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Agricultural impacts on ecosystem functioning in temperate areas of North and South America

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Abstract

Land use has a large impact on ecosystem functioning, though evidences of these impacts at the regional scale are scarce. The objective of this paper was to analyze the impacts of agricultural land use on ecosystem functioning (radiation interception and carbon uptake) in temperate areas of North and South America. From land cover maps generated using high-resolution satellite images we selected sites dominated by row crops (RC), small grain crops (SG), pastures (PA), and rangelands (RA) in the Central Plains of USA and the Pampas of Argentina. These two regions share climatic characteristics and the agricultural conditions (crop types) are also very similar. Both areas were originally dominated by temperate grasslands. In these sites we extracted the temporal series of the normalized difference vegetation index (NDVI) from the NOAA satellites for the period 1989–1998 and calculated the mean seasonal NDVI curve for each site. Additionally, we calculated the mean annual NDVI, the maximum NDVI, the date of the year when the max NDVI was recorded and the interannual variability of these three attributes. We compared the mean values of each NDVI-derived attribute between land cover types and between continents. The NDVI seasonal patterns for each land cover type were roughly similar between the Central Plains and the Pampas during the growing season. The largest differences were observed during the winter and spring, when the NDVI of all land cover types in the Central Plains remained at lower values than in the Pampas. This was probably caused by the high annual thermal amplitude in the Central Plains that results in a much more restricted growing season. As a result of these differences in the shape of the NDVI curve, the mean annual NDVI in the Central Plains was lower than in the Pampas for all land cover types but the maximum NDVI did not differ importantly. In both regions, row crops delayed the date of the NDVI peak, small grain crops advanced it and pastures did not change it importantly, compared with rangelands. The interannual variability of the NDVI attributes was higher for small grains than for row crops in both regions. However, small grains crops were consistently more variable between years in the Central Plains than in the Pampas. The opposite occurred with pastures and rangelands, which

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were more variable in the Pampas than in the Central Plains. This paper confirms and generalizes previous findings that showed important imprints of land use on ecosystem functioning in temperate ecosystems. Our results support the idea that the changes in land cover that have occurred in the Central Plains and the Pampas leaded to similar changes in the way that ecosystems absorb solar radiation and in the patterns of carbon uptake.

Keywords: land use; agriculture; ecosystem functioning; Central plains; Pampas; remote sensing; NDVI

1. Introduction

Changes in land use have important consequences on terrestrial ecosystems. The conversion of natural vegetation into croplands produces strong changes in the carbon and nitrogen cycles (Vitousek et al., 1997), on biodiversity (Sala et al., 2000), and landscape fragmentation (Turner et al., 2001), among others. In recent years, several studies have used remotely sensed data to analyze the dynamics of land use and land cover change. Paruelo and Lauenroth (1995) used the dynamics of the normalized difference vegetation index (NDVI; a surrogate for net primary production) for describing the patterns of net primary production in grasslands and shrublands of North America. Using also remote sensing, Paruelo et al. (2001) studied the impacts of land use change on ecosystem functioning in the Colorado Front Range (USA). They found important changes in the NDVI dynamics driven by agriculture, both in the mean annual NDVI and in the intraannual seasonality of NDVI. Similarly, Guerschman et al. (2003a) analyzed the impacts of land use on the NDVI in temperate Argentina. They also found a strong imprint of agriculture on, mainly, the seasonality of NDVI, both in the difference between the maximum and minimum values and the month of the year when the peak NDVI was registered.

Paruelo et al. (1998) analyzed the degree of convergence between grasslands and shrublands of South America and North America. They showed that ecosystem functioning varied across environmental gradients in a similar fashion in areas unrelated in geographical and evolutionary terms. Does ecosystem functioning change under agriculture in a similar way in North and South America? One would be tempted to compare the studies of Paruelo et al. (2001) and Guerschman et al. (2003a) cited above in order to find similarities and differences on the way that ecosystems respond to land use change in the two continents. However, a direct comparison is not possible because of two main reasons: first, the areas studied in these two papers are not similar in extent and hence, in environmental conditions. The study by Paruelo et al. (2001) concentrated in the eastern portion of Colorado, an area of 135 000 km^2 with a mean annual precipitation from 250 to 500 mm $year^{-1}$ and mean annual temperature of 12 °C. The Guerschman et al. (2003a) paper analyzed the entire Pampas region of Argentina, an area about five times larger than the Colorado Front Range that spans from 500 to 1300 mm $year^{-1}$ and from 13 to 17 °C. A second impediment to directly compare the two studies is the methodological differences. Although both studies used the seasonal patterns of the NDVI as a descriptor of ecosystem functioning, in North America Paruelo et al. (2001) used biweekly 1×1 km composites while for Argentina Guerschman et al. (2003a) used 10-day 8×8 km composites. These two datasets were created from the same source of data (the National Oceanographic Atmospheric Administration (NOAA) satellites), but the processes used for calibrating the data and for correcting for atmospheric contamination are different. The land use information was also different in both areas: it was obtained from locating in county maps sites of 400 ha with different land use classes (Colorado), while it was obtained from an agricultural census, using the county (4300 km^2 in average) as the sampling unit (Argentina).

In this paper we sought to compare the impacts of land use on ecosystem functioning in temperate areas of North and South America. We focused in two areas with homogeneous environmental conditions and we used a common methodological framework for both areas. The general question that drove our research was, does land use change ecosystem functioning