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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 similarly in both continents? We compared three cultivated land cover types with native grasslands, and considered the latter as a proxy for the functioning of native ecosystems. We quantified the fraction of photosynthetically active radiation intercepted by vegetation through an index derived from remotely sensed data and used it as a descriptor of ecosystem functioning.

## 2. Area descriptions, methods, and material studied

We selected two areas, in North and South America, with similar climatic, phytogeographic, and land use characteristics (Paruelo et al., 1995). In North America we used the central portion of the Great Plains (hereon referred as "Central Plains") and in South America we selected three areas in the argentine Pampas (hereon referred as "Pampas"; Fig. 1). Mean annual precipitation in the Central Plains ranges from 700 to 1100 mm year$^{-1}$ and mean annual temperature goes from 8 to 12 °C. In the Pampas the precipitation and temperature ranges are 750–1100 mm year$^{-1}$ and 13 to 16 °C (Leemans and Cramer, 1991). The Central Plains have a more continental climate than the Pampas, and this determines the differences in the mean temperature range. The thermal amplitude (difference between the warmest and coldest months) in the Central Plains is approximately 25 °C while it is only 14 °C in the Pampas. Native vegetation in both cases is temperate grassland. The Central Plains includes the phytogeographic district of the tall-grass prairie (Kucera, 1992). The Pampas are a subdivision of the "Río de la Plata Grasslands", a vast region of humid and sub-humid grasslands in South America (Soriano, 1992).

The Central Plains and the Pampas share a similar colonization history. Europeans settlers arrived to both areas in the 19th century, but only in the 20th century that agriculture expanded widely to occupy its current extent (Lauenroth et al., 1999; Ramankutty and Foley, 1999a,b; Hall et al., 1992). The more extended crops in the Central Plains and the Pampas are also similar: wheat, corn, soybeans, sorghum, and pastures (USDA/JAWF, 1994; Leff et al., 2004). Wheat, referred to here as small grains, is sown in the winter in the Pampas (in the fall in the Central Plains) and harvested in early summer. Corn, soybeans, and sorghum are summer crops, sown during the spring and harvested in fall. We refer to them as "row crops". The term "pasture" generally denominates perennial crops, used for direct cattle grazing or for hay production. They may be composed by alfalfa or other legumes in pure stands or associated with perennial grasses like fescue or rye. Other crops, less important in area coverage, include sunflower, oats, and barley. The distribution of these crops in the space is determined by environmental conditions, such as water availability, temperature, frosts, and soils (Burke et al., 1994; Hall et al., 1992). Native grasslands (called here "rangelands") remain in areas unfavorable for agriculture and are almost with no exception grazed by domestic herbivores (Lauenroth et al., 1994; Soriano, 1992). Grazing caused changes in the structure of these rangelands, compared to those found by the first European settlers. The effects on net primary production are, however, less important (Oesterheld et al., 1999).

We used fine-scale land use maps for selecting the study sites. For North America we used the National Land Cover Characterization (NLCC) (Vogelmann et al., 2001). This is a land cover map of the coterminous USA produced with LANDSAT TM images (mostly from 1992) and has a spatial resolution of 30 m. This land cover map was developed using an unsupervised clustering algorithm and then labeled according to aerial photographs and ground observations. We used the maps corresponding to the entire states of Iowa, Missouri, Illinois, and the western portions of Kansas and Oklahoma (discarding the areas with precipitation lower than 700 mm year$^{-1}$). This land cover map indicates an overall accuracy of 82% for the areas used in this paper (Wickham et al., 2004). The area analyzed in the Central Plains has approximately 660 000 km$^2$. In South America we used the maps produced by Guerschman et al. (2003b) and Baldi (2002). These maps were also generated with LANDSAT TM imagery (from 1996 and 1997) and, consequently, have the same spatial resolution as the NLCC. These maps correspond to three areas in the province of Buenos Aires covering approximately 100 000 km$^2$. They were generated using supervised classification algorithms and ground truth data collected from agricultural farms. The overall accuracy was higher

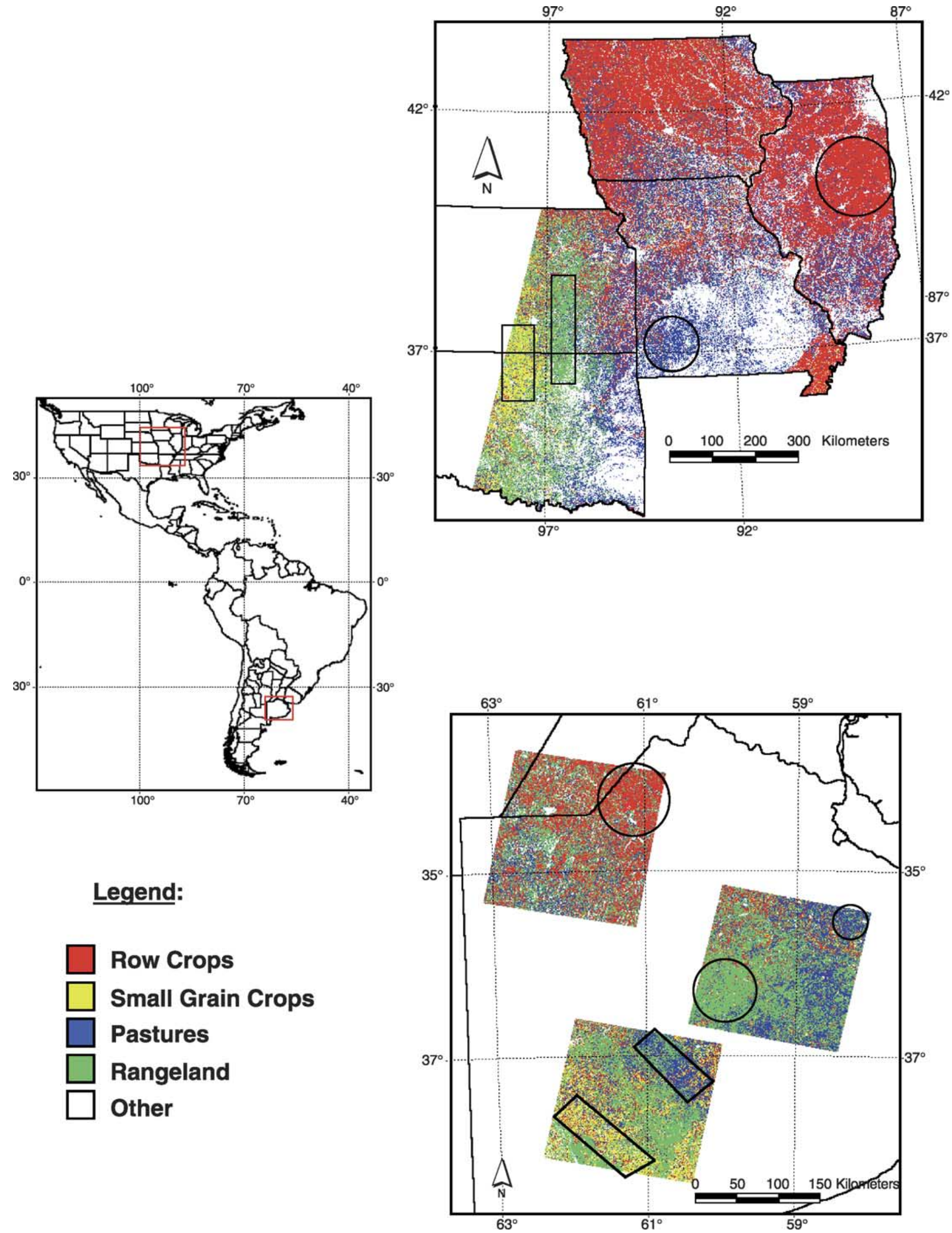


Fig. 1. Map showing the location of the study areas in North and South America. The land cover maps were taken from Vogelmann et al. (2001) (Central Plains) and from Guerschman et al. (2003b) and Baldi (2002) (Pampas). The circles and polygons indicate the areas where the 8×8 km study sites were concentrated.

than 80% in the three classifications involved. From these land cover maps we selected sites of 8×8 km (64 $km^2$) dominated by four different land cover classes: rangelands (RA), cultivated pastures (PA), small grains crops (SG), and row crops (RC). In the Central Plains we selected the 50 8×8 km sites with the highest proportion of each land cover class. This criterion yielded a minimum proportion of 68% for small grains (in the 50th cell). In the pampas the 8×8 km sites of crops were more heterogeneous and then we restricted the number of sites in order to avoid cells with low proportions of the desired classes. The lowest proportions were 50% (small grains) and 62% (pastures). The total number of sites was 200 in the Central Plains and 153 in the Pampas.

For each site we extracted the series of Normalized Difference Vegetation Index (NDVI) from the Pathfinder Advanced Very High Resolution Land program (PAL) (James and Kalluri, 1994). The PAL dataset contains 10-day NDVI composites (36 per year) from 1981 to 2001, at 8×8 km resolution generated from the Advanced Very High Resolution Radiometer (AVHRR) on board of the NOAA satellites. This dataset has been corrected for atmospheric and orbital distortions and has been used in a very large number of research studies (e.g. Nemani et al., 2003; Hicke et al., 2002; Lobell et al., 2002). The NDVI is linearly related to the fraction of photosynthetically active radiation absorbed by green biomass (fPAR) and to the net primary production (NPP; Asrar et al., 1985; Myneni and Williams, 1994; Paruelo et al., 1997). For minimizing the possible remaining contamination in the NDVI signal due to sensor distortions, we extracted PAL NDVI data for both North and South America from the same temporal span (1989 to 1998), and we discarded the data from 1994 because of gaps in the NDVI series. We preferred to use only NDVI PAL data starting in 1989, and not the complete series (which starts in 1981) in order to have NDVI data corresponding to years close to the date of the land cover classifications (1992 and 1996 for North and South America, respectively). Using this approach we are assuming that the land cover classifications are good pictures of the "average" land use in the 10 years analyzed. Although land cover can change in a single farm plot from one year to another, changes in squares of 6400 ha are more subtle and slow. Our assumption is supported also on census data information that show, for instance, little changes in cropland area between 1992 and 1997 (a 1% decrease in Illinois and Missouri; National Agricultural Statistics Service, USDA, http://www.usda.gov/nass/). Changes in cropland area in the Pampas follow a similar pattern.

We compared the seasonal curves of the NDVI among sites and continents performing a discriminant analysis. The input data for this analysis consisted of a matrix of 36 variables (the average value for each 10-day composite for the 9 years) and 200 or 153 sites (Central Plains or Pampas respectively) classified according to their land use. The discriminant analysis located the centroids of each group in the space defined by the 36 variables mentioned and allowed us to compare the mean seasonal NDVI profile between land cover types and between continents. For the Central Plains we considered a season equaling the calendar year (January 1st to December 31st) and for the Pampas the season was considered to start on July 1st and finish on June 30th. Additionally, for each site we calculated the mean seasonal NDVI curve and then derived the NDVI annual integral (NDVI-I), the maximum NDVI (MAX), and the day of the year with the maximum NDVI value (DMAX). We also analyzed the interannual variability of these two attributes by means of the coefficient of variation (for the NDVI-I and MAX) and the standard deviation (for the DMAX). We performed ANOVA and post hoc comparisons following the Tukey's statistic for comparing the mean values of each NDVI-derived attribute between land cover types and between continents.

## 3. Results

### 3.1. NDVI seasonal dynamics

The discriminant analysis showed significant differences in the seasonal curves of NDVI among the four land cover types and among the Central Plains and the Pampas (Table 1). The differences between land cover types were greater in the Central Plains than in the Pampas. In the Central Plains row crops and small grains were the most different classes while rangeland and pastures were the most similar (Fig. 2 and Table 1). In the Pampas, rangelands and row crops were the most different land cover types while the most similar classes were pastures and rangelands.

Table 1
Mahalanobis distances (lower left side) and *F*-statistic for the distances (upper right side) between the centroids of each group of sites

| | | Central Plains | | | | Pampas | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | RA | PA | SG | RC | RA | PA | SG | RC |
| Central plains | RA | | 72 | 85 | 122 | 276 | 347 | 229 | 348 |
| | PA | 115.2 | | 138 | 148 | 281 | 334 | 225 | 295 |
| | SG | 136.6 | 221.8 | | 215 | 267 | 331 | 215 | 350 |
| | RC | 196.3 | 237.4 | 345.1 | | 344 | 410 | 254 | 301 |
| Pampas | RA | 496.9 | 506.8 | 481.3 | 619.4 | | 17 | 29 | 112 |
| | PA | 561.3 | 541.0 | 535.5 | 663.4 | 30.1 | | 38 | 84 |
| | SG | 469.6 | 463.0 | 441.9 | 521.8 | 64.9 | 78.2 | | 88 |
| | RC | 715.6 | 606.5 | 719.0 | 617.4 | 252.0 | 174.3 | 220.8 | |

Rangelands (RA), pastures (PA), small grain crops (SG), and row crops (RC). All *F* values are significant ($p$<0.01).

The annual NDVI integral for a given class was higher in the Pampas than in the Central Plains, except for the class pastures (Fig. 3a). In the Pampas, row crops and pastures had the highest NDVI integral and small grains had the lowest NDVI integral. In the Central Plains, pastures and small grains were the classes with the highest and lowest NDVI-I, respectively, while row crops had a similar value to rangelands.

The largest differences between the seasonal curves of NDVI between the two continents were observed during the winter and spring seasons, when the NDVI stayed at higher values in the Pampas than in the Central Plains (Fig. 2). The maximum values of NDVI for row crops were similar in both continents. Small grains had a lower maximum NDVI in the Great Plains than in the Pampas, while the opposite occurred with rangelands and pastures (Fig. 3b). In the Pampas, the three cultivated land cover types had a higher NDVI peak than rangelands, while in the Central Plains row crops and pastures had a higher peak than rangelands, but for small grains maximum NDVI was lower (Fig. 3b).

Both in North and South America the NDVI peak of row crops occurred much later in the growing season than in the other land cover types, while the opposite occurred with the class small grains (Fig. 3c). In rangelands and pastures, peak NDVI occurred in late spring in the Pampas and in early summer in the Central Plains. In both continents, small grains had a maximum NDVI during mid spring and row crops peaked in mid summer.

### 3.2. Interannual variability in the NDVI seasonal dynamics

Both in the Central Plains and in the Pampas the interannual variability of the mean annual NDVI was higher in the small grains than in the row crops land cover types (Fig. 4a). However, the interannual variability of NDVI-I in rangelands and pastures was higher in the Pampas (with similar values as small grains) than in the Central Plains (with similar values as row crops; Fig. 4a). A similar pattern was found for the interannual variability of the maximum NDVI value where small grains and row crops were the most and the less-variable classes, respectively,

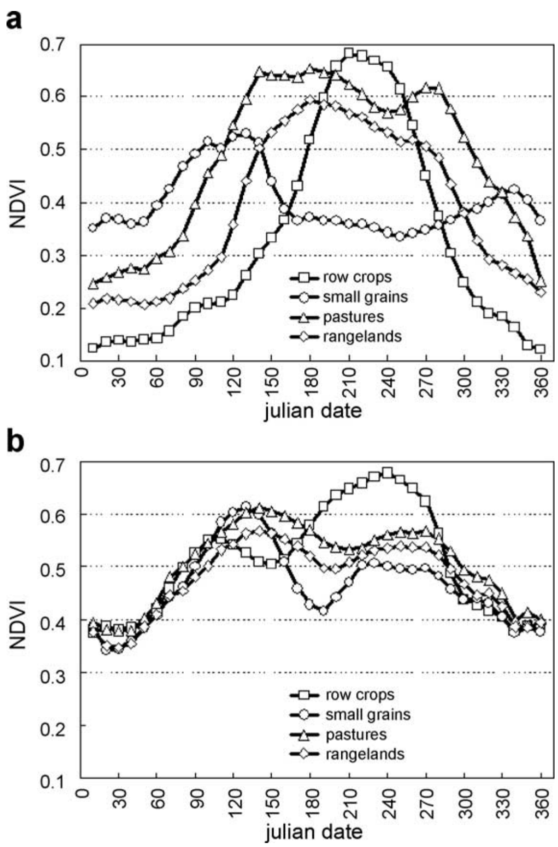


Fig. 2. Mean seasonal patterns of NDVI during the year for the Central Plains (a) and the Pampas (b). Each point represents the mean value for all the sites with the indicated land cover type and for the 9 years analyzed. For the Central Plains we considered a season equaling the calendar year (January 1st to December 31st) and for the Pampas the season was considered to start on July 1st and finish on June 30th.

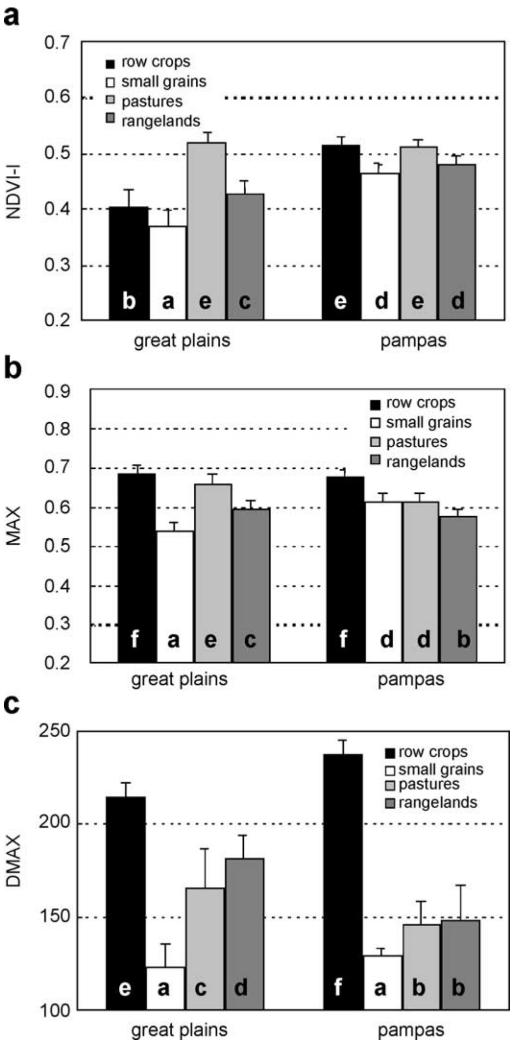


Fig. 3. Mean values of the NDVI annual integral (a), the maximum value of NDVI in the year (b), and the Julian date of maximum NDVI (c) (Note: for the Pampas we considered a growing season beginning on July 1st and finishing on June 30th). Vertical lines on top of the bars represent the standard deviation of each NDVI-derived attribute. Different letters indicate significant differences ($p<0.01$; Tukey's test).

and pastures and rangelands had intermediate values of interannual variability for the maximum NDVI (Fig. 4b).

The interannual variability of the date of maximum NDVI (DMAX), measured through the standard deviation, was low in row crops of the Central Plains and the Pampas (Fig. 4c). In the Central Plains, small grains showed the highest interannual variability of DMAX while rangelands and pastures had intermediate values. In the Pampas, pastures and rangelands were the most variable classes in terms of the date of peak NDVI (Fig. 4c).

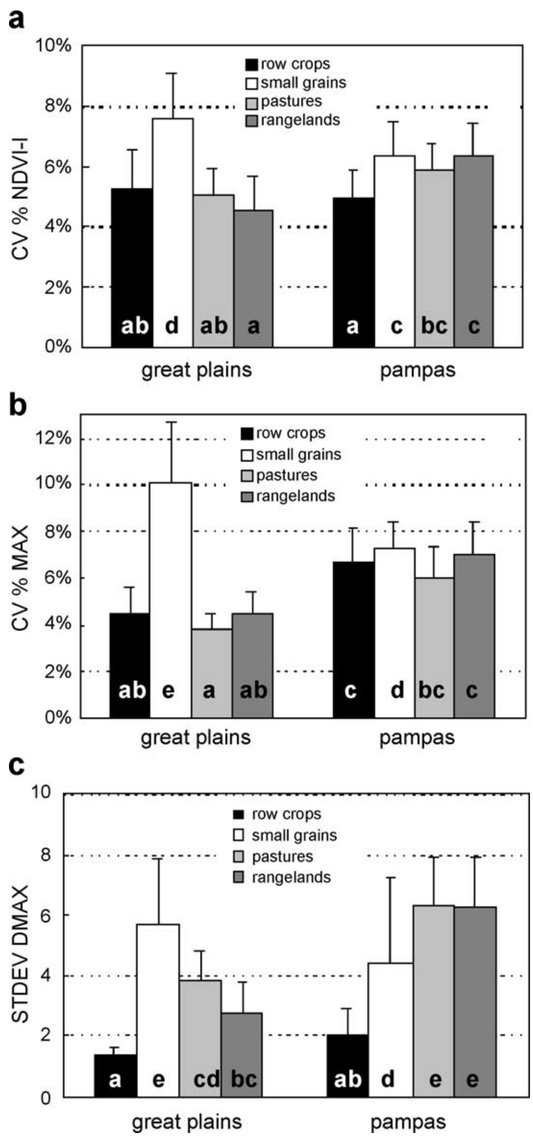


Fig. 4. Coefficient of variation (CV=standard deviation/mean) of the NDVI annual integral (a) and the maximum value of NDVI in the year (b), and Standard Deviation of the Julian date of maximum NDVI (c). Vertical lines on top of the bars represent the standard deviation of each NDVI-derived attribute. Different letters indicate significant differences ($p<0.01$; Tukey's test).

## 4. Discussion

### 4.1. NDVI seasonal dynamics

Our results showed that in North and South America the seasonal dynamic of light interception of the cultivated land cover types differed from the dynamics observed in rangelands, suggesting an important imprint of land use change on one relevant aspect of ecosystem functioning in both areas.

One important difference between the Central Plains and the Pampas was the different behavior of the NDVI seasonal patterns during winter and spring. The vegetation in the Pampas was able to intercept an important portion of the incoming radiation during most of the year while in North America light interception was concentrated in only part of the year. A possible explanation for this may lie in climatic differences. Although we chose areas with similar environmental characteristics and that were shown to share climatic patterns (Paruelo et al., 1995), differences in the thermal annual variability still exist. Winters in the Pampas are mild, with snowfall rarely observed. In the Central Plains, in contrast, the climate is more continental, causing that winters are much colder. Consequently, in North America, the growing season is very well defined. Additionally to the effects of climate, differences in the management of crops may account for some of the differences in the NDVI seasonal dynamics, particularly for row crops areas. In the Central Plains, this class basically corresponds to corn or soybeans, grown mostly in rainfed conditions, with a fallow period between growing seasons. In the Pampas, there are also rainfed corn and soybeans, but since 1990 the wheat–soybean double cropping has gained importance (Calviño et al., 2003). In this cropping system, wheat and soybeans are grown in the same paddock during the growing season. Consequently, the small NDVI peak observed in the row crops class in the Pampas in mid-spring could be accounted for by wheat included in wheat–soybean rotations.

For row crops, within each study area, the seasonal patterns of the NDVI were roughly similar, considering the management differences mentioned above. Compared to rangelands, row crops had a higher NDVI peak, which occurred in average 33 and 89 days later than in rangelands in the Pampas and the Central Plains respectively. The interannual variability of the date of peak NDVI was also lower in row crops than in rangelands, in both regions. Paruelo et al. (2001) found similar results for eastern Colorado, although they did not find differences between the NDVI of row crops and rangelands during the winter months. Guerschman et al. (2003a) also found similar results in the Pampas. The higher NDVI peak of row crops as compared to rangelands indicates a higher radiation interception during the growing season, what additionally indicates a higher net primary production in row crops. A similar pattern was observed by Burke et al. (2000) using bowen ratio towers in eastern Colorado and by Guerschman and Paruelo (unpublished data) in the Pampas, estimating cropland NPP from harvest inventory data. Even though the difference in NDVI-I and then in the fraction of PAR absorbed between row crops and rangelands is only of 15%, row crops intercept such a proportion when incoming radiation is much higher. Such differences may account for the largest differences observed in ANPP between these two land cover types.

For small grains, in both the Central Plains and the Pampas, peak NDVI occurred earlier than in rangelands (58 and 19 days respectively). However, peak NDVI in small grains, compared with rangelands, was lower in the Central Plains but slightly higher in the Pampas. In eastern Colorado (a drier area than the one considered here), Paruelo et al. (2001) found small grains crops to have a slightly higher annual NDVI than rangelands, but Lauenroth et al. (2000) showed that, in eastern Kansas, wheat crops have a lower aboveground net primary productivity than native rangelands, which agrees with our results. Again, for the pampas our results agree with those found by Guerschman et al. (2003a), who found a strong signal of small grain crops on the date of maximum NDVI but a weak effect on the mean annual NDVI. Verón et al. (2002) showed that wheat has a slightly higher aboveground net primary production than rangelands in the Pampas but suggested than when considering total net primary production that trend would be reversed because of the different allocation of carbon to root tissues.

In the Central Plains, small grains was the class with the highest interannual variability for the three NDVI indices. In the Pampas, in contrast, the interannual variability of the NDVI indices was similar between small grains and pastures or rangelands. This is possibly explained by the differences in the management of wheat in the two areas. In the Central Plains, wheat is sown and germinates during fall, remains covered by the snow during the winter and restarts its growth in spring, when it achieves its maximum biomass (USDA/JAWF, 1994; this explains the small peak in NDVI in late fall, Fig. 2). In such a way, wheat growth in the spring becomes very dependent on the amount of water accumulated during fall and winter and in the particular temperature conditions of late fall. These environmental constraints, very variable among years, would generate a large variability in wheat NDVI. As there is no such growth restriction during the winter in the Pampas, the interannual variability of wheat is lower. Paruelo et al. (2001) also found a high interannual variability in NDVI in wheat in Colorado, but suggested that this could be related to the use of a wheat-fallow rotation (one year wheat and the following year fallow) in that area of the USA.

In both continents, the shape of the NDVI curve of pastures was similar to the NDVI curve of rangelands, but the values were slightly higher for pastures than for rangelands during most of the year. As a result, the NDVI integral and the maximum NDVI were higher in pastures than in rangelands, while the date of maximum NDVI did not change importantly. The interannual variability of all the NDVI-derived indices was also not very different between pastures and rangelands, in both continents. However, pastures and rangelands of the Pampas were more variable between years when compared with the same land cover classes in the Central Plains. Again, the climatic differences between regions explained above may account for these differences. Peak NDVI and the date when it occurs in the Central Plains are restricted by the shorter growing season. Also, rainfall is more concentrated in the summer months. In contrast, in the Pampas, the growing season is longer and the particular conditions of precipitation of each year control the exact timing of peak NDVI, resulting in a higher interannual variation.

The methodology used in this paper for comparing current land use and native vegetation forced us to compare areas that are tens or hundreds of kilometers apart. We are comparing, for instance, the NDVI patterns of row crops in Illinois with rangelands in eastern Kansas (Fig. 1), because there are no large areas of remaining rangelands in Illinois. The same occurs in the Pampas. This is an inevitable constraint of using low-resolution satellite imagery. However, the same limitation arises in field-based studies because of the lack of protected areas, particularly in grassland biomes (Garbulsky and Paruelo, 2004) to be used as a reference situation. Despite these shortcomings, our work identified general regional patterns of the impact of agriculture on temperate areas.

## 5. Conclusions

Land use significantly modified the patterns of light interception in former grassland areas. Overall, and in general terms, the impacts of land use on ecosystem functioning are similar in both continents. Row crops have a high NDVI peak, which occurs late in the growing season and is relatively similar among years. The wheat–soybean cropping system, a particularity of the Pampas, produces a different NDVI pattern than row crops on the spring. Small grain crops produce a small change on NDVI maximum but, as row crops, an important effect on the date of peak NDVI. The higher interannual variability of NDVI of small grains in the Central Plains than in the Pampas is perhaps the most important difference between the two regions. The effect of pastures on the NDVI seasonal dynamics is relatively low as it only increases the NDVI (and thus the annual integral and maximum) but it does not change importantly the date of maximum or the interannual variability of all the NDVI-derived indices.

These results confirm previous findings that highlighted important imprints of land use on light interception and carbon uptake over large areas of the Americas. Hicke et al. (2002) and Paruelo et al. (2004) independently showed how land use affected the trends in net primary production over North and South America in the last two decades. Our study supports the idea that, at least in the Central Plains and the Pampas, the changes in land cover that have occurred leaded to similar changes in the way that ecosystems absorb solar radiation and in the patterns of carbon uptake. These changes, covering very large areas, significantly affect the exchange of energy and water between the biosphere and the atmosphere, and have been shown to modify the regional patterns of temperature and precipitation (Stohlgren et al., 1998; Pielke, 2001).

Very often in the environmental sciences, results obtained in a particular location are extrapolated to other similar regions. This is particularly true in areas with less investment in scientific research like South America. The validity of the conclusions derived from these extrapolations is always an important concern in these studies. In this regard, comparative analyses like the one performed here are of invaluable help to better understand the implications of such extrapolations. In the specific case analyzed here, we can conclude that land cover change produced similar changes in ecological functioning.

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