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RESEARCH PAPER

Vegetation changes after 15 years of abandonment of crop fields in the Pampas Region (Argentina)

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Abstract

S. Boccanelli, E. Pire, and J. Lewis. 2010. Vegetation changes after 15 years of abandonment of crop fields in the Pampas Region (Argentina). Cien. Inv. Agr. 37(2): 45-53. Agriculture has been practised in the Argentine Pampa Region for more than a century. This long history of disturbance has strongly modified the native vegetation of the region. Some original species have disappeared or its area has been remarkably reduced. The objective was to evaluate vegetation changes over time after the abandonment of agriculture practice. Our hypothesis was that over time vegetation in this region will evolve towards a "flechillar" (*Stipa* spp. community) similar to the original vegetation. The experiment was conducted at Zavalla (Santa Fe) Argentina (33º 01' S, 60º 53' W and 50 m.a.s.l.). Vegetation evolution was studied during 15 years (1982-1997) after abandonment, considering four initial crop situations (i.e. wheat, soybean, pasture and tillage). Periodically, we measured species cover and abundance in 60 subplots. Data was analyzed using multivariate methods. We identified several groups corresponding to two very well defined successional stages. The first group was very small, and showed predominance of annual species; the second group showed a reduction or almost disappearance of annuals and an increase in perennials such as *Baccharis salicifolia* (Ruiz & Pav.) Pers. and *Sorghum halepense* (L.) Pers. accompanied by *Carduus acanthoides* L. Therefore, a secondary succession was developed, with a first stage of annual species dominance followed by long life cycle species. However, even after 15 years there was no reversion of the vegetation to the original community.

Key words: Abandoned field, agriculture, disturbance, secondary succession, weeds.

Introduction

Floristic composition and relative importance of species in plant communities changes over time. These changes can be induced by factors external to the plant community such as disturbance, (Burrows, 1990).

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Agriculture and cattle raising produce disturbances of different intensities and size, leading to fragmentation or even extinction of original plant communities. Recovery of the original community will depend on the extension, duration and intensity of the disturbance. Return to the original situation is difficult once a threshold of disturbance has been surpassed (Hobbs and Harris, 2001).

Vegetation of abandoned agricultural fields changes over time, through a secondary succession process (Bazzaz, 1968). Diversity generally increases with succession; relatively low species abundance in a successional community may be due to the development of strong dominance, or to species with allelopathic chemicals or some other effective interference mechanisms (Bazzaz, 1975; Hooper *et al*., 2005).

The Argentine Pampas Region is one of the greatest temperate grasslands in the world. Cattle raising and agriculture have been generalized practices in the region for more than a century. This long history of disturbance has strongly modified the natural vegetation consisting of "flechillares" (*Stipa* spp. communities) (Lewis *et al*., 1985) which have been replaced by crops such as wheat, maize, sunflower, and more recently soybean, which presently is the major crop in area and production. As a consequence, some of the original species of the community disappeared or are confined to refugia. These refugia differ in size and frequency, raging from a few square meters to a few hectares. These small areas form a corridors web of semi-natural vegetation, mainly along old abandoned roads or railways (Ghersa and León, 1999). In the west of Buenos Aires province (Argentina), after the abandonment of agricultural fields a broad leaves weed community appears, which is colonized by *Lolium multiflorum* Lam. during the second year. From the fifth year on, perennial grasses replace annual species, however, very few native perennial species are able to grow in the community until ten years after abandonment (D'Angela, *et al*. 1986; Omacini, *et al*. 1995).

The early succession in abandoned fields in Kansas and Oklahoma (USA) begins with a weedy community stage lasting from 2 to 3 years, followed by an annual grass stage from 9 to 13 years and a perennial bunch grass stage up to 30 years, resulting in a tall grass prairie (Booth, 1941; Perino and Risser, 1972).

Vegetation dynamics of abandoned fields has been of great interest for ecological theory, conservation, restoration and from a socio-economic perspective (Cramer *et al*., 2007).

The objective of this paper is to analyze vegetation changes over time when an agricultural field is abandoned after a long history of anthropic perturbation.

The general hypothesis is that over time vegetation in this region will evolve towards a "flechillar" (*Stipa* spp. community) similar to the original vegetation. The particular hypothesis is that vegetation will evolve following a secondary succession process with a first stage in which annuals that behave as crop weeds predominate and over time these species will be replaced by longer cycle species.

Material and methods

This study was carried out at the "J. F. Villarino" Experimental Farm of the School of Agricultural Sciences, University of Rosario at Zavalla, Argentina (33º 01' S, 60º 53' W and 50 m.a.s.l.). The study area is in the risen or undulated Pampas (Rolling Pampas) (Pasotti, 1981). The relief is flat but slightly undulated. Climate is humid, temperate warm, with an annual rainfall of approximately 1000 mm, mainly in Spring and Summer and a mean temperature of 17ºC (Burgos, 1970). The soil is a well-drained Vertic Argiudol with a profound and evolved profile (Soil Survey Staff, 1960).

The study was done in a 3 hectares field, taken out of agriculture since 1983. Previously, this field, as well as the whole region, had a long history of agriculture. The field was divided in three blocks of the same size, and each block into four 45 x 50 m plots. In each plot, four different initial situations were established at random and they can be considered treatments. Initial situations were: 1) Ploughed, harrowed and abandoned. This situation is taken as a control called "abandoned treatment" (AT). 2) A consociated pasture (*Festuca arundinacea* Schreber, *L. multiflorum* and *Medicago sativa* L.) sown in April 1983, called "pasture treatment" (PT). 3) Wheat crop (*Triticum aestivum* L.), the most common winter crop in the region, sown in July 1983, harvested and abandoned, called "wheat treatment" (WT). 4) Soybean crop (*Glycine max* (L.) Merrill.), the most common summer crop in the region, sown in October 1983, harvested and abandoned, called "soybean treatment" (ST) .Periodically, in five 1 m^2 permanent quadrats laid out at random in each plot, the floristic list was recorded and the cover-abundance was estimated for each species using the Braun-Blanquet (1979) scale. For the numerical data analysis, values were converted to the cover-abundance cuantitative scale of van der Maarel (1979). Vegetation was recorded every two months in the first two years (1984-1985), twice a year (Autumn and Spring) during the following two years (1986-1987), and from then on, once a year at the end of spring. Nomenclature follows Zuloaga *et al*. (1994, 1996, 1999). This study includes the 15 years after abandonment.

Vegetation shifts after field abandonment was studied considers the four initial situations.

Significant differences among the five permanents quadrats within each plot, and among the three plots of each treatment, were studied with the randomization test for multifactorial comparisons (Pillar and Orlóci, 1996), using MULTIV programs (Pillar, 2006). When significant differences were not detected, data were averaged, and therefore, they were reduced. When differences were significant they were not averaged and were considered replications of the same treatment took account the variation of the data. The same test was used for analyzing the differences in floristic composition and species abundance between years and treatments. To reach 1% significance level, 5000 permutations were made as suggested by Manly (1997). Data was analyzed with multivariate methods. Quadrats were classified with the minimal variance method (Orlóci, 1967), using a resemblance matrix of standarized Euclidean distances (Pielou, 1984) and were ordered with PCA (Principal Component Analysis) (Hotelling, 1933) using a species covariance matrix. Analyses were done using PC-ORD programs (McCune and Mefford, 1999). Biplots of samples and species dispersion diagram were made on the plane of the first two axes with SYN-TAX program (Podani, 2001).

Results

A matrix of 202 quadrats x 128 species was constructed with the simplified information. When this matrix was classified with the minimal variance method, five groups were identified (Figure 1), each one characterized by a species set, which became important at different stages of the analyzed period (Table 1). Group I is the initial stage of the consociated pasture samples (PT) between 1983 and 1988. It is a very homogeneous and clearly identified group, probably because it includes perennial species which remained longer (Table 1). Group II contains samples of AT from 1983 to 1986 (Table 1). Group III includes WT and ST samples between 1984 and 1985 and a small group of AT samples (Table 1). Group IV contains samples from the "chilcal" (*B. salicifolia* shrubland) confined to plot B, from 1985 to 1997 (Table 1). Group V gathers samples of the later stages of all treatments (from 1987 to 1997) (Table 1). In this last stage treatments effects vanish and samples are very similar to each other. Vegetation becomes on *S. halepense* with *C. acanthoides* community and a "chilcal" of *B. salicifolia*. The total number of species drops along the analyzed period (Table 1).

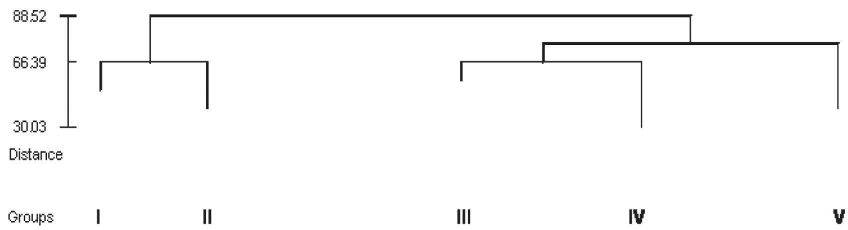

Figure 1. Dendrogram of all treatments samples classified with the minimal variance method. Groups: I: samples of PT (Pasture treatment). II: samples of AT (Abandoned treatment). III: samples of WT (Wheat treatment) and ST (Soybean treatment). IV: *Baccharis salicifolia* community (Chilcal). V: *Sorghum halepense* with *Carduus acanthoides* community.

Table 1. Phytosociological condensed table. Columns correspond to the groups formed by the classification. Values are averages of cover-abundance (van der Maarel scale). Only species with ≥ 0.1 values are shown. Periods (years) of space occupation and total number of species in the different groups of species are shown in Table caption.

Species	G I	G II	G III	G IV	G V
Sorghum halepense (L.) Pers.	6.6	8.3	8.3	8.0	8.1
Medicago sativa L.	6.0	0.4			
Lolium multiflorum Lam.	4.8	1.8	1.6		
Chenopodium album L.	1.5	1.3	2.3		
Festuca arundinacea Schreb.	3.7		0.3		
Digitaria sanguinalis (L.) Scopoli	0.4		1.0		
Ammi sp. L.	3.0				
Cerastium glomeratum Thuill.	1.5	3.5	3.6	1.0	1.6
Carduus thoermeri Weinm.	0.2	1.0	0.7		0.6
Carduus acanthoides L.	2.3	2.6	3.0	4.5	5.1
Cichorium intybus L.	0.2	0.5			
Anagallis arvensis L.	1.5	5.0	0.1		
Bowlesia incana Ruiz et Pav.	0.3	1.3	0.5		
Trifolium repens L.	0.2				
Conyza bonariensis (L.) Cronquist	0.2	1.3	2.6	0.7	0.8
Ammi majus L.		3.3	1.8		
Rumex crispus L.		0.4			
Chenopodium hircinum Schrad.		0.2			
Avena fatua L.		0.5			
Modiolastrum gillesii (Steud.) Krap.			0.2		
Verbena intermedia Gill. et Hook.			0.2		
Glycine max (L.) Merr.			1.7		
Gnaphalium gaudichaudianum DC.		0.7			
Anthemis cotula L.			0.8		
Gamochaeta filaginea (DC) Cabr.			0.3		
Melilotus officinalis (L.) All.			0.2		
Lactuca serriola L.			0.2		
Ammi visnaga (L.) Lam.			0.7		0.1
Triticum aestivum L.			2.1		
Portulaca oleracea L.			0.7		
Sonchus oleraceus L.			0.1		
Medicago lupulina L.			0.2		
Amaranthus quitensis H.B.K.			0.3		
Senecio grisebachii Bak.			0.2		
Baccharis salicifolia (Ruiz & Pav.) Pers.				4.0	
Total species number	24	40	33	25	21
Years	1983-88	83-86	84-85	85-97	1987-97

When the matrix was analyzed with PCA, the first two axes accounted for only 33% of the total variance. The biplot on the plane of the first two axes of data for samples and species showed the same five groups of the classification (Figure 2). Group I is a set of samples characterized by species of the consociated pasture (*L. multiflorum*, *M. sativa* and *F. arundinacea*) (PT). Group II is a sample set characterized by species that behave as weeds (*Anagallis arvensis* L., *Ammi majus* L. and *Bowlesia incana* Ruiz et Pavon.) which appear immediately after abandonment in the AT plots. Group III is a small samples set of WT and ST. The group is formed by species adapted to annual crops which soon disappear from the field without agriculture. Group IV belongs to the *B. salicifolia* shrubland (chilcal). And group V belongs to the community of *S. halepense* y *C. acanthoides*.

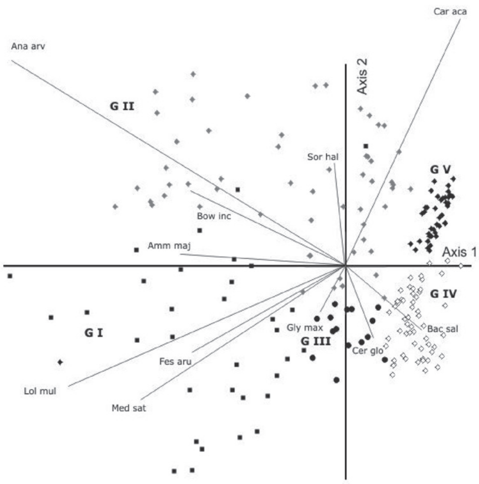

Figure 2. Biplots of the scatter diagram of all treatments samples on the plane of the two first PCA axes and species importance represented by arrows length. Species name abridgements are: *Ammi majus* (Amm maj), *Anagallis arvensis* (Ana arv), *Baccharis salicifolia* (Bac sal), *Bowlesia incana* (Bow inc), *Carduus acanthoides* (Car aca), *Cerastium glomeratum* (Cer glo), *Festuca arundinacea* (Fes aru), *Glycine max* (Gly max), *Lolium multiflorum* (Lol mul), *Medicago sativa* (Med sat), *Sorghum halepense* (Sor hal). Sample groups are: **I** (■) pasture treatment (PT), **II** (♦) abandoned treatment (AT), **III** (●) wheat and soybean treatments (WT, ST), **IV** (◇) *Baccharis salicifolia* community (Chilcal) and V (♦) *Sorghum halepense and Carduus acanthoides* community.

When the randomization test for multifactorial comparisons was used with all treatments, it showed no significant differences between treatments, nor between years, but the interaction (treatment x years) was significant ($P \leq 0.05$) (for both factors), it is shown by changes observed over time, as in the case of PT, where the species disappeared after the fifth year of the experiment, and WT and ST which remained in the community a short period of time (Table 1).

Discussion

Results show that changes in vegetation during the analyzed period show a directional course, associated with a successional process. This process consists of the replacement of one species by another. Immediately after the field abandonment there is a short period with vegetation of short cycle species which were weeds of the crop present in the initial situation. Some of the weed species are *Conyza bonariensis* (L.) Cronq. *Cerastium glomeratum* Thuill., *Chenopodium album* L., *A. arvensis*, *B. incana* (Table 1). The pioneer community of short cycle annual species was already observed in abandoned fields by several authors (Booth, 1941; Kaputska and Molenski, 1976; Perino and Risser, 1972; D'Angela *et al*., 1986; Omacini *et al*., 1995), and the most commonly observed pattern is a rapid exponential increase of its populations and all microsites are occupied in only one or two generations (Law, 1981).

The establishment of short cycle annuals at the beginning of this situation may be due to the presence of long-lived seed banks (Roberts, 1981), while early successional ruderals show no-dormancy have high fecundity and a wide seed dispersion, (e.g. anemochorie, such as *C. acanthoides* and *B. salicifolia*) that insure their persistence (Egler, 1954). These two types of plants have different dynamics, thus knowledge of their germination can explain their coexistence. Also, the relative abundance of these species each year depends on the size and the precise moment of the disturbance and on the existence of a nearby source of propagules. Other species as *S. halepense* always appear with high abundance values during all the analyzed period. This concurs with Monk's observations (Monk, 1983) that many of the species associated with a late secondary succession stages are already present at early stages, often from the beginning of the process or soon after field abandonment (Egler, 1954).

S. halepense is a perennial grass that propagates from rhizomes (asexual reproduction) as well as from seeds (sexual reproduction). Apart from being a strong competitor for resources, it is a source of allelopathics (Acciaresi and Asenjo, 2003).

C. acanthoides is an annual dicots which competitive ability may be due to the formation of an initial rosette that quickly develops on the the soil surface or to allelopathy such as other species of the *Carduus* genus (Wardle *et al*., 1991).

The disappearance of many annual species during the more advanced stages of the succession could be associated with an increase in *S. halepense* and *C. acanthoides* dominance (Bazzaz, 1975). Furthermore, litter accumulation can modify soil temperature (Thompson and Grime, 1983; Facelli and Facelli, 1993). This may occur at the beginning of spring when there is a large amount of standing organic matter that prevents light penetration and soil warming, retarding seed germination. Many species do not germinate below a dense canopy and others require many gap-sensing stimuli (light and temperature fluctuations) in order to germinate (Crawley, 1990), so when they do germinate, they are at a disadvantage with the species already established, in our case with big rosettes and rhizomes.

Baccharis salicifolia appeared at a later stage invading initially one plot and later on spread to neighboring plots and remained in a restricted part of the total surface. The dominance of *B. salicifolia* is probably due to the species ability to compete for space and light, as it is a perennial woody shrub. Woody species can modify local microsites conditions so strongly that the recruitment of annual species is almost impossible, so the populations of annual species decline and even become locally extinct (Watkinson, 1990). The initial propagules of *B. salicifolia* probably came from a parent plant located in the fence near the study site and survived because there was no large herbivorous interference nor cultivation. So fences, roadsides, abandoned railways, etc. become refuges for several species of the original grassland and some native woody species such as *Baccharis* spp. (Ghersa *et al*., 2002).

In the present study, as in most successions in abandoned fields, at the beginning there is a rapid growth of annual species, short life perennial, with a high abundance turnover rate. Over time, these species are replaced by others of lower growth rate, long life perennial grasses, which are stronger competitors (Tilman and Wedin, 1991; Grubb 1986; Foster and Tilman, 2000). Two relatively well-defined stages can be distinguished. An initial short period with annual species behaving like arable weeds and pasture species (*M. sativa, L. multiflorum and F. arundinacea).* This species are perennials and remain longer in the site. The following stage is characterized by the consolidation of perennials, such as *B. salicifolia* and *S. halepense,* accompanied by *C. acanthoides*, the only annual species that increases its relative importance over time (Table 1).

During the entire period analyzed the original species of the community such as *Stipa* spp. were not observed. This is due to the fact that there is not a stand of the species nearby which is needed as a source of propagules (Bazzaz, 1968; Glenn - Lewin, 1980). Furtehermore, the species is not present in the seedbank (Etchepare and Boccanelli, 2007). The seed banks of this region's croplands are very different from those of the *Stipa* spp. community (Lewis and Leguizamón, 1991; Boccanelli and Lewis, 1994). Stable habitats species, such as *Stipa* spp generally have low persistent soil seeds (Zimmerman *et al*., 2000). In addition to this, seed dispersion is drastically reduced with distance to native vegetation patches (Zimmerman *et al*., 2000; Cubiña and Aide, 2001; Standish *et al*., 2007) and there are no relicts of this community in the vicinity. Besides, the prolific seed production, early germination and higher competitive ability of the exotic species can explain the replacement of the native ones (Hooper *et al*., 2005; Cramer *et al*., 2007).

After 15 years there is no vegetation shift to the original community. The general hypothesis that after abandonment of a crop field vegetation will evolve into a stable community similar to the *Stipa* spp. community has not been verified. Considering that it has been reported in other places that disturbed grassland recovery is a very slow process (Booth, 1941; Kaputska and Molenski, 1976; Glenn-Lewin, 1980), probably more time is needed to observe a shift to the original community. In some cases, vegetation may remains for several decades, in a state dominated by invasive exotics (D'Angela *et al*., 1986; Omacini *et al*., 1995; Cramer *et al*., 2007; Standish *et al*., 2007).

However, these results support the particular hypothesis that a secondary succession with a first stage of annual species, replaced later on by longer life cycle species would develop.

It is evident that more than 100 years of agriculture in the Pampas Region with increasing adoption of technology in the last few years resulting in higher crop yields and financial profits, implies a strong intensity, size and frequency of disturbance in the ecosystems of the region, and it will probably affect the natural vegetation for many. Often, these changes result in novel ecosystems that are different in composition and function from the ones present historically in the system (Hobbs *et al*., 2006). Probably, we are very close to composing a "Requiem for the Pampas grasslands".

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Resumen

S. Boccanelli, E. Pire y J. Lewis. 2010. Cambios en la vegetación a lo largo de 15 años, luego del abandono de campos agrícolas en la Región Pampeana (Argentina). Cien. Inv. Agr. 37(2): 45-53. La región Pampeana Argentina fue sometida a agricultura por más de un siglo. Esta larga historia de perturbación ha modificado fuertemente la vegetación natural de la región. Por lo tanto, algunas de las especies originales han desaparecido o han quedado confinadas a escasos refugios. El objetivo fue evaluar los cambios de la vegetación a través del tiempo luego del abandono de la agricultura. Nuestra hipótesis fue que con el tiempo la vegetación retornaría a la comunidad original (pastizal de *Stipa* spp.). En una clausura experimental ubicada en la Pampa Ondulada (33º 01' S, 60º 53' W y 50 msnm), se estudió la evolución de la vegetación por un período de 15 años (1982-1997) luego del abandono, partiendo de cuatro situaciones iniciales (trigo, soja, pastura y labranza sola). Periódicamente, se midió la abundancia-cobertura de especies en 60 subparcelas. Los datos se analizaron con métodos multivariados. Se identificaron varios grupos que corresponden a dos estados sucesionales muy bien definidos. El primero, muy breve, mostró un predominio de especies anuales, y el segundo presentó la reducción o casi desaparición de plantas anuales y la consolidación de perennes como *B. salicifolia* y *S. halepense* acompañadas de *C. acanthoides*. Por lo tanto, se desarrolló una sucesión secundaria, con una primera fase de dominio de especies anuales seguido por las especies de ciclo de vida largo. Sin embargo, aún después de 15 años no hubo reversión de la vegetación a la comunidad original.

Palabras clave: Agricultura, campo abandonado, disturbio, maleza, sucesión secundaria.

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