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Mapping grassland productivity with 250-m eMODIS NDVI and SSURGO database over the Greater Platte River Basin, USA

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

[a] ASRC Research & Technology Solutions, Contractor to US 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

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ABSTRACT

This study assessed and described a relationship between satellite-derived growing season averaged Normalized Difference Vegetation Index (NDVI) and annual productivity for grasslands within the Greater Platte River Basin (GPRB) of the United States. We compared growing season averaged NDVI (GSN) with Soil Survey Geographic (SSURGO) database rangeland productivity and flux tower Gross Primary Productivity (GPP) for grassland areas. The GSN was calculated for each of nine years (2000–2008) using the 7-day composite 250-m eMODIS (expedited Moderate Resolution Imaging Spectroradiometer) NDVI data. Strong correlations exist between the nine-year mean GSN (MGSN) and SSURGO annual productivity for grasslands ($R^2 = 0.74$ for approximately 8000 pixels randomly selected from eight homogeneous regions within the GPRB; $R^2 = 0.96$ for the 14 cluster-averaged points). Results also reveal a strong correlation between GSN and flux tower growing season averaged GPP ($R^2 = 0.71$). Finally, we developed an empirical equation to estimate grassland productivity based on the MGSN. Spatially explicit estimates of grassland productivity over the GPRB were generated, which improved the regional consistency of SSURGO grassland productivity data and can help scientists and land managers to better understand the actual biophysical and ecological characteristics of grassland systems in the GPRB. This final estimated grassland production map can also be used as an input for biogeochemical, ecological, and climate change models.

1. Introduction

Ecosystem performance (EP) is a surrogate for approximating ecosystem productivity (Tieszen et al., 1997). Dynamic monitoring of EP (Wylie et al., 2008) provides important information to land managers and decision makers to aid in implementing best management. There are currently a number of data sources available for monitoring or inventory of EP, including flux tower observations, National Agricultural Statistics Service (NASS) crop yield data, and Soil Survey Geographic (SSURGO) productivity. However, all of these have limitations for dynamic monitoring of EP, including a lack of continuous spatial coverage (e.g., sparse field observations), low spatial resolution (e.g., county level statistics), spatial discontinuities (e.g., differences across state and county lines), and significant time lags in the annual estimates. Satellite remote sensing has become an essential tool for measuring and monitoring ecosystem performance over large areas because of its wide coverage, high spatial and temporal resolutions, and consistency and robustness (Wylie et al., 2008; Gu and Wylie, 2010; Gu et al., 2012).

The Normalized Difference Vegetation Index (NDVI) is the normalized reflectance difference between the satellite near infrared (NIR) band and the visible red band (Rouse et al., 1974; Tucker, 1979). NDVI represents the photosynthetic potential of a vegetation canopy and is extensively used in ecosystem monitoring. A variety of studies on the relationships between NDVI and biomass production using different satellite sensors, such as the Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS), and different ground observation data (e.g., field sampling data, state soil geographic database, and NASS yield data at the county level) have been conducted over the last several decades (Rouse et al., 1974; Tucker et al., 1985; Hobbs, 1995; Tieszen et al., 1997; Ricotta et al., 1999; Wang et al., 2005; Becker-Reshef et al., 2010). These studies have shown relationships between NDVI and biomass productivity.

The growing season averaged NDVI (GSN) has been used as a proxy for EP (Tieszen et al., 1997) and rangeland herbaceous biomass (Wylie et al., 1995) instead of NDVI or maximum NDVI because it captures the seasonal dynamics of multiple variables, including grazing and ecological disturbances, throughout the

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

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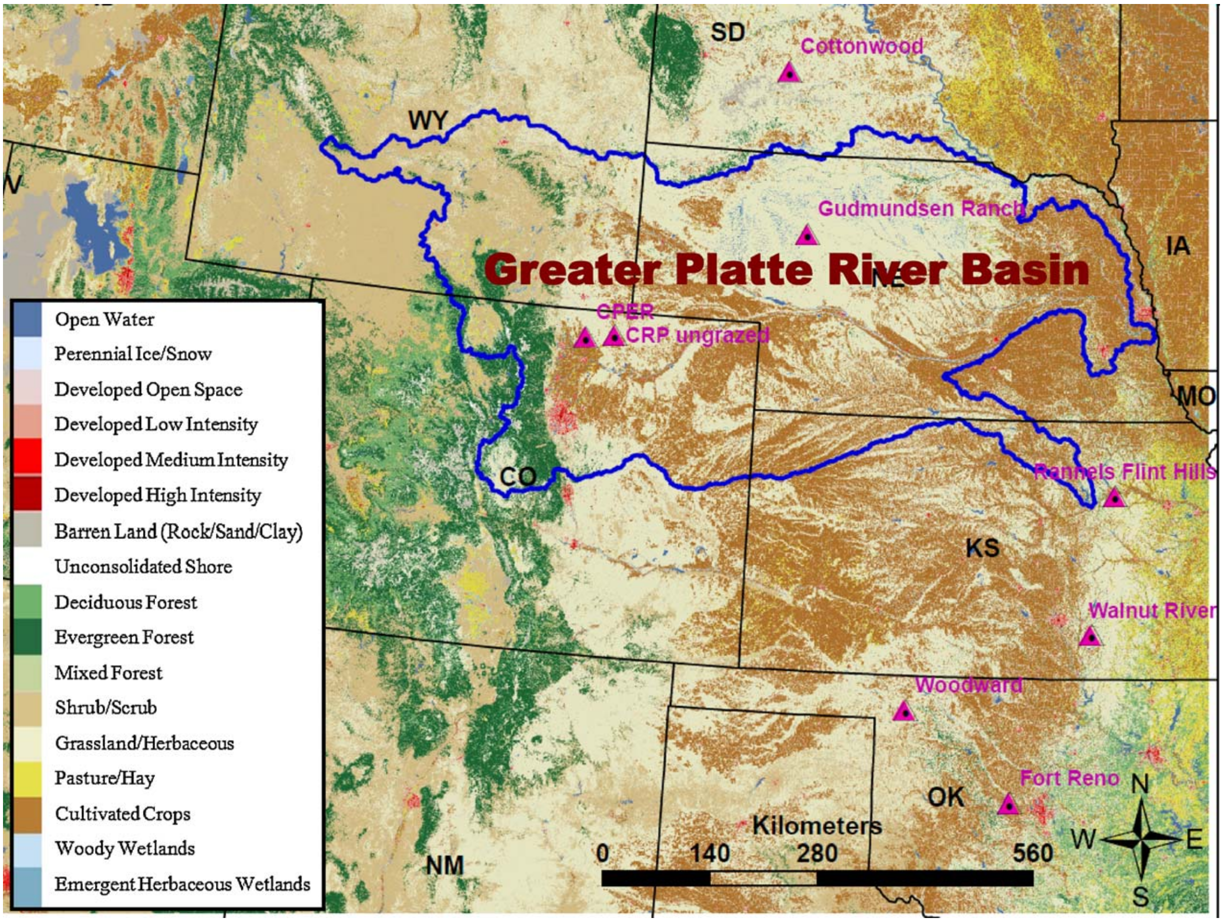

Fig. 1. Location (the blue outline) and land cover types of the GPRB. Magenta Triangles represent the eight flux towers selected in this study.

growing season. However, this approach (i.e., using GSN as a proxy for EP) was only based on the correlation analysis between 1-km AVHRR NDVI and biomass productivity. Further verifications of the wide application of this approach based on the different satellite sensors (e.g., MODIS) and biomass production data (e.g., SSURGO biomass production data) are needed.

The SSURGO biomass production map is considered as the best available high spatial resolution rangeland production map for the Greater Platte River Basin (GPRB). SSURGO data were created county by county through collaboration with the states and the Natural Resources Conservation Service (NRCS). Each county uses slightly different criteria for their soil surveys. A disadvantage of SSURGO data is that it has spatial discontinuities (e.g., differences across state and county lines). In order to overcome the spatial discontinuities of SSURGO rangeland production data and to better represent the actual biophysical and ecological characteristics of the grassland system in the GPRB, we compared the nine-year GSN with SSURGO total productivity and flux tower Gross Primary Productivity (GPP) for grasslands to develop a regionally consistent grassland biomass production map over the GPRB. The GSN was derived from the expedited MODIS (eMODIS) nine-year (2000–2008) time series temporally smoothed NDVI data (Swets et al., 1999; Jenkerson et al., 2010). Our goals were to (1) enhance our understanding of the relationship between satellite-derived GSN and biomass production; (2) establish an empirical equation to estimate the grassland biomass productivity over a wide range of grassland conditions based on the relationship between SSURGO biomass production and GSN and (3) generate a grassland biomass production map in the GPRB using 250-m eMODIS GSN. The anomalies near state and county boundaries in the SSURGO map are expected to be reduced and the regional consistencies are anticipated to be improved in the resulting grassland production map. The final grassland production map provides useful information for land managers and decision makers to aid in implementing best management practices. This final map can be used for many purposes, such as (1) land assessments for ranching; (2) biofuel and wildlife habitat assessments; (3) ecosystem service mapping and (4) input for biogeochemical, ecological, and climate change models.

2. Materials and methods

2.1. Study area

Our study area is the Greater Platte River Basin, which covers parts of Wyoming, Colorado, South Dakota, Kansas, and most of Nebraska (Fig. 1). The main vegetation cover types are grassland (~50%) and cultivated crops (~30%). The western part of the GPRB (southeastern Wyoming and northeastern Colorado) has very low rangeland productivity in general because of the unfavorable vegetation growth conditions (e.g., shallow or rocky soils, low annual precipitation which is less than 250 mm). The eastern part of the GPRB has higher rangeland productivity because of the favorable vegetation growth conditions. The land cover types (Homer et al., 2004) and the study area (within the blue outline) are shown in Fig. 1.