Ecological Indicators 48 (2015) 472–476

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Estimating switchgrass productivity in the Great Plains using satellite vegetation index and site environmental variables

Yingxin Gu [a,*], Bruce K. Wylie [b], Daniel M. Howard [c]

[a] ASRC InuTeq, Contractor to U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, 47914 252nd Street, Sioux Falls, SD 57198, USA
[b] USGS EROS, 47914 252nd Street, Sioux Falls, SD 57198, USA
[c] Stinger Ghaffarian Technologies, Inc. Contractor to USGS EROS, 47914 252nd Street, Sioux Falls, SD 57198, USA

ARTICLE INFO

Article history:
Received 4 April 2014
Received in revised form 2 September 2014
Accepted 8 September 2014

Keywords:
Cellulosic biofuel
Switchgrass productivity
Satellite NDVI
Environmental variables
Multiple regression model
Great Plains

ABSTRACT

Switchgrass is being evaluated as a potential feedstock source for cellulosic biofuels and is being cultivated in several regions of the United States. The recent availability of switchgrass land cover maps derived from the National Agricultural Statistics Service cropland data layer for the conterminous United States provides an opportunity to assess the environmental conditions of switchgrass over large areas and across different geographic locations. The main goal of this study is to develop a data-driven multiple regression switchgrass productivity model and identify the optimal climate and environment conditions for the highly productive switchgrass in the Great Plains (GP). Environmental and climate variables used in the study include elevation, soil organic carbon, available water capacity, climate, and seasonal weather. Satellite-derived growing season averaged Normalized Difference Vegetation Index (GSN) was used as a proxy for switchgrass productivity. Multiple regression analyses indicate that there are strong correlations between site environmental variables and switchgrass productivity ($r = 0.95$). Sufficient precipitation and suitable temperature during the growing season (i.e., not too hot or too cold) are favorable for switchgrass growth. Elevation and soil characteristics (e.g., soil available water capacity) are also an important factor impacting switchgrass productivity. An anticipated switchgrass biomass productivity map for the entire GP based on site environmental and climate conditions and switchgrass productivity model was generated. Highly productive switchgrass areas are mainly located in the eastern part of the GP. Results from this study can help land managers and biofuel plant investors better understand the general environmental and climate conditions influencing switchgrass growth and make optimal land use decisions regarding switchgrass development in the GP.

1. Introduction

Switchgrass (*Panicum virgatum*), a perennial native grass and a highly productive species, has been evaluated as a potential feedstock source for cellulosic biofuels (Liebig, 2006; McLaughlin and Kszos, 2005). Cultivating switchgrass for biofuel is more economically and environmentally sustainable than using corn for producing ethanol and can improve ecosystem goods and services (Bransby et al., 1998; Liebig et al., 2008; Liebig, 2006; McLaughlin and Kszos, 2005; Perrin et al., 2008). The use of switchgrass could help mitigate the negative effects of intensive cropping (e.g., reduce soil erosion and water quality impairment from pesticides and fertilizer, improve retention of soil carbon stocks) and minimize impacts on the global food supplies.

Switchgrass is currently being cultivated as a bioenergy crop in several states in the United States (e.g., Kansas, Missouri, Oklahoma, and North Carolina) in response to the United States Department of Agriculture (USDA) Farm Service Agency Biomass Crop Assistance Program (http://www.fsa.usda.gov/Internet/FSA_File/bcapoctrules.pdf). Investigations on the relationships between switchgrass biomass productivity and site environmental or climate conditions based on the experimental site observations have been conducted (Hartman and Nippert, 2012; Hartman et al., 2012) (http://www.ksre.ksu.edu/bookstore/pubs/mf3018.pdf). However, mapping switchgrass productivity over large areas (e.g., Great Plains), which can inform land managers about the productive switchgrass area and their common environmental conditions, using satellite vegetation index and site environmental and climate conditions is still under investigation.

* Corresponding author. Tel.: +1 605 594 6576; fax: +1 605 594 6529.
E-mail address: ygu@usgs.gov (Y. Gu).

http://dx.doi.org/10.1016/j.ecolind.2014.09.013
1470-160X/

The recent availability of switchgrass land cover maps derived from the National Agricultural Statistics Service (NASS) cropland data layer (CDL) (http://www.nass.usda.gov/research/Cropland/SARS1a.htm) for the conterminous United States provides an opportunity to assess the relationships between environmental and climate conditions and switchgrass productivity over large areas and across different geographic locations. Moreover, the satellite-derived growing season averaged Normalized Difference Vegetation Index (NDVI), which is often used as a proxy for aboveground biomass productivity (Gu et al., 2012b; Paruelo et al., 1997; Rigge et al., 2013; Svoray et al., 2013; Tieszen et al., 1997), is well-suited for developing switchgrass biomass productivity maps. Approaches for modeling vegetation productivity or habitat suitability (Guisan and Zimmermann, 2000) include (but is not limited to) multiple regression (Ji and Peters, 2004), boosted or committee regression trees (Quinlan, 1996), and neural network (Lek et al., 1996).

This study focuses on assessing switchgrass productivity over the Great Plains (GP). The objectives of this study are to (1) develop a data-driven multiple regression switchgrass productivity model to estimate switchgrass biomass productivity for the entire GP and (2) quantify the environmental characteristics associated with productive switchgrass areas within the GP. Results from this study can help land managers and biofuel plant investors identify the general environmental conditions of productive switchgrass areas to assist land use decisions regarding switchgrass development in the GP.

2. Materials and methods

2.1. Study area

The study area is the GP, which covers 14 states of the United States and contains 17 ecoregions (Omernik, 1987). The GP includes a variety of vegetation cover types and a broad range of climate conditions and plant productivity. The main vegetation cover types in the GP are grassland (36%) and cultivated crops (30%). Other land cover types include shrubs, forests, urban, wetlands, and open water (Homer et al., 2004). The average annual temperature generally increases from the northern GP (less than 4 °C) to the southern GP (exceeds 22 °C), and the annual precipitation increases from the western GP (less than 200 mm) to the eastern GP (over 1100 mm) (Gu et al., 2012b). The land cover types, with state and ecoregion names, of the GP are shown in Fig. 1.

2.2. Satellite-derived growing season averaged NDVI (GSN)

Satellite-derived GSN was used as a proxy for aboveground vegetation biomass productivity in this study. The 7-day composite 250 m eMODIS (expedited Moderate Resolution Imaging Spectroradiometer) (Jenkerson et al., 2010) NDVI data obtained from the U.S. Geological Survey (USGS) eMODIS data archive (https://lta.cr.usgs.gov/emodis) were used to calculate GSN. The 2010–2012 7-day composite NDVI data were stacked by year and were then smoothed using a moving temporal window regression approach to reduce

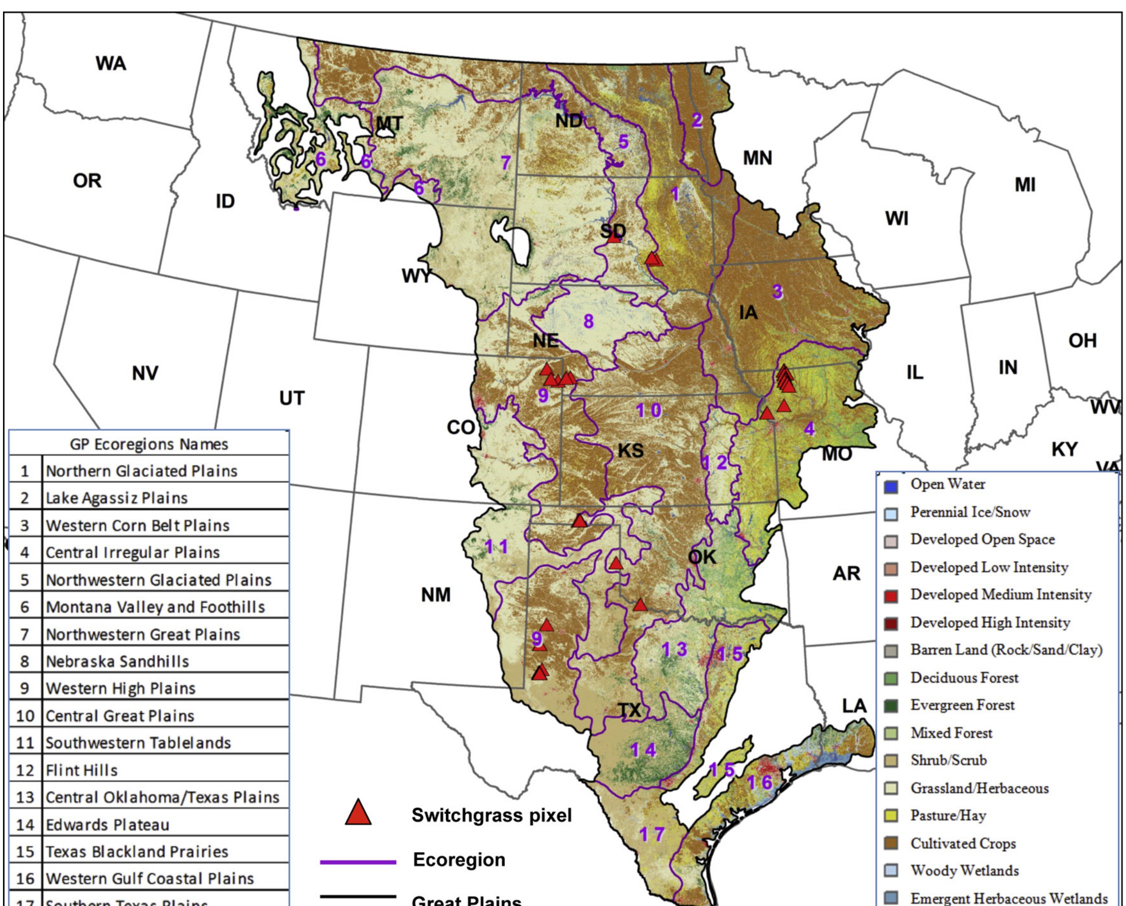

Fig. 1. Land cover types as identified in the 2001 National Land Cover Database (Homer et al., 2004) and ecoregion names of the Great Plains. The red triangles represent switchgrass pixels. (For interpretation of the references to color in text, the reader is referred to the web version of this article.)