 derived from Weather Research and Forecasting (WRF) model (Flores et al.).
- 1 km spatial, and 3 hr temporal resolution
- Grids representing locations with EC tower stations (Site I & Site II) in RCEW were selected for some analyses.

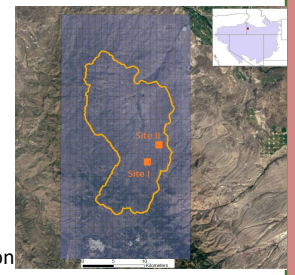

Figure 1. Study area covering RCEW, and its location in the Great Basin shown in the inset

Modeling scenarios

- EDv2.2 was run for 22 years with three different scenarios to observe GPP for each of the PFTs;
  1. Bare earth: with minimum vegetation (0.1 plants / m2 for each shrub, C3 grass, and conifers) and default ambient CO_2 (370 ppm).
  2. Increased CO_2: with minimum vegetation and increased ambient CO_2 (740 ppm).
  3. Initial vegetation: with vegetation close to current conditions (0.25 plants/m2 of shrub and C3 grass) and default ambient CO_2.
- Bare earth simulation was further run up to 34 years by introducing fire at the 25th year of simulation to observe differences in GPP prediction with fire and without fire.

Ecosystem Demography (EDv2.2) model

- A cohort based dynamic vegetation model where land surface is composed of a series of gridded cells, that experiences meteorological forcing (Medvigy, 2009; Moorcroft et al., 2001).
- This study uses an updated EDv2.2 which includes an additional PFT for sagebrush (shrub) based on our previous study.

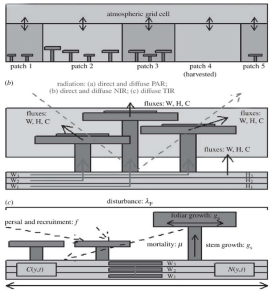

Figure 2. EDv2.2 model structure and processes (source: Medvigy et. al., 2009)

Preliminary results

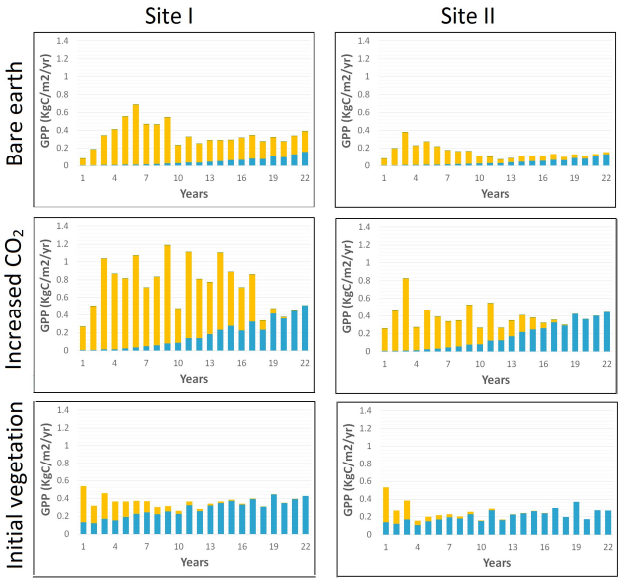

Figure 3. Average annual Gross Primary Production (GPP) for different PFTs simulated from EDv2.2 for three different scenarios for grids corresponding to EC sites

- Increased CO2 condition had highest total GPP by the final simulation year (Site I: 0.51 KgCm^2/yr), followed by initial vegetation.
- Bare earth condition: C3 grass shows higher GPP in initial years while shrubs pick up slowly and outgrows C3 grass in later years.
- Initial vegetation condition: C3 grass shows decline from the beginning years while shrubs continue to grow.
- Increased CO_2 and initial vegetation scenarios show higher GPP for shrubs by the end of simulation period.

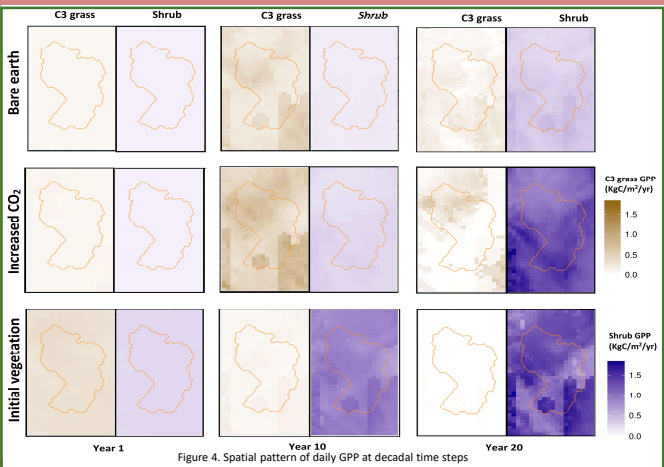

Figure 4. Spatial pattern of daily GPP at decadal time steps

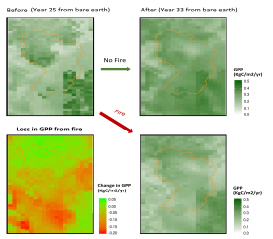

Figure 5. Spatial pattern of daily GPP with and without fire

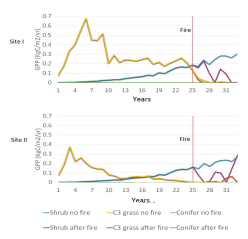

Figure 6. Effect of fire on C3 grass and shrub for Sites I and II

- Spatial pattern of loss of GPP from fire is observed in 8 years.
- Site I had a loss of 0.18 KgC/m^2/yr in this duration.
- Steady growth of shrub is checked with fire disturbance.

Future works

- Incorporate restoration measures like seeding and mowing (using plantation and disturbance scenarios) to explore sagebrush ecosystem dynamics under those conditions.
- Identify suitable conifer (Juniper) parameters in EDv2.2 to better represent them in this region.

References and Acknowledgements

- Chambers, J. C., Miller, R. F., Board, D. I., Pyke, D. A., Roundy, B. A., Grace, J. B., Schupp, E. W., and Taush, R. J. Resilience and Resistance of Sagebrush Ecosystems: Implications for State and Transition Models and Management Treatments. Range Ecol Manage 67: 440-454, 10.2111/REM-D-13-00074.1, 2010.
- Connelly, J. W., Knick, S. T., Schroeder, M. A., and Stiver, S. J.: Conservation Assessment of Greater Sage-grouse and Sagebrush Habitats. Western Association of Fish and Wildlife Agencies, Unpublished Report, Cheyenne, Wyoming, 2004.
- Dietze, M. C., Serbin, S. P., Davidson, C., Desai, A. R., Fend, X., Kelly, R., Kooper, R, LeBauer, D., Mantooth, J., McHenry, K., and Wang, D.: A quantitative assessment of a terrestrial biospheremodel's data needs across North American biomes, J. Geophys. Res.Biogeosci., 119, 286 –300, doi:10.1002/2013JG002392, 2014.
- Flores, A., Masarik, M., and Watson, K.: A 30-Year, Multi-Domain High-Resolution Climate Simulation Dataset for the Interior Pacific Northwest and Southern Idaho [Data set]. Retrieved from http://dx.doi.org/10.18122/B2LEAFD001, 2016.
- Glenn, N.F., Spaete, L. P., Shrestha, R., Li, A., Ilangakoon, N., Mitchell, J., Ustin, S. L., Qi, Y., Dashti, H., and Finan, K.: Shrubland Species Cover, Biometric, Carbon and Nitrogen Data, Southern Idaho, 2014. ORNL DAAC, Oak Ridge, Tennessee, USA. [Data set] retrieved from https://doi.org/10.3334/ORNLDAAC/1503, 2017.
- McArthur, E. D. and Plummer, A. P.: Biogeography and management of native western shrubs: a case study, Section Tridentatae of Artemisia, Great Basin Naturalist Memoirs, 2 , 15, https://scholarsarchive.byu.edu/gbnm/vol2/iss1/15, 1978.
- Mciver, J. and Brunson, M.: Multidisciplinary, Multisite Evaluation of Alternative Sagebrush Steppe Restoration Treatments: The SageSTEP Project, Range Ecol. Manage., 67, 435-439, https://doi.org/10.2111/REM-D-14-00085.1, 2014.
- Medvigy, D., Wofsy, S.C., Munger, J. W., Hollinger, D. Y., and Moorcroft, P. R. 2009. Mechanistic scaling of ecosystem function and dynamics in space and time: Ecosystem Demography model version 2. Journal of Geophysical Research, Vol. 114.
- Moorcroft, P. R. , G. C. Hurtt , and S. W. Pacala . 2001. A method for scaling vegetation dynamics: the ecosystem demography model (ED). Ecological Monographs 71: 557–585.
- Schroeder, M. A., Aldridge, C. L., Apa, A. D., Bohne, J. R., Braun, C. E., Bunnell, S. D., Connelly, J. W., Deibert, P. A., Gardner, S. C., Hilliard, M. A., Kobriger, G. D., McAdam, S. M., McCarthy, C. W., McCarthy, J. J., Mitchell, D. L., Rickerson, E. V., and Stiver, S. J.: Distribution of Sage-Grouse in North America, The Condor, 106, 363-376, https://doi.org/10.1650/7425, 2004.

Funded by Joint Fire Science Program (JFSP) grant (Project ID: 15-1-03-23), NASA-Terrestrial Ecology (NNX14AD81G), and Western Wildland Environmental Threat Assessment Center (WWETAC).