Ecosystem performance assessment for grasslands in the Greater Platte River Basin: implications for cellulosic biofuel development

Yingxin Gu[1] (ygu@usgs.gov), Stephen P. Boyte[2] (sboyte@usgs.gov), Bruce K. Wylie [3] (wylie@usgs.gov), and Larry L. Tieszen[3] (tieszen@usgs.gov)

[1]ASRC Research & Technology Solutions, contractor to U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD. Work performed under USGS contract 08HQCN0007. [2] SGT Inc, Contractor to USGS EROS Center, Sioux Falls, SD. Work performed under USGS contract G10PC00044. [3] USGS EROS Center, Sioux Falls, SD.

Introduction

Cellulosic biofuels produced from grasses, forest woody biomass, and agricultural and municipal wastes will significantly increase in the near future [*Bracmort,* 2010]. Switchgrass is being evaluated as one potential source for cellulosic feedstock [e.g., *Liebig*, 2006; *Sanderson et al.*, 2006]. Several studies have been conducted regarding the environmental effects of using switchgrass for cellulosic biofuels [*Guretzky et al.*, 2010; *Liebig et al.*, 2008]. However, investigations based on ecosystem performance that identify regions suitable for probable switchgrass development (i.e., cellulosic biofuel feedstocks) within the Northern Great Plains are still under development.

Satellite remote sensing has become an essential tool for measuring and monitoring ecosystem performance over large areas because of its wide coverage and high spatial and temporal resolutions. The growing season integrated Normalized Difference Vegetation Index (NDVI) derived from satellite observations is used as a proxy for ecosystem performance (EP) [*Tieszen et al.*, 1997]. Wylie *et al.* [2008] developed an approach that separates weather- and nonweather-related annual ecosystem performance variations using satellite-derived NDVI data, weather data, and ecosystem or land cover performance models. This method provides historical trend mapping in both weather- and disturbance-related EP variations, which helps identify the potential causes of ecosystem variations and can help guide best management practices.

The objective of this study is to identify lands where switchgrass biofuel expansion will probably focus within the Greater Platte River Basin (GPRB) using satellite observations, weather data, and ecosystem performance models. Dynamic monitoring of ecosystem performance for the GPRB grasslands was implemented in this study. Results from this study will provide a prototype to land managers and decision makers as they focus on more detailed assessments of biofuel economics and sustainability.

Method

- Our approach is based on the successful applications of ecosystem performance studies in the Yukon River Basin, Alaska, and the Upper Colorado River Basin [*Wylie et al.*, 2008; *Gu and Wylie*, 2010].
- We hypothesize that areas with fairly consistent high grassland productivity (i.e., high ecosystem site potential) in fair to good range condition (persistent ecosystem overperformance or normal performance with less ecological disturbance) are potentially suitable for cellulosic biofuel (switchgrass) development.

Study area

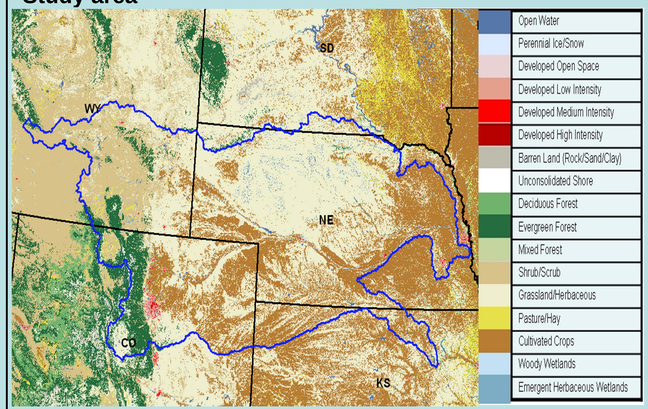


Figure 1. Location of the Greater Platte River Basin (inside the blue outline) and the land cover types as identified in the 2001 National Land Cover Database (NLCD).

- Greater Platte River Basin is formed by the Platte River Basin, the Niobrara River Basin, and the Republican River Basin.
- The main vegetation cover types are grassland (~50%) and cultivated crops (~30%). More than 60% of grasslands are warm season (C_4) grass.
- Other vegetation cover types include shrubland, evergreen and deciduous forests, and pasture/hay.

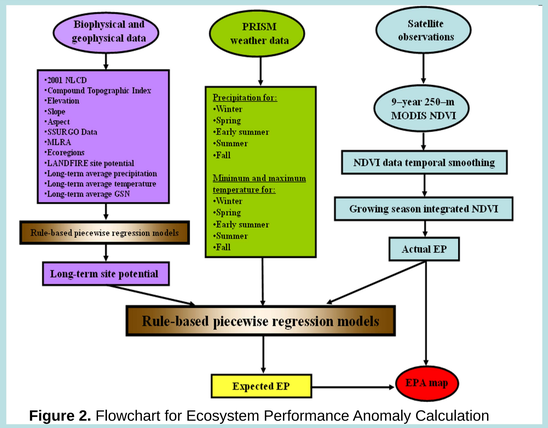


Figure 2. Flowchart for Ecosystem Performance Anomaly Calculation

Data inputs

- Soil organic carbon (SOC) derived from USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database;
- USGS 30-m Multi-Resolution Land Characteristics (MRLC) land cover data
- USGS 30-m compound topographic index (CTI) and digital elevation model (DEM);
- North and south aspect and slope maps derived from the USGS DEM data;
- USGS LANDFIRE environmental site potential data;
- USDA NRCS Major Land Resource Areas (MLRA) data;
- Omernik's Level III Ecoregions map;
- Long-term (1971–2000) averaged precipitation and temperature derived from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) database [PRISM Climate Group, Oregon State University, http://www.prismclimate.org];
- 2000–2008 PRISM climate datasets (precipitation and temperature);
- 9-year (2000–2008) growing season integrated NDVI (GSN) calculated from eMODIS (expedited Moderate Resolution Imaging Spectroradiometer) NDVI data.

Results and discussions

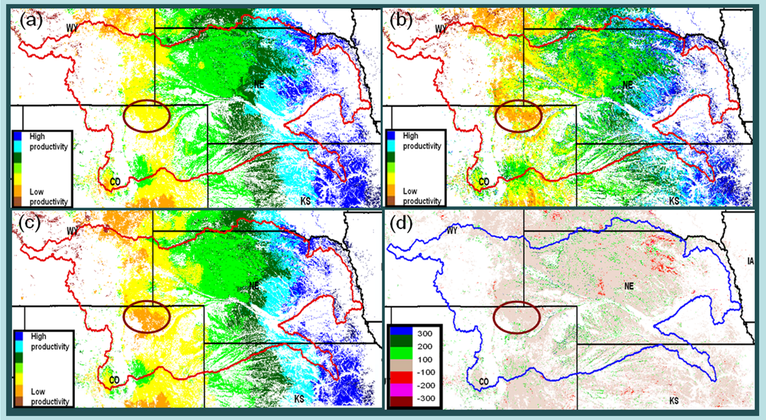


Figure 3. Examples of site potential map, the actual EP map, the EEP map, and the EPA map for grassland in the GPRB. (a) site potential map; (b) 2006 actual EP map; (c) 2006 EEP map; (d) 2006 EPA map in which green-blue areas represent overperformance and red-pink areas represent underperformance. White areas are not grassland.

- Site potential gradually increases from west to east within the GPRB.
- The general spatial patterns shown in the site potential, EP, and EEP maps are similar (e.g., productivities increase from west to east).
- Many differences exist among the three maps because of ecological disturbances and different weather conditions.
- Both actual EP and EEP are significantly lower than the normal site potential within the dark red outline area due to the extreme drought that occurred in 2006.

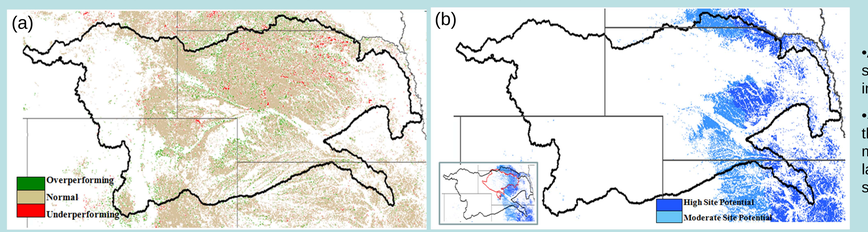
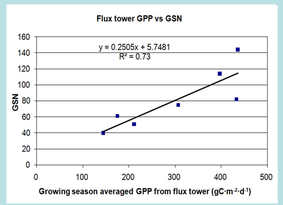


Figure 4. (a) 4-year (2005–2008) persistent EPA map; (b) final map delineating potential suitable areas (blue) for cellulosic biofuel development within the GPRB (excludes Sand Hills Ecoregion). The areas in blue represent pixels that either overperformed or normally performed for three of four years from 2005 to 2008 and with moderate or high site potential.

- Areas identified as suitable places for switchgrass development are mainly located in the eastern section of the GPRB.
- Sand Hills Ecoregion is excluded based on the SSURGO available water capacity (awc) map (awc<10%) to avoid any undesirable land use (i.e., removing biomass may lead to sand dune activation).

Verification of growing season NDVI as a proxy for ecosystem productivity



Strong correlation between GSN and flux tower Gross Primary Productivity (GPP).

Conclusions and future plans

- Areas with high to moderate ecosystem site potential and persistent ecosystem overperformance and normal performance are identified.
- The resulting map delineating areas potentially suitable for cellulosic biofuel development within the GPRB is useful to land managers and decision makers as a prototype to make optimal land use decisions for cellulosic biofuel development and sustainability within the GPRB.
- This study is part of a larger effort that will evaluate the environmental and climate impacts (e.g., carbon sequestration, soil, and land cover changes) caused by potential switchgrass development in the suitable regions.
- Extending this method to the other geographic areas (e.g., Northern Great Plains) is planned.

References

Bracmort, K. (2010), Meeting the renewable fuel standard (RFS) mandate for cellulosic biofuels: questions and answers, *Cong. Research Serv., Report for Congress, RL41106.*

Gu, Y., and B. K. Wylie (2010), Detecting ecosystem performance anomalies for land management in the upper Colorado River Basin using satellite observations, climate data, and ecosystem models, *Remote Sens.*, *2*(8), 1880–1891; doi:10.3390/rs2081880.

Guretzky, J. A., J. T. Biermacher, B. J. Cook, M. K. Kering, and J. Mosali (2010), Switchgrass for forage and bioenergy: harvest and nitrogen rate effects on biomass yields and nutrient composition. *Plant and Soil*, Springer, Netherlands, 1–13.

Liebig, M. A. (2006), USDA and DOE favor switchgrass for biomass fuel, *Industrial Bioprocessing*, *28*(8), 7.

Liebig, M. A., M. R. Schmer, K. P. Vogel, and R. B. Mitchell (2008), Soil carbon storage by switchgrass grown for bioenergy, *BioEnerg. Res.*, *1*, 215–222.

Sanderson, M. A., P. R. Adler, A. A. Boateng, M. D. Casler, and G. Sarath (2006), Switchgrass as a biofuels feedstock in the USA, *Can. J. Plant Sci.*, *86*(5), 1315–1325.

Tieszen, L. L., B. C. Reed, N. B. Bliss, B. K. Wylie, and D. D. DeJong (1997), NDVI, C3 and C4 production, and distributions in Great Plains grassland land cover classes, *Ecol. Appl.*, *7*(1), 59–78.

Wylie, B. K., L. Zhang, N. B. Bliss, L. Ji, L. L. Tieszen, and W. M. Jolly (2008), Integrating modelling and remote sensing to identify ecosystem performance anomalies in the boreal forest, Yukon River Basin, Alaska, *Int. J. Dig. Earth*, *1*(2), 196–220.

Acknowledgments

This work was performed under USGS contracts 08HQCN0007 and G10PC00044, and funded by the USGS Geographic Analysis and Monitoring Program in support of Renewable Energy-Biofuels initiative . The authors thank Norman Bliss for providing SSURGO soil organic carbon and available water capacity data. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U. S. Government.