Ecological Indicators 60 (2016) 64–70

Contents lists available at ScienceDirect

Ecological Indicators

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

Using satellite vegetation and compound topographic indices to map highly erodible cropland buffers for cellulosic biofuel crop developments in eastern Nebraska, USA

Yingxin Gu[a,*], Bruce K. Wylie[b]

[a] ASRC Research & Technology Solutions, 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

ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form 15 June 2015
Accepted 16 June 2015
Available online 7 July 2015

Keywords:
Cellulosic biofuel
Highly erodible cropland
Compound topographic index (CTI)
High topographic relief waterway buffer
Switchgrass biomass productivity
Land management

ABSTRACT

Cultivating annual row crops in high topographic relief waterway buffers has negative environmental effects and can be environmentally unsustainable. Growing perennial grasses such as switchgrass (*Panicum virgatum* L.) for biomass (e.g., cellulosic biofuel feedstocks) instead of annual row crops in these high relief waterway buffers can improve local environmental conditions (e.g., reduce soil erosion and improve water quality through lower use of fertilizers and pesticides) and ecosystem services (e.g., minimize drought and flood impacts on production; improve wildlife habitat, plant vigor, and nitrogen retention due to post-senescence harvest for cellulosic biofuels; and serve as carbon sinks). The main objectives of this study are to: (1) identify cropland areas with high topographic relief (high runoff potentials) and high switchgrass productivity potential in eastern Nebraska that may be suitable for growing switchgrass, and (2) estimate the total switchgrass production gain from the potential biofuel areas. Results indicate that about 140,000 hectares of waterway buffers in eastern Nebraska are suitable for switchgrass development and the total annual estimated switchgrass biomass production for these suitable areas is approximately 1.2 million metric tons. The resulting map delineates high topographic relief croplands and provides useful information to land managers and biofuel plant investors to make optimal land use decisions regarding biofuel crop development and ecosystem service optimization in eastern Nebraska.

1. Introduction

Growing annual crops in riparian zones or waterway buffers with high topographic relief (i.e., steep slope areas) has numerous negative environmental consequences (e.g., soil erosion and water-quality effects of pesticide and fertilizer leakage) and can be environmentally unsustainable (Dosskey, 2001; Dosskey et al., 2002; Logan, 1990; Simpson et al., 2008; Spruill, 2000; http://water.epa.gov/lawsregs/guidance/cwa/305b/upload/2009_01_22_305b_2004report_2004_305Breport.pdf). Several national conservation programs have provided incentives for converting agriculture lands to perennial grasses and trees within riparian zones (e.g., Conservation Reserve Program, Environmental Quality Incentives Program, Conservation Reserve Enhancement Program) to reduce negative environmental impacts, improve ecosystem services, and retain future sustainability in biomass production in these specific areas (Addy et al., 1999; Castelle et al., 1994; Lee et al., 2000; Piechnik et al., 2012; Sheridan et al., 1999; Tomer et al., 2003).

Previous studies indicate that cultivating perennial grass feedstocks such as switchgrass (*Panicum virgatum* L.) and prairie cordgrass (*Spartina pectinata*) for biofuel is more economically and environmentally sustainable than using corn (*Zea maize* L.) for producing ethanol (Bracmort, 2010; Bracmort et al., 2010; Bransby et al., 1998; Guretzky et al., 2011; Monti et al., 2012; Perrin et al., 2008; Sanderson et al., 2006, 1996; Schmer et al., 2010, 2008; Vadas et al., 2008). Corn-based ethanol development has been associated with global food shortages, livestock and food price increases, soil erosion, greater demands for irrigation water, and water-quality impairment (Buyx and Tait, 2011; Gelfand et al.,

* 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.2015.06.019
1470-160X/

2010; Pimentel, 2009; Schnepf and Yacobucci, 2010; Searchinger et al., 2008; Trostle, 2008). As a result of dramatically increasing demand for biofuel products (Perlack et al., 2005; http://www.usda.gov/documents/USDA_Biofuels_Report_6232010.pdf; http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf) and future environmental sustainability, the development of perennial grass feedstocks for biofuel production is likely to increase in the near future (Bracmort, 2010; Bracmort et al., 2010; Schnepf and Yacobucci, 2010). Commercial production of switchgrass for bioenergy will be undertaken on a large scale when bioenergy infrastructures and refineries (biomass supply chains, centralization of fuel supplies) are well developed (Mitchell et al., 2012).

Growing perennial grasses such as switchgrass and prairie cordgrass for biofuel in riparian zones, stream waterway buffers, and highly erodible cropland areas has been proposed and investigated (Dominguez-Faus et al., 2009; Mersie et al., 2006; Powers et al., 2010; Sanderson, 2008; Sanderson et al., 2001; Tufekcioglu et al., 2003; Koh et al., 2009; http://nac.unl.edu/buffers/guidelines/4_opportunities/6.html; http://www.globalbioenergy.org/uploads/media/0702_FAO_-Water_quality_and_environmental_dimensions_in_biofuel_production.pdf; https://bioenergy.ornl.gov/papers/misc/switgrs.html). Cultivating perennial grass in these high reliefs, intensive agriculture areas can improve local environment conditions and ecosystem services (Dominguez-Faus et al., 2009; Powers et al., 2010; Sanderson et al., 2001; Tufekcioglu et al., 2003). However, thus far, investigations are only at the planning stages or are limited to a few experimental field sites. To date, we are not aware of previous studies that identify and map high topographic relief, marginally productive croplands (where grass waterways would be highly beneficial) over large regions that may be considered for cellulosic biofuel development.

In this study, we used 30-m hydrological data (i.e., U.S. Geological Survey Compound Topographic Index) to map waterway buffers in high topographic relief croplands. Our main objectives were to: (1) identify cropland with steep slopes, high erosion potential, and high switchgrass productivity potential in eastern Nebraska that are potentially suitable to convert to cellulosic biofuel crops, and (2) estimate the total production gain from switchgrass in the high erosion croplands with conversion potential. Results from this study will help land managers and biofuel plant investors make optimal land use decisions regarding sustainable biofuel crop development to optimize ecosystem services in eastern Nebraska.

2. Materials and methods

2.1. Study area

Eastern Nebraska (Fig. 1) was selected as a pilot study area for demonstration and illustration purposes. The main land cover types in the study area are cultivated crops (approximately 64%) and grassland (approximately 28%) (Homer et al., 2004). Crops and grasslands are highly productive in this study area because of the humid continental climate. Annual precipitation ranges from 600 to 900 mm and generally increases from west to east in the study area.

2.2. USGS Compound Topographic Index (CTI) map

The CTI is a commonly used hydrological measure of a site and may be interpreted as the steady-state wetness of an area (i.e., areas with probable run-on moisture). CTI is a function of both the slope and the upstream contributing area and can be calculated from a DEM (Digital Elevation Model) (http://geology.er.usgs.gov/eespteam/terrainmodeling/dem_derived_maps.htm). Pixels with high CTI values (i.e., >12) usually represent water catchment areas (wetlands, lakes, streams and rivers). The 30-m spatial resolution CTI map developed by the USGS Elevation Derivatives for National Applications (EDNA) program (http://edna.usgs.gov/Edna/datalayers/cti.asp) was used in this study (Fig. 2a and b).

2.3. Crop mask and switchgrass productivity estimation maps

A 10-year series (2000–2009) of yearly crop type maps for eastern Nebraska (250-m resolution) (Howard et al., 2012) was used to develop a crop mask for the study area. A crop pixel was assigned when 5 or more years were in crops. In addition, a 3-year (2008–2010) averaged switchgrass productivity potential (i.e., predicted growing season averaged Normalized Difference Vegetation Index (GSN)) map developed by Gu et al. (2015) for eastern Nebraska was used to identify the highly productive switchgrass (GSN ≥ 0.5) regions. Fig. 2c and d show the crop mask and the

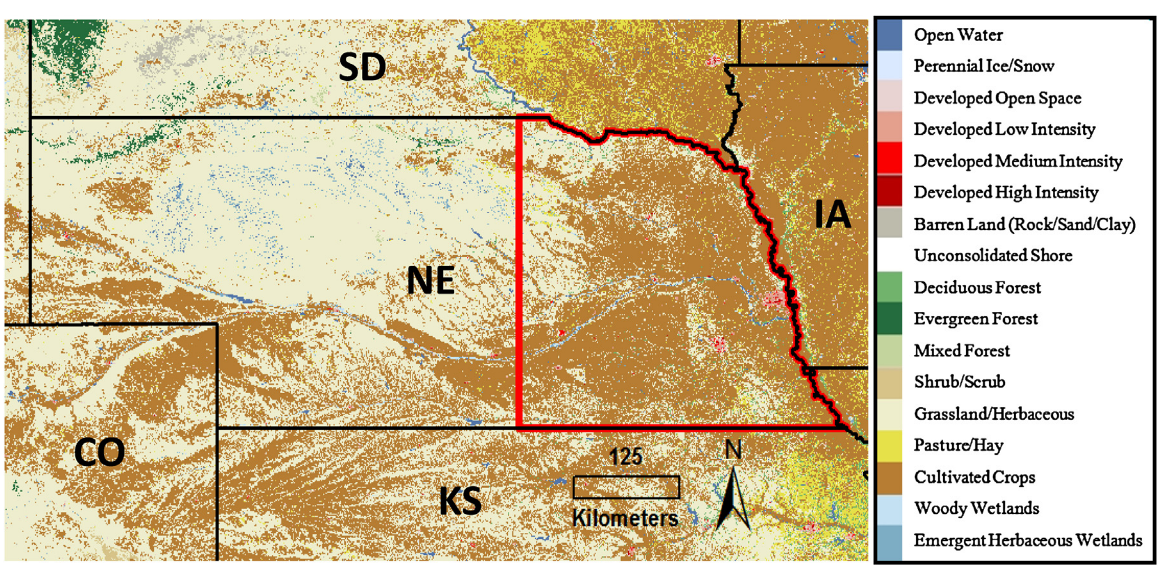

Fig. 1. Land cover type and location of the study area (within the red boundary) in eastern Nebraska, USA. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)