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RESEARCH ARTICLE

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Land cover and land use changes of native forests categories: the case of the Atencio District, Argentina, in the period from 1984 to 2013

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Abstract

Aim of study: The aim of this work was to assess land use and land cover change in Distrito Atencio, near Feliciano, in the province of Entre Ríos, Argentina, from 1984 to 2013 and to make a projection of possible changes in the native forests of Espinal Phytogeographic Region.

Area of study: Espinal Ecorregion, Atencio (Argentina)

Material and Methods: Ten LANDSAT 5-TM and LANDSAT 8-OLI satellite images were used and two classes were distinguished by vectorization: NF-Native Forests and OL-Other Lands. Besides, four categories were defined by supervised classification: CNF-Closed Native Forest, ONF-Open Native Forest, RF-Riverside Forest with Shrub Jungle, and ONG-Open Native Grassland or Savanna.

Main results: It was estimated NF as being 76,619 ha and 59,994 ha for years 1984 and 2013 respectively, which represented a 21.69% reduction over a period of 30 years. In 1984, 32.93% of the district surface was occupied by CNF; the same proportion was covered by ONF; and ONG followed with 16.361 ha (20.66%). In 2013, contrarily, CNF was reduced by 13.67%. Land use change was noted to be directed towards the central eastern region. By 2015, OL are expected to keep 88% of their surface, while ONG areas might suffer a 28.80% and 41.25% reduction for years 2025 and 2050 respectively.

Research highlights: District's areas with higher incidence on changes due to ecosystem fragmentation processes were identified. It is hoped that this study may contribute to settling native forests protection and recovery areas.

Keywords: land change; land cover; Landsat; remote sensing; Espinal Region; spatial trend..

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Introduction

Cultivated lands have globally experienced an increase of 12 million km^2 in the last 300 years at the expense of reducing not only forest areas but also grasslands and wetlands (Richards, 1990; Myers & Turner, 1991). The surface occupied by native forests currently reaches approximately 4,000 million hectares (FAO, 2007), representing 30% of the Earth's surface. By using satellite images at a spatial resolution of 30 m, recent studies by Hansen *et al.* (2013) quantified that forest loss was 2.3 millon km^2 and gain was 0.8 millon km^2 over the period 2000-2012. In such a world context, South America suffered the greatest net forest loss estimated in 4.3 million hectares between 2000 and 2005 (FAO, 2007).

Argentina is not out of the global deforestation phenomenon. It has been estimated that it lost two thirds of its forest patrimony due to agricultural expansion. In 1914, the total surface of native forests was 106 million hectares, which represents 38% of the national territory (FAO, 2001); while by 1956 the forest surface scarcely reached 60 million hectares (Cozzo, 1979). Nevertheless, the native forest surface represented 12.1% of the total land surface of the country in 2005 (FAO, 2009).

Land use and land cover changes are the most salient signature of human occupation of Earth's ecosystems (Weng & Wei, 2003). Land cover is one of the main biophysical attributes that affect ecosystem functioning (Brown *et al.*, 2000); while land use is influenced by economic, cultural, political, and historical factors. In Argentina, the "agriculturation" phenomenon of extensive production systems is a characteristic and frequent case of land use change (Paruelo *et al.*, 2004) that influences significantly on ecosystem goods and services supply.

Studies related to multitemporal analysis of land cover are of highest significance (Conese & Maselli, 1991) and they have been developed more successfully in detailed studies on land use (Jensen & Toll, 1982). On the other hand, Geographic Information Systems (GIS) allow evaluating land cover changes (Treviño, 2002) and also facilitate spatial data management (Qi & Wu, 1996; De Koning *et al.*, 1999). Since the 1990's, researchers have been using Markov models to understand the dynamic characteristics of land use (Meyer & Turner, 1991; Mertens & Lambin, 2000; Flamenco-Sandoval *et al.*, 2007).

Antecedents in the forested region of Argentina (Britos & Barchuk, 2008; Fernández *et al.*, 2012; Navarro Rau *et al.*, 2012) and in the province of Entre Rios (Sabattini & Sabattini, 2012; Brizuela *et al.*, 2013) indicate severe changes in land cover and land use due to deforestation. The Province of Entre Ríos is strategically located in relation to various local and international markets such as Uruguay and Brazil. At the beginning of the 20th century, the province of Entre Ríos had 2.5 million hectares of native shrublands. It was recently estimated that the forest surface in seven departments was 1,565,302 ha (Sabattini *et al.*, 2009 a,b,c,d; 2010a) and that the Feliciano Department contributes with 15.89% of the total surface of native forests in the province.

The object of this work is to evaluate land use and land cover change in Atencio District in the geographical Department of Feliciano, province of Entre Ríos, Argentina, from 1984 to 2013 and make a projection of possible changes in the native forests of Espinal Phytogeographic Region.

Materials and Methods

Atencio District is located in the northcentral region of the province of Entre Ríos and in the south area of Feliciano Departament (Figure 1). The studied area is 79,200 ha and is located at Latitude 30°30'-30°42' S and Longitude 58°36'-59°00' W.

According to Rojas & Saluso (1987), the northern region of Entre Ríos corresponds to the humid temperate climate of plains. The mean annual temperature is

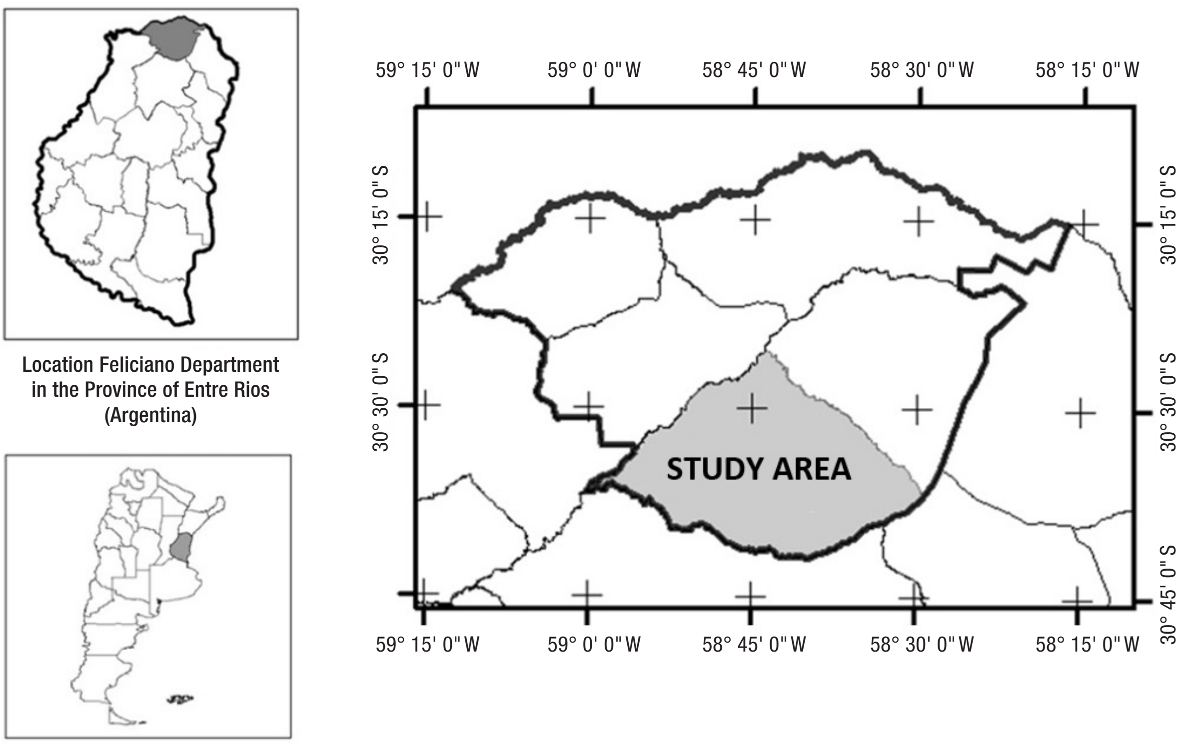

Figure 1. Location of Atencio District in Feliciano Departament, Entre Ríos, Argentina

18.9°C, while average maximum temperature is 24.8 °C. In winter seasons, average minimum temperature is 12.0 °C (Plan Mapa de Suelos [Soil Mapping Plan], 1986). Mean annual rainfall is 1,300 mm mainly concentrated between the months of October and March.

Native forests of Atencio District are quite heterogeneous in appearance and in the arboreal stratum structure and shrub stratum develoment, depending on soil diversity and the profuse hydrographic network running across the region. In general, the current state of the native forest is characterized by the arrangement of plant succession where it is possible to identify: virgin or pristine (stable) forests at the final stage of succession, successional forests that correspond to intermediate stages in which diversity is improved but the native forest is not stabilized, and renewable shrublands at the beginning of the succession after land clearing where *Acacia caven* usually predominates (Sabattini *et al.*, 2013b).

The area under study (Cabrera, 1976) corresponds to the Espinal Phytogeographic Province, which is characterized by xerophilous forests dominated by *Prosopis nigra*, *Prosopis affinis,* and *Acacia caven*. The so-called “wetlands with shrublands” and “shrublands” are also found, which correspond to the Paranaense Phytogeographic Province. According to Sabattini *et al.* (1999), the latter denomination corresponds to those native forests that, judging by their conjunction and transition, are located in proximity to rivers and streams and include elements of both Espinal and Paranaense Phytogeographic Provinces.

For allocating classes and categories for native forests in Atencio District, the following satellite images were used: (path/row: 226/82) LANDSAT 5-TM (11/04/1984, 29/10/1987, 21/10/1990, 27/09/1993, 22/11/1996, 15/11/1999, 27/10/2004, 16/10/2008 y 31/10/2011) and LANDSAT 8-OLI (07/12/2013) taken from USGS Global Visualization Viewer (EROS). The false-color composite composition of satellite images used is RGB-543 since it allows to distinguish Native Forest categories.

Atmospheric calibration was performed by using the COST model (Chavez, 1996). Georeferencing was based on a pattern satellite image by applying 50 to 75 sample points to obtain an average quadratic error that is smaller than pixel size (Chuvieco, 1996).

A manual vectorization was carried out, distinguishing classes NF-Native Forests (natural environments defined by their characteristic arboreal structure) and OL-Other Lands (farming and ranching areas, irrigation dams, urban zones, roads and routes, and rural settlements), thus creating a thematic layer with the particular attributes for each of the 10 selected images. Vectorization was based on the interpretation of visual patterns for each class, land regularity and spectral signatures uniformity; and it was confirmed by analyzing geo-referenced censuses in field (Sabattini *et al.,* 2009c; 2013a). Photographs of fields and interviews with local producers were also taken into account to confirm the aforementioned situation.

Subsequently, images of native forest surface taken in 1984 and 2013 were used to perform maximum likelihood supervised classification with bands 5, 4, and 3, training places being previously created for each class. Spectral bands TM3, TM4, and TM5 correspond to red, near-infrared, and mid-infrared wavelengths respectively, which are combined in a FCC-543. This is considered the most suitable combination for distinguishing vegetation and forest types of different forest regions (Horler & Ahern, 1986; Lencinas & Farías, 2005). Four Native Forest categories were distinguished: CNF-*Closed Native Forest* (presenting shrub and tree stratum covering more than 50% of land surface), ONF-Open native Forest (presenting tree and shrub stratum covering less than 50% of land surface), RF-Riverside Forest with Shrub Jungle (100% covered by trees and multi-stratified system), and ONG-Open Native Grassland - Savanna (ecotonal areas between grassland and forest biomas). These Native Forest categories have been described by Sabattini *et al.* (1999; 2009 a,b,c,d; 2010b), considering height of tree stratum (high forest: more than 6 m high; low forest: less than 6m high) and covering of shrub stratum (open and closed) as structural features. These characteristics correspond to Categories Forests and Other Forrest Lands areas according to FRA, 2010. A contingency matrix (Chuvieco, 1996), the global reliability index (0-100%) and Kappa index were assessed in each classification.

Native Forests classes and categories were identified by gathering 297 instances of information in surveyed works by Sabattini *et al.* (2009c, 2013a), referenced with GPS and in which sample points were performed with preferential method (Matteuci & Colma, 1982). In each sample point, a form was filled for native forest characterization, specifying the most conspicuous tree (native and exotic) and shrub species characterizing plant succession state, native forest type, and degradation as follows: overgrazing, thinning, naked soil, fire and land clearing (Sabattini *et al.*, 2010c).

Changes occured in land cover classes from 1984 and 2013 ware analyzed by using the Change Analysis module. Maps were obtained to show the changes ocurred in every class and to depict losses, gains, and remains for each class. Predictive trend about the possible land cover changes among classes and categories of native forests was carried out by using the Change Prediction module for years 2025 and 2050 (Eastman, 2009).

Results

Changes of Native Forests and Other Lands

According to the analysis of LANDSAT images, 76,619 ha of Native Forests were estimated for Atencio District in 1984, which represents 96.74% of the district's total surface. The remaining areas corresponded to Other Lands. There is no record of areas with dams from 1984 to 1993 but they are detected since 1996. Figure 2 shows the surface occupied by Native Forests and Other Lands in Atencio District for each date of the study. In 2013, the proportion of Native Forest represented 75.75% (59,994 ha) of the total surface. It is to be noted that in the last 30 years native forest areas decreased to 16,624 ha, which represents a 21.69% reduction in relation to this class.

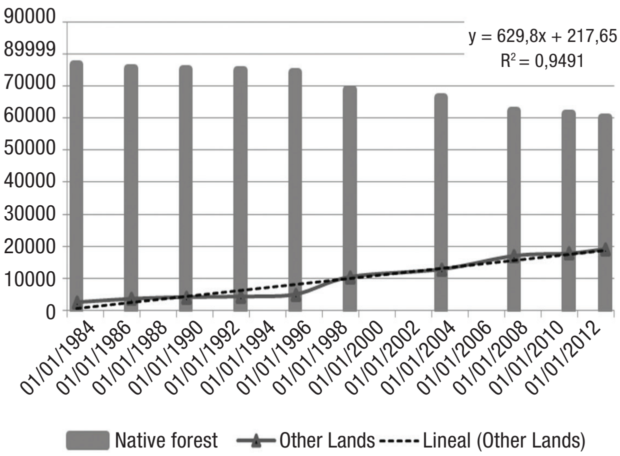

Figure 2. Evolution of Native Forest and Other Lands areas in Atencio District from 1984 to 2013.

The relative weight of Other Lands is due to the increase in the areas devoted to dams for irrigation, where there was a significant increase between 1996 and 1999: from 92 ha to 2,038 ha respectively. Later on, the increase was significant with values close to 2,709 ha in 2013, which represents 14% of Other Lands surface.

Occupation of Native Forest categories

Native Forest categories were classified in the 1984 and 2013 images, identifying their spatial location (Figure 3A and 3B) and surface estimation (Table 1). In 1984, 32.93% of the district's surface was occupied by Closed Native Forests, representing 26,081 ha. The same proportion was covered by Open Native Forests (Table 1). Open Natural Grassland-Savanna category follows with 16,361 ha (20.66%) and is mostly located in the northcentral region of the district (Figure 3A). Riverside Forests occupied 11.53% of the department's surface (9,134 ha); and Other Lands covered the smaller proportion (3.28%). On the contrary, when compared to 1984, Closed Native Forests had a 13.67% reduction in 2013, representing 22,514 ha (28.43% of the district's surface). Open Native Forests represent 25.36% (20,080 ha), recording a 19.75% loss in relation to the initial cover (Table 1). It is important to mention the 22.22% increase of Riverside Forests in 2013 when compared to year 1984, representing 11,164 ha (14.10% of the total district's surface in 2013).

Table 1. Surface estimation for each Native Forest categories in 1984 and 2013

Native Forest categories	11/04/1984		07/12/2013	
	Surface (ha)	Percentage (%)	Surface (ha)	Percentage (%)
CNF	26,081	32.93%	22,514	28.43%
ONF	25,021	31.59%	20,080	25.36%
ONG	16,361	20.66%	6,428	8.12%
RF	9,134	11.53%	11,164	14.10%
OL	2,597	3.28%	19,192	24.23%
Total	79,194	100.00%	79,378	100.23%

Other Lands category increased considerably, occupying 19,192 ha (24.23% of the district surface) in 2013 (Figure 3B). This is equivalent to a 6.39 times increase in relation to 1984. In contrast, Open Natural Grassland-Savanna category suffered a significant decrease in occupation, reaching 6,428 ha in 2013 (8.12% of the district's surface). Figure 3B shows the increase of Other Lands areas located in the eastern zone of the district.

Satellite images classifications had good global reliability indexes for both dates: 76.4% for 1984 and 82.7% for 2013. The Kappa index is 0.654 and 0.762 for years 1984 and 2013 respectively. Both indexes were qualified as good according to Chuvieco (1996). According to the confusion matrix, confusions were observed between Open Native Forest and Open Natural Grassland-Savanna categories in 1984. In 2013, in contrast, better results were obtained in distinguishing each class (Table 2) while the aforementioned confusion remains.

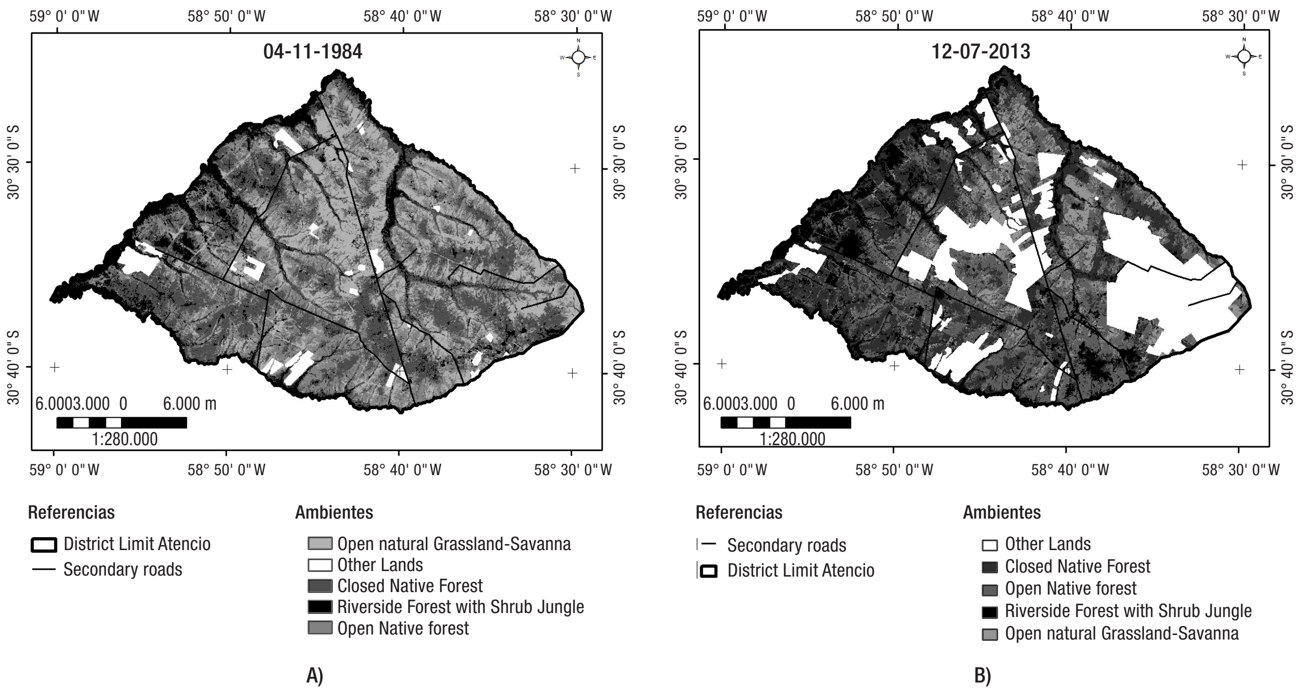

Figure 3. Environment map of Atencio District, Feliciano, Entre Ríos, Argentina. A: year 1984; B: year 2013.

Table 2. Confusion matrix of supervised classification expressed in percentages (%)

	ONG	RF	CNF	ONF
Year 1984				
ONG	76.66	0	0.75	25.42
RF	0.03	90.47	7.26	0.41
CNF	1.33	9.33	82.07	10.68
ONF	21.98	0.2	9.92	63.49
Year 2013				
ONG	87.68	0.03	0.95	20.96
RF	0.07	96.82	4.32	0.23
CNF	2.22	2.88	75.68	4.93
ONF	10.02	0.27	19.05	73.87

Dynamics of Changes in Native Forest Categories

First of all, it is important to mention that over the period 1984 and 2013, approximately 31,650 ha remained unchanged, which would indicate that 40% of the district's surface remained without any changes in the ecosystem structure. The district surface conversion from Other Lands to Native Forests was 0.68% of the district surface, representing 540.12 ha. The significance conversion rate was towards Closed Native Forest category (256 ha) while 60% of the district's surface (47,520 ha) suffered changes in system composition. During the analyzed period, 35% of the surface that had changes corresponds to Other Lands class and would indicate a total change in vegetation structure and composition of natural systems (Figure 4).

The main changes occurred in Open Natural Grassland-Savanna category, which constituted a negative conversion of 5,903 ha to Other Lands. However, other Native Forest categories were suppressed as Closed Native Forest, losing 5,497 ha and 5,007 ha of Open Native Forest (Figure 4).

At the same time, there was a conversion of 5,375 ha from Open Native Forest category to Closed Native Forest, which would indicate a degradation process of these ecosystems as a result of shrub expansion in a competition for light and nutrients against herbaceous species. This process also took place in Open Natural Grassland-Savanna category but in a lower proportion (2,236 ha).

As regards Riverside Forest with Shrub Jungle category, it has suffered changes because local producers use wire fences to avoid problems of cattle handling in pasturelands near water courses. This process, thus, was evidenced in the 5,774 ha increase of this category, belonging 53.56% to Closed Native Forest followed by Open Native Forest (36.99%), and the remaing proportion to Open Natural Grassland-Savanna.

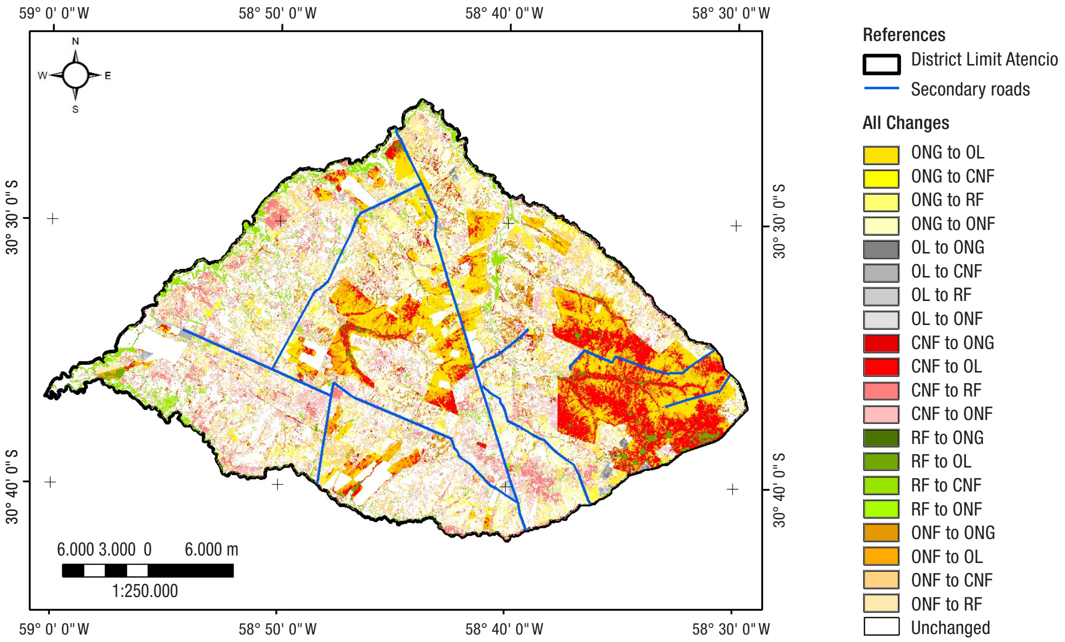

Figure 4. Land cover changes in Atencio District (1984-2013)

By carrying out isolated analyses, it was shown observed that Other Lands class lost 539 ha in the period between 1984 and 2013, which were converted to other areas while 2,052 ha remained in the category. Gain areas of this class represent 17,130 ha (Figure 5A). On the contrary, by analyzing the Closed Native Forest category (Figure 5C), a 14,558 ha loss is noted, while gains were 10,962 ha. It is also important to mention that 11,540 ha of this category remained unchanged. The most relevant losses are identified in the central eastern sector and are associated to conversion to Other Lands. Changes behaviour for Open Native Forest category is similar to that for Closed Native Forest category as regards losses and persistence of this cover (14,922 ha and 10,093 ha respectively). Contrarily, gains of this ecosystem were lower, recording 9,986 ha over the period under study. Figure 5B shows that the area in which these ecosystems remained is the southeastern region, which borders Provincial Route No. 28.

Open Natural Grassland-Savanna areas presented the highest losses over the analyzed period: approximately 13,243 ha in the central western region of the district (Figure 5D). Threfore, only 3,114 ha remained and 3,307 ha were gained in the central northern region of the district. In Riverside Forest with Shrub Jungle category, a 4,280 ha reduction was observed in the borders of Feliciano Stream, while 6,156 ha were gained. In this case, it was due to fluvial action of the stream, which refers to greater energy absorbed by Band 3 and is interpreted as a swelling or downspout condition (Figure 5E).

Trends of change in land cover and use

Taking into account transition matrixes for years 2025 and 2050, Other Lands areas are expected to keep 88% of their surface by 2025. Meanwhile, Open Natural Grassland-Savanna cover is expected to have a 28.80% conversion to Other Lands. Likewise, 12.69% of Closed Native Forests and 9.91% of Open Native Forests will become Other Lands. Probability that Closed and Open Native Forests will remain is 56.61% and 54.47% respectively (Table 3A). The probability that Riverside Forests will be modified is low or null and they are expected to keep 69.57% of their surface.

Permanence probability for Native Forest categories is expected to be notably reduced by year 2050 (Table 3B). It is expected that 35% of the current surface of Closed Native Forests (7,880 ha) to remain unchanged, which means a significant reduction when compared to year 2025. In addition, 25.75% of the surface in this category will be converted to Other Lands, while 15.11% would turn into Riverside Forests with Shrub Jungle due to weed expansion by smaller shrub and tree species. On the contrary, Other Lands class will make new contributions to Open Natural Grassland-Savanna category, since 41.25% of the surface in this category is likely to be converted to areas for agricultural production or forage taking into account that they correspond to areas with high agroecological potential.

A significant increase in Other Lands areas (29,070 ha) would be observed by year 2050 as a result of a decrease in Open Natural Grassland-Savanna (74%),

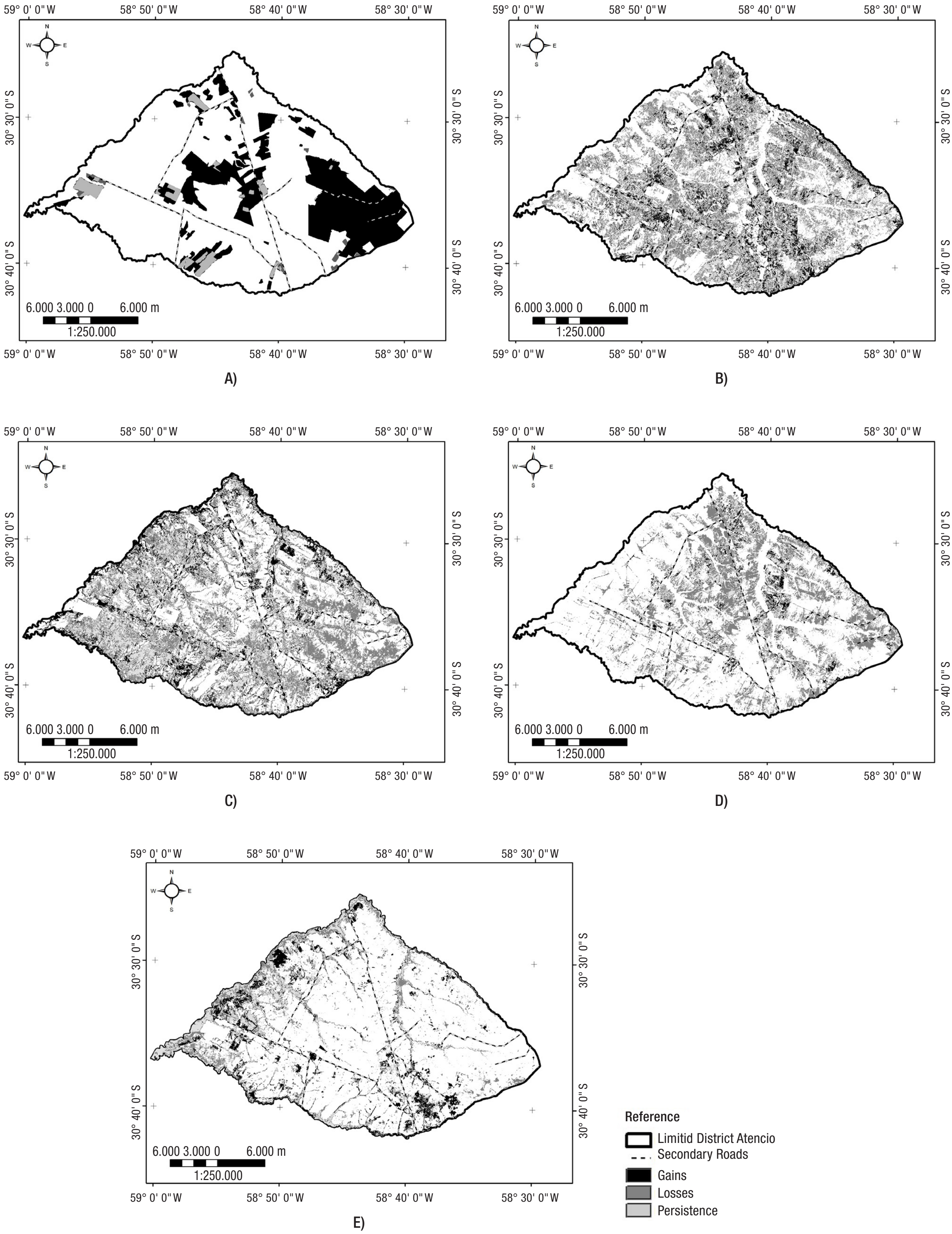

Figure 5. Spatial location of gains, losses, and persistence of Other Lands class (A) and Native Forest category in Atencio District from 1984 to 2013: Open Native Forest (B), Closed Native Forest (C), Open Natural Grassland-Savanna (D) and Riverside Forest with Shrub Jungle(E).

Table 3. Probability of Change for Native Forest class and categories: A- Year 2025 and B- Year 2050. References: OL Other Lands; CNF: Closed Native Forest; ONF: Open Native Forest; ONG: Open Natural Grassland-Savanna; RF: Riverside Forest with Shrub Jungle

	OL	CNF	ONF	ONG	RF
		A - Year 2025			
OL	88.33	6.26	1.48	3.27	0.66
CNF	12.69	56.61	18.65	1.21	10.84
ONF	9.91	18.37	54.47	11.52	5.72
ONG	28.8	8.51	33.12	29.49	0.08
RF	0.71	29.72	0	0	69.57
		B - Year 2050			
OL	74.21	11.96	6.31	4.33	3.18
CNF	25.75	35.09	19.94	4.11	15.11
ONF	25.82	24.29	30.72	8.7	10.47
ONG	41.25	17.36	25.46	10.72	5.2
RF	10.7	37.72	7.65	0.97	42.97

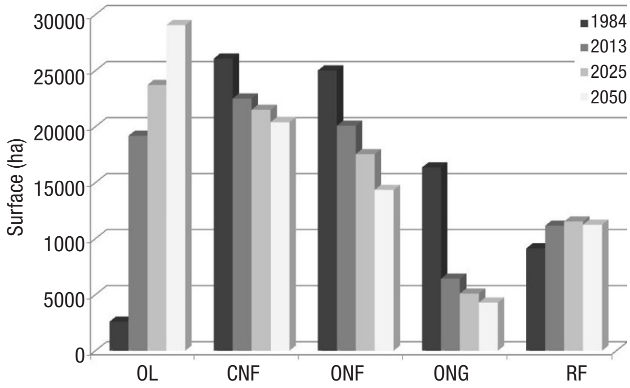

Figure 6. Projection of surface for Other Lands classes and Native Forest categories by 2025 and 2050. References: OL Other Lands; CNF: Closed Native Forest; ONF: Open Native Forest; ONG: Open Natural Grassland-Savanna; RF: Riverside Forest with Shrub Jungle.

Open Native Forest (42%), and Closed Native Forest (22%) categories. An increase in Riverside Native Forest with Shrub Jungle category will be also observed (Figure 6).

Discussion

Land use change phenomenon became evident in Atencio District during the period from 1984 to 2013 due to an increase in Other Lands class and consequent decrease in all Native Forest categories. The studied area is located in a region affected by intense agriculturation and sudden land use change, moving from extensive cattle ranching in natural shrublands to rice and soybean cultivation (Díaz *et al.,* 2009). It is important to mention that over the first 10 years (1984-1996), the surface devoted to Other Lands kept a 206 ha/year trend, while a positve linear trend with a higher change rate is noted in the subsequent period (1996-2013). A global average increase of 629.8 ha/year was estimated for the period 1984-2013 (Figure 2). In turn, the increase of damming up areas for irrigation since 1996 is a result of two necessary conditions for rice cultivation: water availability in quantity and quality together with the impervious subsuperficial horizon of soils (Muzzachiodi, 2007).

This phenomenon was also observed in other regions of Argentina Espinal Phytogeographic Region. The situation is clearly serious in the Province of Córdoba where a very strong decline was detected of Chaco Forest, disappearing over 90 % of the original forest between 1966-1999; while only in four years, 1998-2002, the decline was 12 %, equivalent to an annual rate of 2.93%. This value was the highest in the country and one of the highest rates in the world (Reboratti, 2010).

It should be highlighted that Muzzachiodi (2007) estimated a net change of 25,220 ha in Feliciano Departament from 1987 to 2006. These hectares were converted to agricultural areas and represent 7.70% of the department's surface over 19 years. According to statistics by the SIBER Project of Entre Rios Grain Exchange, 13,200 ha and 29,700 ha were cultivated in Feliciano Department during the agricultural campaign of 2000/2001 and 2012/2013 respectively, which represents a 225% increase.

Agricultural frontier expansion in the district occurred in the central eastern region, associated to proximity and accessibility to paved routes, leads to agricultural frontier expansion due to higher availability of production factors (Briassoulis, 1999); and, at the same time, is due to an edaphological aptitude with agricultural characteristics (Plan Mapa de Suelos [Soil Mapping Plan], 1986). However, in the south western and western region, nearby Provincial Route No. 20, soils with shallow superficial horizon are found with high water retention on its surface producing conditions of radicle anoxia. Few crops may adapt or tolerate such condition, but plant composition of native forest is very well adjusted, and there are species of *Carex*, *Cyperus* or *Eleocharis*, which have medium forage potential.

Over the period between 1999 and 2004, moreover, there was a decrease in Other Lands areas in the western region. Other Lands areas conversion to Native Forest during the period from 1999 to 2004 may be due to farm neglect and, consequently, it gives rise to the secondary succession of the forest. This process is also associated to weather variability (droughts and floods) and to variations in farm products prices, among other causes. In addition, this region presents edafic limitations for farming activity, the latter being quite marginal and scarsely stable over time (Plan Mapa de Suelos [Soil Mapping Plan], 1986).

More recent studies carried out in Feliciano Department would indicate not only native forest surface by 2008 but also its conservation level (Sabattini *et al.*, 2009c). Comparing this data with Muzzachiodi (2007) work, the trend of native forests can be outlined for that area of Entre Ríos. Therefore, native forest represented 79.27 % of the total department's surface. According to its conservation state, 79.33% of the forest surface corresponded to the Red Zone (high level of conservation) and Yellow Zone (medium level of conservation), while 20.17 % are forests with low level of conservation (Green Zone). This enables the possibility of changing land cover –land clearing– and land use –agricultural use.

Other Lands conversion to Native Forests is due to farm neglect for various reasons (biological, productive, technical, and economic). These lands start to convert to initial forest sucessions that are called 'renewable' and are associated to loss of soil productivity as a result of erosion or lack of planning e.g. crop rotation. It could be also related to a sample error (Sabattini & Sabattini, 2012).

It can be also highlighted that the area under study is located in a region where the impact of natural system conversion is lower when compared to other areas with marked 'agriculturation'. In another study carried out in Departamento La Paz (Entre Ríos), in Alcaraz 2° District, which is an area highly impacted by land clearing, native forest was estimated to represent 31.97% of the district's total surface by 2011 (Sabattini & Sabattini, 2012).

Land use change in Atencio District confirms that "the substitution of agriculture for native forests in the province had a considerable growth in the last years, thus increasing hydric erosion and loss of streams flow volume" (Casermeiro *et al.*, 2001; Muñoz *et al.*, 2005). In turn, the pattern of change, in areas where deforestation of Atencio District predominates, is geometric in the form of patches, corridors and islands (Mertens & Lambin, 2000), creating a fragmented environment that results in loss of biodiversity (Bustamante & Grez 1995) and soil degradation (Farina, 2006).

The resulting deforestation was produced in three stages, as it is expressed by Reboratti (2010). Degradation and loss of native forests by selective logging of valuable species was the starting point; then fragmentation or patch deforestation reducing forest areas in smaller fragments from the original, and finally the complete and total deforestation of the native forest. This phenomenon was observed in the Northern area of Atencio District due to the increasing rice cropping and to the construction of dams for irrigation (Diaz *et al.*, 2009).

On the other hand, landscape fragmentation observed as an increase of Other Lands causes changes in physical flows across the landscape, such as radiation, wind, water and can have important effects on the remaining native vegetation (Saunders *et al.*, 1991). Removing native vegetation and substituting it with cultivable species with different morphology and phenology, as it was the case in the studied area, may alter radiation balance and affect the nutrient cycling process (Parker, 1989) and it may alter the local water regime (Kapos, 1989). Besides, in fragmented landscapes it increases wind exposure leading to damages on vegetation (Lovejoy *et al.*, 1986).

Closed Native Forests conversion to Open Native Forests may be due to the incorporation of technology used for recovering these ecosystems. Many authors, then, posed strategies for handling and restoring forests by means of mechanical and chemical practices (Cottani & Sabattini, 2006); and considering phosphated fertilization, intercropping, cattle load handling, grazing time and pressure (Casermeiro & Spahn, 1999) would allow taking these factors as grounds for analyzing the occurred changes.

Changes observed in Open Native Forest and Open Natural Grassland-Savanna categories would be due to issues related to classification processing, taking into account the extent of confusion between both categories (Table 2). Ecotonal proximity between grassland and forest biomas creates a mosaic view of areas with Open Low Native Forest, Savannas, and natutalized Grasspland, as pointed out by some authors (Sabattini *et al.*, 2009c).

Conclusions

District's areas with higher incidence on changes due to ecosystem fragmentation processes were identified. By using this information, trends were projected for 2025 and 2050. In this way, the study would allow settling native forest protection and recovery areas so as to improve the layout and planning of strategies for conservation and use of forest areas in Atencio District. The testing of this remote sensing technique together with field support in identifying vegetation units shows possible answers to solve environmental problems at local and regional scales.

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References

Briassoulis H, 1999. Analysis of land use change: Theoretical and modeling aproaches, The web Book of Regional Science, Regional Research Institute, West Virginia University, USA.

Britos AH, Barchuk AH, 2008. Cambios en la cobertura y en el uso de la tierra en dos sitios del Chaco Árido del noroeste de Córdoba, Argentina. Agriscientia, 15(2):97-110.

Brizuela AB, Sabattini, RA, Sabattini JA, 2013. Capítulo 16. Utilización de imágenes Landsat en la Cuenca del Arroyo Feliciano para la detección de cambios en la ocupación agrícola en el período 1990-2010 (Entre Ríos). 349-360 pp. En: Bases conceptuales y metodológicas para el Ordenamiento Territorial en el Medio Rural. Región Centro Argentina. 672 pp.

Brown DG, Pijanowski BC, Duh DJ, 2000. Modeling the relationships between land use and land cover on private lands in the Upper Midwest, USA. J Environ Manage (59): 247-263. http://dx.doi.org/10.1006/jema.2000.0369

Bustamante R, Grez A, 1995. Consecuencias ecológicas de la fragmentación de los bosques nativos. Ciencia y ambiente, 11(2): 58-63.

Cabrera AL, 1976. Regiones Fitogeográficas Argentinas. Enciclopedia Argentina de Agricultura y Jardinería. 2da Edición. Tomo II, Fascículo 1. Editorial Acme. Buenos Aires. 85 pp.

Casermeiro J, Spahn E, 1999. Sistemas agroforestales para pequeños productores de zonas húmedas. Centro Zip. Santa Fe, Argentina. 214 pp.

Casermeiro J, De Petre A, Spahn E, Valenti R, 2001. Efectos del desmonte sobre la vegetación en el suelo en un bosque nativo. Invest Agraria: Sistemas y recursos Forestales 10(2): 233-244.

Chavez PS, 1996. Image-Based Atmospheric Corrections – Revisited and Improved, Photogramm Eng Rem S 62(9): 1025-1036.

Chuvieco E, 1996. Fundamentos de Teledección Espacial. 3ª Edición Revisada. España. Editorial Rialp. 568 pp.

Conese C, Maselli F, 1991. Journal of Photogrammetry and Remote Sensing. Elsevier Science Publishers B. V. Amsterdam (46): 187-197.

Cottani F, Sabattini RA, 2006. Manejo y control de arbustivas en un pastizal con alta carga animal en pastoreo rotativo. Revista Científica Agropecuaria 10 (2): 109-120.

Cozzo D, 1979. Árboles forestales, maderas y silvicultura de la Argentina. Enciclopedia Argentina de Agricultura y Jardinería. 2 da edición AGME S.A.C.I. Buenos Aires. 156 pp.

De Koning G, Verburg P, Veldkamp A, Fresco O, 1999. Multiscale modeling of land use change dynamics in Ecuador. Agricultural Systems. 61: 77-93. http://dx.doi.org/10.1016/S0308-521X(99)00039-6

Diaz EL, Romero EC, Boschetti NG, Duarte O, 2009. Vulnerabilidad del agua subterránea en la cuenca del Arroyo Feliciano. Entre Ríos, Argentina. Bol Geológico y Minero, 120 (4): 533-542.

Eastman JR, 2009. IDRISI Taiga: guide to GIS and Image Processing. Worcester, MA: Clark Lab: Clark University. 325 pp.

FAO, 2001. Global Tables in FRA 2000 Summary Report-Overview. Rome, Italy. 150 pp.

FAO, 2007. Situación de los Bosques del Mundo 2007. Rome, Italy. 143 pp.

FAO, 2009. Situación de los Bosques del Mundo 2009. Rome, Italy. 158 pp.

Farina A, 2006. Principles and methods in Landscape Ecology. Toward a Science of Landscape. 2nd ed., XXII, 412 pp.

Fernández JM, Britos A, Barchuk A, 2012. Cambios y tendencias de la cobertura/uso de la tierra en zonas áridas: Expansión de la frontera agrícola en una cuenca del Chaco árido. Rev Asoc Argentina Ecología Paisajes (3): 1-21.

Flamenco-Sandoval A, Ramos MM, Masera OR, 2007. Assessing implications of land-use and land-cover change dynamics for conservation of a highly diverse tropical rain forest. Biol Conserv 138: 131–145. http://dx.doi.org/10.1016/j.biocon.2007.04.022

FRA, 2010. Evaluación de los Recursos Forestales Mundiales. Informe Nacional: Argentina. Departamento Forestal, FAO. Roma, Italy. 66 pp.

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, et al., 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342: 850. http://dx.doi.org/10.1126/science.1244693

Horler DN, Ahern FJ, 1986. Foresty information content of Thematic Mapper data. International J Rem Sens. 405-428 pp.

Jensen JR, Toll DL, 1982. Detecting Residential Land-Use Development as the Urban Fringe. Photogramm Eng Rem S (48): 629-643.

Kapos V, 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. J Trop Ecol (5): 173-185. http://dx.doi.org/10.1017/S0266467400003448

Lencinas JD, Farias MF, 2005. Native Forest Mapping in Patagonian Andes Base don Optical Satellite Imagery. Photogrammetrie, Fernerkundung-Geoinformation I. 147-156 pp.

Lovejoy TE, Bierregaard BO, Rylands A, 1986. Edge and other effects of isolation on Amazon forest fragments. In Burges and Sharpe Editor. Conservation biology. The science of scarcity and diversity, Sinauer Associates, Sunderland, Massachusetts, USA. Pp. 257-285.

Matteuci SD, Colma A, 1982. Metodologías para el estudio de la vegetación. Secretaría General de la Organización de los Estados Americanos, Programa Regional de Desarrollo Científico y Tecnológico, 168 pp.

Mertens B, Lambin E, 2000. Land-cover-change trajectories in southern Cameroon. Ann Ass Am Geogr 90(3): 467–494. http://dx.doi.org/10.1111/0004-5608.00205

Meyer WB, Turner BL II, 1991. Changes in land use and land cover: a global perspective. Cambridge University Press, Cambridge, UK.

Muñoz J, Milera S, Romero C, Brizuela A, 2005. Bosques Nativos y Selvas Ribereñas en la Provincia de Entre Rios. Temas de la Biodiversidad del Litoral Fluvial Argentino II. Instituto Superior de Correlación Geológica Miscelánea, (14): 169-182.

Muzzachiodi F, 2007. Dinámica de la ocupación del uso de suelo en el período 1987-2006 para el Departamento Feliciano de la Provincia de Entre Ríos, Argentina. Trabajo Final de Graduación, FCA-UNER. 111 pp.

Navarro Rau MaF, Matteio H, Barrios R, 2012. Dinámica de la Cobertura y Uso del Suelo: Ecorregión Mesopotamia, Provincias Misiones y Corrientes, Argentina. Informe PNECO 092022 – INTA. 13 pp.

Paruelo JM, Guerschman JP, Baldi G, Di Bella CM, 2004. La estimación de la superficie agrícola. Antecedentes y una propuesta Metodológica. Interciencia 29, 421-427.

Plan Mapa de Suelos Provincia de Entre Ríos, 1986. Carta de Suelos de la República Argentina. Departamento Feliciano, Provincia de Entre Ríos. Serie Relevamiento de recursos naturales Nº3. Convenio INTA Gobierno de Entre Ríos. 96 pp.

Qi Y, Wu J, 1996. Effects of changing spatial resolution on the results of landscape pattern analysis using spatial autocorrelation indices. Landscape Ecology 11(1): 39-49. http://dx.doi.org/10.1007/BF02087112

Reboratti C, 2010. Capítulo 15. Impactos de la expansión agropecuaria sobre la sociedad y el ambiente. 369-390. En: El crecimiento de la agricultura argentina. Medio siglo de logros y desafíos. Reca L.G., Lema D., Flood C. (eds). 1° Edición. Buenos Aires, Argentina. 488 pp.

Richards JF, 1990. Land transformation. In Turner II B.L. (1993): Relating Land Use and Global Land-Cover Change: A Proposal for an IGBP-HDP Core Project. A report from the IGBP-HDP Working Group on Land Use- Land Cover Change. IGBP Report No. 24 HDP Report No.5, 65 pp.

Rojas A, Saluso JH, 1987. Informe Climático de la Provincia de Entre Ríos. INTA EEA Paraná, Publicación Técnica Nº 14. Entre Ríos, Argentina.

Sabattini RA, Wilson MG, Muzzachiodi N, Dorsch AF, 1999. Guía para la caracterización de agroecosistemas del centro-norte de Entre Ríos. Revista Científica Agropecuaria 3: 7-19

Sabattini RA, Ledesma S, Brizuela A, Sabattini JA, Fontana E, Diez JM, Muracciole B, 2009a. INFORME I. Zonificación de los bosques nativos en el Departamento La Paz (Entre Ríos) según las categorías de conservación. Convenio FCA-DGRN-Sec. Producción Entre Ríos, Argentina. 21 pp.

Sabattini RA, Ledesma S, Brizuela A, Sabattini JA, Fontana E, Diez JM, Muracciole B, 2009b. INFORME II. Zonificación de los bosques nativos en el Departamento Federal (Entre Ríos) según las categorías de conservación. Convenio FCA-DGRN-Sec. Producción Entre Ríos, Argentina. 20 pp.

Sabattini RA, Ledesma S, Brizuela A, Sabattini JA, Fontana E, Diez JM, Muracciole B, 2009c. INFORME III. Zonificación de los bosques nativos en el Departamento Feliciano (Entre Ríos) según las categorías de conservación. Convenio FCA-DGRN-Sec. Producción Entre Ríos, Argentina. 20 pp.

Sabattini RA, Ledesma S, Brizuela A, Sabattini JA, Fontana E, Diez JM, Muracciole B, 2009d. INFORME IV. Zonificación de los bosques nativos en el Departamento Villaguay (Entre Ríos) según las categorías de conservación. Convenio FCA-DGRN-Sec. Producción Entre Ríos. 30 pp.

Sabattini RA, Ledesma S, Sabattini JA, Fontana E, Diez JM, Sabattini IA, 2010a. INFORME V. Zonificación de los bosques nativos de los Departamentos Paraná, Nogoyá y Tala (Entre Ríos) según las categorías de conservación. Convenio FCA-DGRN-Sec. Producción Entre Ríos. 38 pp.

Sabattini JA, Sabattini RA, Ledesma S, 2010b. Caracterización del bosque nativo del centro norte de Entre Ríos. XVIII Jornadas de Jóvenes Investigadores. AUGM. Santa Fe, Argentina.

Sabattini RA, Ledesma S, Brizuela A, Sabattini JA, Diez JM, 2010c. Metodología y Criterios para el ordenamiento territorial de bosques nativos de Entre Ríos. III Jornadas Red-VITEC. Mendoza, Argentina.

Sabattini JA, Sabattini RA, 2012. Cambios y tendencias en la cobertura y uso de la tierra durante el período 1991-2011 en el Distrito Alcaraz 2°, Departamento La Paz (Entre Ríos, Argentina). Rev Científica Agropecuaria. 16(2): 59-71.

Sabattini RA, Boschetti NG, Quintero C, Hernandez JP, Befani R, Sabattini I, Cian JC, Sabattini JA, Kruger A, Arbello P, 2013a. Informe Técnico Final: Zonificación: Diagnóstico estado de los montes nativos y tipos de suelos. Convenio FCA-Las Taperitas S.A. 40 pp.

Sabattini RA, Ledesma S, Sione S, Sabattini JA, 2013b. Capítulo 14. Ordenamiento territorial de bosques nativos en la cuenca del Arroyo Feliciano (Entre Ríos). 313-332 pp. En: Bases conceptuales y metodológicas para el Ordenamiento Territorial en el Medio Rural. Región Centro Argentina. 672 pp.

Saunders D, Hobbs R, Margules C, 1991. Biological consequences of ecosystem fragmentation: A review, Conservation Biology (5) 1: 18-27.http://dx.doi.org/10.1111/j.1523-1739.1991.tb00384.x

Treviño E, 2002. Estratificación de la información en el procesamiento digital de imágenes de satélite aplicado a la cartografía de los bosques de Pinus cembroides. Investigaciones Geográficas, Boletín del Instituto de Geografía. UNAM Núm. 44 2000, pp. 54-63.

Weng Q, Wei D, 2003. Land use and land cover change un China under the reform and globalization. Asian Geographer 22: 1-3. http://dx.doi.org/10.1080/10225706.2003.9684095