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FIELD EDGE PLANT COMMUNITY DIVERSITY IN AN INTENSIVELY MANAGED AGRICULTURAL LANDSCAPE

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ABSTRACT

Field edges are important non-crop areas in agricultural landscapes because they foster biodiversity in the landscape. Field edges also support important ecosystem services like pollination by providing floral resources and habitat for pollinators. The main goal of this study was to examine how field edge management and occurrence of adjacent crop influences plant community diversity in the field edge. Twenty-eight field edges in Selommes, France were surveyed in the summer of 2010. Plant species richness and abundance data were collected and analyzed using Analysis of Variance (ANOVA) statistical methods. Field edge management was found to be a significant determinant of plant diversity in field edges, with untreated edges hosting the most diverse plant communities, and chemically treated edges the least diverse. These findings are evidence to support a shift in field edge management toward less herbicide application in order to increase the plant community diversity and provision of ecosystem services.

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Introduction

Agricultural Intensification

The impact of agricultural intensification on agro-ecosystem biodiversity is an issue of growing concern. Agricultural intensification is characterized by less diverse crop rotations, larger fields and higher inputs of agrochemicals to obtain higher yield outputs (Tscharntke *et al* 2005).

In an intensely managed agricultural landscape, less diverse crop rotations mean that annual crops are more prevalent at the expense of perennial cropping systems and fallow areas (Tscharntke *et al* 2005). Short rotations of annual grain crops decrease the likelihood of having multiple crop species present in a field at one time, and decrease the number of species planted in a specific field over time. This reduces the diversity of resources and ecological interactions provided by the crop, like floral resources for pollinators or support of nitrogen fixing bacteria (Tscharntke *et al* 2005).

Also, as fields are more intensely managed for maximum crop yield, use of chemical fertilizers and pesticides usually increases (Tscharntke *et al* 2005). The availability of crops genetically modified for herbicide tolerance has provided further incentive for farmers to increase herbicide use. In 2010, herbicide tolerant crops were planted on 89.3 million hectares globally, out of the total area of 148 million hectares of biotech crops (James 2010).

At the landscape level, as field size has increased with agricultural intensification, there is less non-cropped land area in the landscape. Non-cropped field edges or forest fragments contain much of the plant diversity within an agricultural landscape, because crop fields are managed to be a monoculture and eliminate weeds that might compete with the crop. With agricultural intensification, the landscape matrix becomes increasingly simple and homogeneous, covered in arable crop land (Tscharntke *et al* 2005).

The loss of regional biodiversity from agricultural intensification also translates into loss of global biodiversity, because agricultural land makes a significant contribution to biodiversity and species conservation. In Germany, regions of managed agriculture and forestry cover 50% of the country and host 75% of the endangered species. Conserved natural areas support the remaining 25% of endangered species while covering only 2% of the land area (Kaule 1991). Overall, Europe has relatively small areas of conserved natural land compared to North America, Asia and Africa, which make it particularly vulnerable to the loss of biodiversity from agricultural intensification (Chape *et al* 2003).

Ecosystem Services and Pollination

Ecosystem services provided by insects, like pollination, are jeopardized by agricultural intensification, because the loss of plant biodiversity in a landscape also reduces insect biodiversity (Biesmeijer *et al* 2006, Ricketts *et al* 2008). Klein *et al* (2007) reviewed 16 studies on the impact of agricultural intensification on local or regional pollination services. The proportion of semi-natural habitat in the landscape, or distance of the crop from semi-natural habitat was used as a measure of agricultural intensification. The studies reviewed covered nine crops over four continents, and all found a negative impact of agricultural intensification on pollination services provided.

Kremen *et al* (2002) also found that native bee diversity and abundance was diminished by agricultural intensification. This study examined the pollination of watermelons, and showed that agricultural intensification decreased pollination services such that pollen deposition fell below the threshold necessary for marketable crop production.

Pollination is one of the most important ecosystem services provided by insects. Globally, 87 food crops rely on animal pollination for fruit, vegetable, or seed production in some way. Pollinator dependent crops represent 35% of the world food production by volume, and include many crops that supply the nutrients necessary for a healthy diet. Sixty-three crops are at least ten percent animal pollinated, and are therefore are vulnerable to yield decreases if pollinator abundance and diversity declines (Klein *et al* 2007).

Even while there is little empirical evidence to show the exact mechanisms behind how biodiversity promotes ecosystem services, the connection between high biodiversity and ecosystem services like pollination has been consistently demonstrated (Tscharntke *et al* 2005). The loss of landscape diversity, and therefore loss of pollination and other ecosystem services would severely injure worldwide food production.

Diversity and Landscape Complexity

An agricultural landscape can support biodiversity in both its cropped and non-cropped areas. This study chose to examine floristic biodiversity in non-cropped field edges, because they typically have more diverse plant communities than the cropped areas, and therefore a higher potential to provide important ecosystem services like pollination and insect pest biocontrol in the adjacent crop (Klein *et al* 2007, Thies and Tscharntke 1999).

Also, complex landscapes with more non-cropped land have been shown to augment diversity within the fields themselves. Roschewitz *et al* (2005) and Holzschuh *et al* (2007) found that in a homogeneous landscape dominated by cropped land, organically managed fields have a higher gamma diversity of weedy species than conventionally managed fields. However, in a complex landscape with a lower percentage of arable land, the gamma diversity of weed species in conventional and organic systems was similar.

Roschewitz *et al* (2005) and Holzschuh *et al* (2007) showed that non-crop areas around conventional fields can increase the field weed species diversity enough to compensate for the difference in management. This probably occurs via immigration and establishment of weed species from the non-cropped areas to the field itself. These authors established the potential of field edges to augment biodiversity, and the need to examine weed species diversity on landscape scale.

Field Edges

Field edges are an important part of the agricultural landscape, and for the purpose of this paper they are defined as the non-cropped area between a cropped field and a roadway. There are many different types of vegetation in field edges, but this study examined edges with herbaceous, non-woody vegetation, as opposed to the aquatic, shrub, or woody vegetation found in some field margins.

The mechanization and intensification of agriculture has provided incentives for larger field sizes and the elimination of field edges. Also, agriculture has become more specialized, with fewer producers raising both crops and animals. These changes in agriculture have made many of the original purposes of field edges obsolete, but a new set of conservation and environmental purposes for field edges have emerged. Marshall and Moonen (2002) provide a review of the major agronomic, environmental, conservation, and recreational purposes of field margins. They summarize the reasons field edges were created, and the roles they are currently believed to fulfill. Their table is reproduced here as Table 1.

Table 1. Functions and requirements of semi-natural field margins. (Taken from Marshall and Moonen 2002, after Marshall 1993).

Original Role	Current Role
1. To define the field edge	1. Promotion of ecological stability in crops
2. To be stock and trespasser-proof, to keep animals in or out	2. Reducing pesticide use: exploiting pest predators and parasitoids
3. To provide shelter for the stock	3. Enhancing crop pollinator populations
4. To provide shelter for crops, particularly as windbreaks	4. Reducing weed ingress and herbicide use
5. To reduce soil erosion by wind or water	5. Buffering pesticide drift
6. Not to compete with the crop for light, moisture, or nutrients	6. Reducing fertilizer and other pollutant movement, especially in runoff
7. Not to harbor weeds, pests, or diseases	*7. Reducing soil erosion*
8. To harbor beneficial plants and animals	8. *Promotion of biodiversity and farm wildlife conservation*
9. To act as a refuge or corridor for wildlife	9. Maintaining landscape diversity
10. To provide a source of fruits and wood	10. Promotion of game species
Equivalent original and current roles are marked with italics.	

As previously discussed, the edge functions of supporting pollinator populations and increasing landscape biodiversity were of primary interest for this project. In order for a non-cropped field edge to increase the landscape biodiversity, it has to have a diverse plant community itself. Le Coeur *et al* (1997) found that both local and landscape factors influence the plant community structure in field edges, however, the local factors like shrub and tree vegetation, edge management, and adjacent land use were of first importance. In line with these findings, our study chose to also examine local factors that contribute to the diversity of individual field edge plant communities, including adjacent crop culture, soil type, and edge management. The field edges chosen for this study do not have shrub or trees present, so this factor was not considered.

There is not a clear consensus about the relative importance of any one of these local variables like field edge management. Le Coeur *et al* (1997) reported a relatively small effect of edge management on the plant community composition compared with earlier studies (Marshall and Birnie 1985, Parr and Way 1988, and Watt *et al* 1990). This might be explained simply by the variation in where the studies were conducted. In the results of Le Coeur *et al* (1997), location alone accounted for 21.8% of the total variation, and perhaps includes some factors, like soil characteristics or land cover pattern, that were not measured in the included environmental variables.

Similarly, Kleijn and Verbeek (2000) did not find margin management, including herbicide use to be a significant determinant of plant species diversity in the field edges. However, they had little variation in management type within the studied margins due to the descriptive nature of their study. This could explain their inability to show a significant difference in plant species richness according to field edge treatment. This study did show significant differences in nutrient input and edge plant community composition according to crop rotation. Species richness declined with higher levels of nitrogen and phosphorus applied to the adjacent crop.

Conversely, de Snoo (1999) reported a substantial effect of margin management and herbicide application. There was a significant difference between margins that were sprayed and those that were not. The field edges in this study were most commonly sprayed with glyphosate, but MCPA and dalapon were also used by at least 30% of the farmers. This study reported a much higher percent plant cover in the unsprayed margins than those that received herbicide application, regardless of the adjacent crop. The total plant species richness, and conservation value of the edges was greater in the unsprayed edges.

In light of these inconsistent results, this study also sought to correlate local factors, including soil type, edge treatment type (chemical, mechanical, or no treatment), and adjacent crop culture with plant species richness and abundance. It was hypothesized that 1) overall plant diversity would be highest in the untreated edges, 2) that herbicide use and mowing would reduce plant diversity, and 3) that field edge management is more important than the soil type or adjacent crop culture in determining plant biodiversity.

Methods

Project Scope

This honors thesis project was conducted in the summer of 2010 during a three-month internship at Agro Paris Tech in Paris, France. The methodology used and data collected are from a larger landscape biodiversity project of the Ecologie, Systématique and Evolution lab at the Université de Paris Sud 11. This larger study spanned five years from 2006 to 2010.

My thesis project provided an opportunity for me to learn the flora of field edges in France, agricultural practices associated with this region of central France, and methods of field flora survey methods and data analysis. Because I was directly involved in data collection during my 2010 stay, I have chosen to focus my analysis on the data I helped to collect. My work represents a subset of studies underway in my host lab. In addition to my work, a number of researchers are examining the relationship between field edge species richness and prevalence of oilseed rape fields and natural areas (forests, hedges, etc.) in the landscape. There is also interest in the presence of volunteer oilseed rape plants in field edges, and the potential for pollen flow between oilseed rape fields and field edges.

Field Site Description

The field site for this study was a region of 46 km^2 near Selommes, France in the Centre region and the Loir-et-Cher department; GPS coordinates are 47° 45’ 24” N; 1° 11’ 34” E. The area is an open field, intensive agricultural landscape, with agricultural production covering 75% of the land (Poirel 2008). There is very little non-cropped land or forest fragments. Annual grain and oilseed crop production dominates the landscape in this region, which has almost no livestock production operations.

Figure 1. Aerial photos of the study area show the intensive agricultural landscape, with relatively little developed or natural land in the landscape (Photo credit to J.C. Andrieux, courtesy of A. Ricroch and E. Alapetite).

The fields to be studied were chosen randomly within the study zone. These ranged in size from 1.36 to 25.9 ha., with a median field size of 4.8 ha, and an average field size was 7.75 ha. The adjacent field edges ranged in size from 0.56 to 18.21 ha.

Of the 28 field edges surveyed, 16 had clay soil; two were classified as clay loam, and the remaining 10 had loamy soil. The primary bedrock in the Selommes region is limestone, with 15 of 28 the field edges situated on this parent material (Baize 2009).

Annual grain crops included soft wheat, hard wheat, and winter canola, the most important crops in the region. There is also some barley, sunflower, corn, beet, and pea production in the Selommes region. With the exception of a few producers reporting alfalfa production, this region has no perennial cropping systems (Moles 2010).

This region in France is a maritime temperate climate, classified as Cfb by the Köppen climate classification system (Peel *et al* 2007). The average rainfall in Orleans, a city about 60 km from Selommes, is 635.8 mm per year. The average minimum temperature in Orleans is 6.5°C, and the average maximum temperature 15.4°C over the same time period (Previsions 2011).

Plant Species Survey

Plant species data were collected in 28 randomly chosen field edges within the study area. Field edges were delineated based on boundaries in the adjacent crop, and within each field edge a 25-meter length was randomly chosen for data collection. For this study, the field edge was considered to be the area between the road edge and the crop field, which was delineated by the presence of cultivated soil.

After choosing the field margins, GPS coordinates were used to relocate the field edges for additional data collection. Within each field edge a 25-meter segment was marked with stakes at either end, and the same segment was used each year for the floristic surveys. The field edge width was not controlled, and consequently it varied from 0.5 m to 5.83 m in 2010.

Field edge management was not manipulated, rather field edges were chosen to represent farmer practiced management methods in the region. The government manages field edges that are along two-way paved roads, while farmers manage the edges adjacent to one-way roads and along unpaved paths in the interior of their farms. State employees and 98 producers in the field study area were interviewed to collect data about field edge management. Data collected included general information about crop rotations, past herbicide application, mechanical weed control, along with manure and fertilizer application practices.

State employees mow field edges along two way paved roads twice a year, in June and November. Local producers mow their field edges up to 3 times per year in May, June, and November. The average number of mowing passes in the Selommes region is 1.53 times a year, and if an edge is only mowed once, this occurs in June. The producers that reported chemical use on their field edges used Round-up® (glyphosate), Allié® (metsulfuron-methyl), or Printazol® (Piclorame, 2 4-D, 2 4-MCPA). Chemical application mainly occurred between April and July, although four producers also reported one chemical application in October.

In addition to the producer interviews, visual observations about weed management techniques applied, adjacent crop culture, and opposite crop culture, were made during the field data collection. Opposite crop culture is the crop present on the other side of the road, opposite the middle of the field edge being surveyed. Field edge width and soil type were also recorded for each field edge.

Table 2. Braun-Blanquet scale for measuring plant species abundance.

BB Notation	**Percent Cover**
+	few individuals
1	< 5%
2	5-25%
3	25-50%
4	50-75%
5	>75%

Two types of plant species data were collected. The first is a measure of species richness within each margin, which was collected by identifying all plant species present along a 25 meter transect. Species abundance data was collected in 5 1 m^{-2} quadrats. These quadrats were randomly placed within each field edge, and the Braun-Blanquet scale (Braun-Blanquet 1929, 1964) was used to estimate relative abundance of each plant species present. These data were collected three times in 2010, on April 19-21, May 17-19, and June 28-30, 2010.

Two botanists, Jean-Michel Dreuillaux and Robert Haïcour, were primarily responsible for the floristic surveying work, with lab members assisting in data recording. I worked with Mr. Haïcour to collect the species abundance data for 5 1 m^{-2} quadrats in each field edge. I found him to be an excellent teacher as well as a botanist, and I learned many of the common French field edge plant species. I also practiced visual estimation of plant species abundance, via the Braun Blanquet scale within a quadrat.

After field data collection, plants observed during the census were also classed by taxonomic family, life cycle, reproductive system, and, if possible, mode of pollination as described in USDA GRIN, INPN, and Tela Botanica.

Biodiversity Measures and Rank Abundance Curves

Species richness, species evenness, and the Shannon and Simpson diversity indices were all used to measure biodiversity in this study. Species richness (*S*) is the number of species present in each field edge. According to Magurran (2004), species evenness is "a measure of how similar species are in their abundances (18)." Shannon's evenness measure was used to calculate species evenness as follows:

$J' = H'/\ln(S)$

The quantity H' is the Shannon diversity index and is calculated as follows:

$H' = -\text{ sum } (p_i*\ln(p_i))$

The variable p_i is estimated by n_i/N (the number of individuals in the *i*th species/ the total number of individuals). The Simpson diversity index is the probability of selecting two individuals of the same species and is given as:

$D = 1 - \text{sum } (p_i)^2$

The Shannon and Simpson indices both take into account species richness and evenness, but the Simpson index is more strongly influenced by the most abundant species, and is not as sensitive to rare species in a community. As a plant community becomes more even the Simpson index measure will increase (Magurran 2004).

Rank abundance curves, also known as Whittaker plots (Whittaker 1965), are often one of the first methods employed to compare species abundance data (Magurran 2004). They present a graphical view of both species richness and evenness data. Rank abundance curves with shallow slopes indicate high species evenness, while steeper slopes signify communities with higher dominance of a few species. Rank abundance curves are also very effective at showing changes in plant assemblages over time, or after an environmental effect (Magurran 2004).

Statistical Methods

Rank abundance curves were used to examine general trends in the plant species richness and abundance for each treatment type. Because rank abundance is influenced by area sampled (Magurran 2004) it was necessary to examine an equal number of field margins from each treatment type. Because the number of edges wasn't equal in each treatment type (18 non-treated, 4 chemically managed, and 6 mowed) the minimum number of transects of a treatment type therefore constrained the number of transects used in the analysis for all treatments.

To create these rank abundance curves, subsets of four margins from the mechanical and no treatment edges were chosen to compare with the four chemically treated edges. A random number generator was used to randomly select four subsets of four margin numbers. The rank abundance curves for these subsets were graphed, and the curve with the median slope was selected to compare with the other treatments.

One-way ANOVA analysis was used to test if the predictor variables (soil type, edge treatment and adjacent crop culture) explained a significant amount of the variability in species richness, species evenness, Shannon diversity index, and Simpson diversity. Tukey's procedure for multiple comparisons was used to reduce the probability of incorrectly rejecting the null hypothesis. For these analyses the 95% confidence level was used to determine significance ($p \leq 0.05$).

Results

Across the 28 field edges studied, 135 plant species were observed. These species include species from 27 different plant families, with the most commonly observed families being Poaceae, Asteraceae, and Geraniaceae (See Figure 2). Despite the high frequency of monocot species observation, there were 105 dicot species in these field edges and only 30 monocot species.

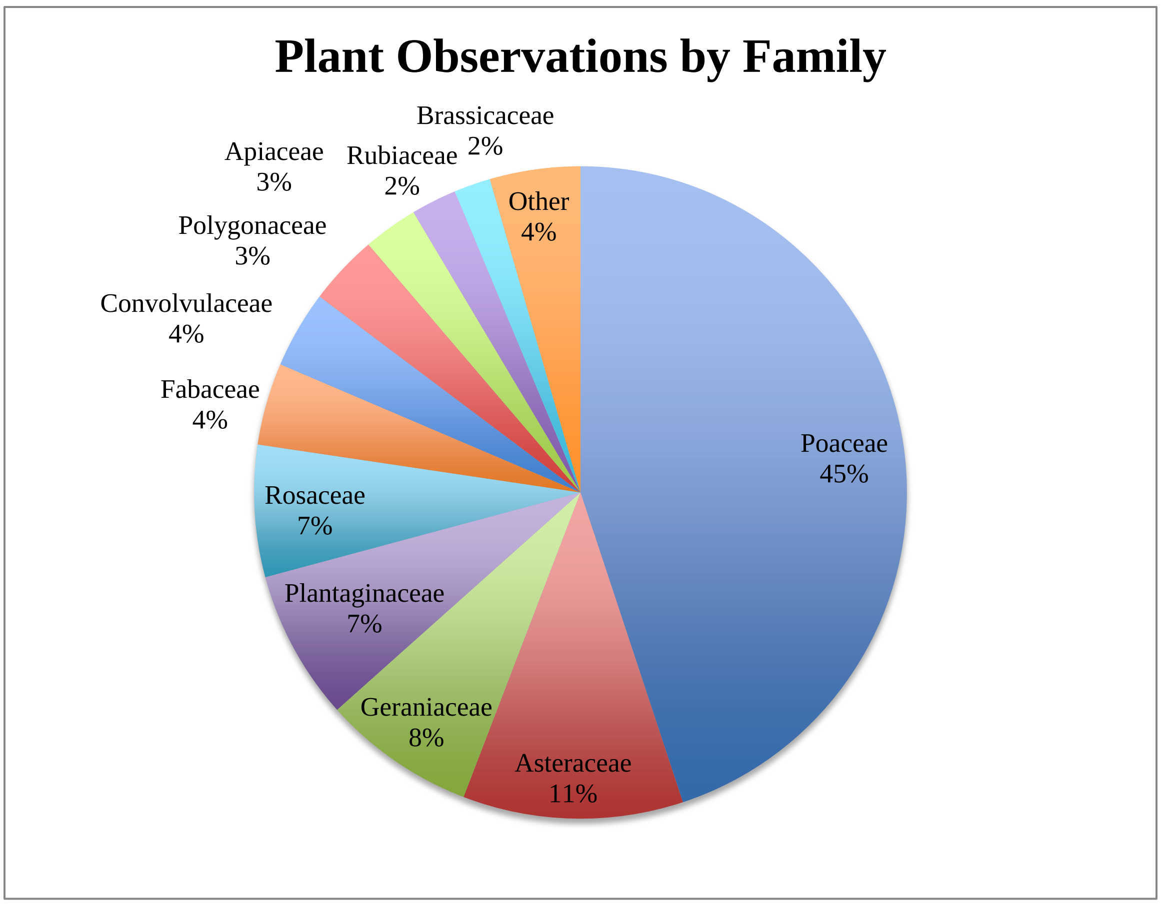

Figure 2. Most commonly observed plant families.

The plant species observed in each field edge varied according to the edge management. In total in the chemically treated edges there were 43 plant species, the mechanically treated edges had 69, and the untreated hosted 120 plant species. For both monocot and dicot species the chemically treated edges had the fewest number of species present (see Tables 3 and 4).

Ninety-one of the observed dicot species and two of the monocot species are insect pollinated, and similar to the overall trend, the untreated edges had 79 insect pollinated species, compared with 25 in the sprayed edges. Most of this difference is represented in the dicot species observed (see Table 4), which is logical given the 2, 4-D and MCPA herbicides applied are active on many broadleaf species.

Table 3. Monocot species observed

Chemical Edges	Mechanical Edges	Untreated Edges
Monocots (insect pollinated)		
		Allium vineale
		Hordeum murinum
Monocots (non insect pollinated)		
Agrostis capillaris	*Agrostis capillaris*	*Agrostis spp.*
Avena barbata	*Arrhenatherum elatius*	*Agrostis capillaris*
Avena sativa	*Bromus hordeaceus*	*Alopecurus myosuroides*
Bromus hordeaceus	*Bromus sterilis*	*Arrhenatherum elatius*
Bromus sterilis	*Carex echinata*	*Avena barbata*
Dactylis glomerata	*Carex hirta*	*Avena sativa*
Elytrigia repens	*Dactylis glomerata*	*Bromus arvensis*
Festuca pratensis	*Elytrigia repens*	*Bromus erectus*
Lolium perenne	*Festuca pratensis*	*Bromus hordeaceus*
Poa annua	*Festuca rubra*	*Bromus secalinus*
Poa pratensis	*Lolium perenne*	*Bromus sterilis*
Poa trivialis	*Phleum pratense*	*Carex hirta*
Triticum aestivum	*Poa annua*	*Carex muricata*
	Poa pratensis	*Dactylis glomerata*

	Poa trivialis	*Elytrigia repens*
		Festuca spp.
		Festuca pratensis
		Festuca rubra
		Lolium perenne
		Phleum pratense
		Poa annua
		Poa pratensis
		Poa trivialis
		Trisetum flavescens
		Triticum aestivum
		Triticum turgidum
		Vulpia myuros

Table 4. Dicot species observed

Chemical Edges	Mechanical Edges	Untreated Edges
Dicots (non insect pollinated)		
Artemisia vulgaris	*Artemisia vulgaris*	*Artemisia vulgaris*
Brassica napus	*Brassica napus*	*Brassica napus*
Brassica nigra	*Capsella bursa-pastoris*	*Brassica nigra*
Plantago lanceolata	*Chenopodium album*	*Capsella bursa-pastoris*
Plantago major	*Fallopia convolvulus*	*Chenopodium album*
	Plantago lanceolata	*Fallopia convolvulus*
	Plantago major	*Plantago coronopus*
	Rumex crispus	*Plantago lanceolata*
		Plantago major
		Rumex acetosa
		Rumex crispus
		Rumex obtusifolius
		Rumex sanguineus
		Urtica dioica
Dicots (insect pollinated)		
Achillea millefolium	*Achillea millefolium*	*Achillea millefolium*
Agrimonia eupatoria	*Anagallis arvensis*	*Agrimonia eupatoria*
Anagallis arvensis	*Bellis perennis*	*Ajuga reptans*
Brassica spp.	*Cerastium spp.*	*Anagallis arvensis*
Cirsium arvense	*Cerastium semidecandrum*	*Anthriscus spp.*
Cirsium vulgare	*Cirsium arvense*	*Centaurea jacea*
Convolvulus arvensis	*Cirsium vulgare*	*Centaurea nigra*
Euphorbia helioscopia	*Convolvulus arvensis*	*Centaurea scabiosa*
Galium aparine	*Cornus sanguinea*	*Cerastium spp.*
Geranium dissectum	*Crepis capillaris*	*Cerastium arvense*
Geranium molle	*Daucus carota*	*Cerastium triviale*

Chemical Edges	Mechanical Edges	Untreated Edges
Geranium pusillum	*Galium mollugo*	*Cirsium arvense*
Lamium purpureum	*Geranium spp.*	*Cirsium vulgare*
Lotus corniculatus	*Geranium dissectum*	*Convolvulus arvensis*
Malva neglecta	*Geranium molle*	*Conyza canadensis*
Matricaria discoidea	*Geranium pusillum*	*Coronopus squamatus*
Matricaria perforata	*Heracleum sphondylium*	*Crepis capillaris*
Picris hieracioides	*Lathyrus tuberosus*	*Crepis setosa*
Polygonum aviculare	*Lotus corniculatus*	*Daucus carota*
Senecio vulgaris	*Medicago spp.*	*Dianthus armeria*
Taraxacum officinale	*Medicago lupulina*	*Eryngium campestre*
Trifolium campestre	*Medicago sativa*	*Euphorbia helioscopia*
Trifolium repens	*Picris hieracioides*	*Galium spp.*
Veronica arvensis	*Polygonum aviculare*	*Galium aparine*
Veronica persica	*Potentilla spp.*	*Galium mollugo*
	Potentilla reptans	*Galium verum*
	Prunus cerasus	*Geranium spp.*
	Prunus spinosa	*Geranium columbinum*
	Ranunculus repens	*Geranium dissectum*
	Rubus fruticosus	*Geranium pusillum*
	Senecio vulgaris	*Geranium pyrenaicum*
	Sisymbrium officinale	*Heracleum sphondylium*
	Sonchus asper	*Hypericum perforatum*
	Taraxacum officinale	*Knautia arvensis*
	Torilis arvensis	*Lactuca serriola*
	Trifolium spp.	*Lamium purpureum*
	Trifolium arvense	*Lathyrus spp.*
	Trifolium campestre	*Lathyrus pratensis*
	Trifolium pratense	*Lathyrus tuberosus*
	Trifolium repens	*Lithospermum arvense*
	Verbena officinalis	*Lotus corniculatus*
	Veronica chamaedrys	*Malva neglecta*
	Veronica officinalis	*Matricaria spp.*
	Veronica persica	*Matricaria chamomilla*
	Vicia spp.	*Matricaria discoidea*
	Vicia sativa	*Matricaria perforata*
		Medicago lupulina
		Medicago sativa
		Ononis repens
		Papaver rhoeas
		Pastinaca sativa
		Picris hieracioides
		Polygonum aviculare
		Potentilla reptans
		Prunus spinosa
		Ranunculus spp.
		Ranunculus repens
		Rosa spp.

Chemical Edges	Mechanical Edges	Untreated Edges
		Rubus fruticosus
		Salvia pratensis
		Senecio vulgaris
		Silene alba
		Silene dioica
		Sisymbrium officinale
		Sonchus asper
		Sonchus oleraceus
		Taraxacum officinale
		Torilis anthriscus
		Trifolium arvense
		Trifolium campestre
		Trifolium pratense
		Trifolium repens
		Verbena officinalis
		Veronica arvensis
		Veronica hederaefolia
		Veronica persica
		Viola arvensis

ANOVA Results

Species richness and evenness did not differ among the field edge management approaches, but the Shannon and Simpson diversity indices did differ significantly among the field- edge treatments (see Table 5).

Table 5. One-way ANOVA results with field edge treatment as the explanatory variable. Significantly different results are marked in bold.

Response Variable	Results	
	Sum of Squares	p-value
Richness	250.6	0.117
Evenness	0.00934	0.129
Shannon Index	**0.885**	**0.03**
Simpson Index	**0.01717**	**0.009**

For both the Shannon and Simpson indices the ANOVA test identified significant differences between the chemical and untreated edges. The untreated field edges were more diverse according to both indices than the chemically treated edges. The Shannon and Simpson index measures for the mechanically treated edges were not different from either the chemically treated or the untreated field edges (see Table 6).

Table 6. Floristic diversity by edge treatment.

Treatment	Mean Richness	SE Richness	Mean Evenness	SE Evenness	Mean Shannon Index	Mean Simpson Index
No Treatment	25.94 a	1.58	0.837 a	0.008	2.690 a	0.904 a
Mechanical	22.50 a	3.41	0.803 a	0.027	2.459 ab	0.872 ab
Chemical	17.50 a	4.33	0.794 a	0.032	2.199 b	0.835 b

a, b denotes means within a column that were significantly different ($p \leq 0.05$), SE is standard error.

The field edges studied were adjacent to 8 different crop cultures: peas, small grains (wheat, barley, or rye), beets, sunflowers, corn, canola, fallow, or a hedge. The average plant species richness varied from 14.0 to 36.0 in field edges with different adjacent crop cultures. However, species richness, evenness, Shannon and Simpson index values did not differ significantly among crop species ($p = 0.077$, 0.232, 0.402, 0.403, respectively, see Table 7).

Table 7 Floristic diversity by adjacent crop culture. No means were found to be significantly different.

Adjacent Crop Culture	# Edges Surveyed	Mean Richness	Mean Evenness	Mean Shannon Index	Mean Simpson Index
peas	1	14.0	0.723	1.907	0.793
small grain	14	21.6	0.836	2.500	0.882
beets	1	23.0	0.729	2.285	0.840
sunflower	1	25.0	0.801	2.579	0.876
corn	2	26.0	0.840	2.738	0.913
canola	7	26.6	0.825	2.699	0.902
fallow	1	34.0	0.838	2.955	0.928
hedge	1	36.0	0.803	2.879	0.922

Plant species richness did differ among soil types, ($p = 0.027$) but evenness, Shannon or Simpson diversity indices measures did not differ significantly among the three soil types ($p = 0.818, 0.068, 0.096$, see Table 8).

Table 8. Floristic diversity by soil type.

Soil Type	Mean Richness	Mean Evenness	SE Evenness	Mean Shannon Index	SE Shannon Index	Mean Simpson Index	SE Simpson Index
clay	29.56 a	0.820 a	0.015	2.447 a	0.107	0.872 a	0.0133
clay loam	22.00 ab	0.810 a	0.002	2.504 a	0.044	0.890 a	0.0002
loam	21.19 b	0.831 a	0.009	2.799 a	0.044	0.913 a	0.0052
a, b denotes means within a column that were significantly different ($p \leq 0.05$), SE is standard error.							

Rank Abundance Curves

The rank abundance curves for four subsets of randomly chosen mechanically treated and untreated edges are presented in Appendix A. Both the mechanically managed edges and the untreated edges show substantial variation in the total richness depending upon the subset of margins chosen. Figure 3 shows the comparison of the median rank abundance curves of the mechanical and no treatment subsets with the rank abundance curve for all the chemically treated edges.

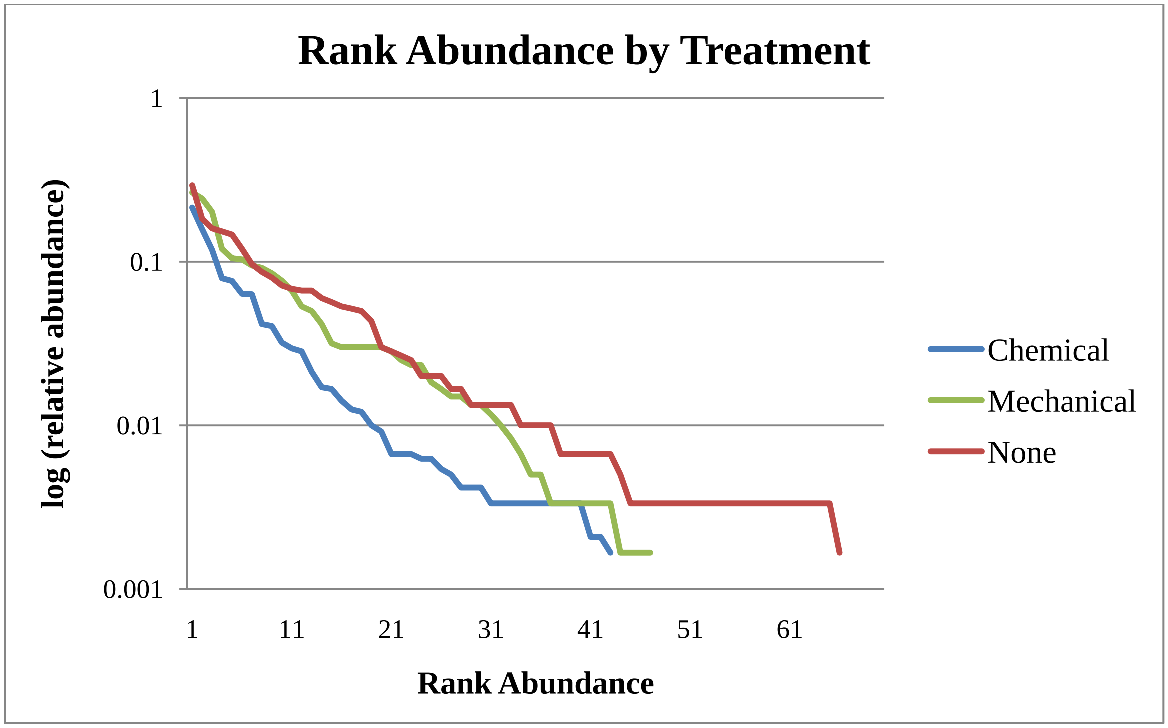

Figure 3: Rank abundance curves for all treatments.

The rank abundance curve for the chemically treated margins has a steeper slope, which indicates fewer species that are abundantly present. The curve for the untreated margins shows a higher total species richness, and more even plant communities in these margins.

Discussion

The results of this study generally support the hypothesis that untreated field edges have the highest plant species diversity. There is a trend toward more species present in the untreated field edges than the mechanical and chemically treated edges (see Tables 3 and 4).

The rank abundance curves presented in Figure 3 show the range in total species richness and abundance between the different treatment types. The broad-spectrum herbicide applied on the chemical edges eliminated many broadleaf species present in these communities (see Table 4). The chemical weed management selected for species that are most competitive after a disturbance, which probably explains the lower total species richness in the chemically treated edges.

The rank abundance curve for the mechanically treated margins has a similar slope to the no treatment curve but the total species richness is lower in the mechanically treated edges. In contrast to this trend, Parr and Way (1988) and Van Schaik and Van den Hengel (1994) found that cutting roadside vegetation produced higher species richness than the uncut edges. This contradiction is likely explained by the high variation in the species richness within the mechanically treated edges in our study. It is possible that we observed a different trend due to the small sample size and variable data for species richness.

The Shannon and Simpson diversity indices, were significantly higher in the chemically field edges than untreated field edges. The total species richness may have significantly differed by field edge treatment if the number of field edges studied had been larger.

An adequate sample size is necessary to compensate for the innate variability between different field edges. The rank abundance curves in Figures 4 and 5 in Appendix A illustrate this variability by comparing subsets of margins of the same management type. Even within the same management type, the specific local conditions of margins chosen substantially impact the total species richness and abundance trends.

Also, this study was carried out in descriptive manner without controlling how the field margins were managed. Rather, data was gathered from producers about the management practices that are currently in place. This approach increases the real world applicability of research findings, but also increases the variation in the specific parameters (herbicide used, application rate, timing, etc.) of the treatments applied. Consequently, it is necessary to have a larger sample size in a descriptive study than a controlled field study where the treatments are more uniform.

In 2010, of the field edges surveyed, four margins were chemically managed, six were mechanically managed, and 18 were untreated. The small number of chemical and mechanical edges surveyed decreases the power of the statistical analyses performed, and potentially has masked some significant differences that might be evident with a larger sample size of the edge treatments.

Field edge treatment was the only variable that explained significant variability in two of the response variables (Shannon and Simpson indices). Species richness differed significantly with soil type, and none of the diversity measures differed among adjacent crop culture. Our results support the importance of field edge treatment in determining plant community diversity, in line with the findings of de Snoo (1999), rather than Kleijn and Verbeek (2000) and Le Coeur *et al* (1997).

Kleijn and Verbeek (2000) showed a significant impact of adjacent crop culture on field edge diversity, but this effect is mainly attributed to differences in fertilization inputs in the adjacent crops. Crops, like corn, which often receive high inputs of nitrogen fertilizer, have high spillover of fertility into the adjacent field edges. In our study area there were only two field edges that were adjacent to corn, unlike Kleijn and Verbeek's (2000) study, which might explain the lack of a significant differences between the diversity measures according to the adjacent crop culture.

Overall, the results of this study support the original hypotheses, and sample size limitations may have explain why we did not find a significant difference in species richness due to edge treatment. Additional research needs to be performed to confirm these findings, and test their applicability for other intensive agricultural landscapes. If these findings are replicated, then further research could be performed to determine more specifically what type of chemical or mechanical edge treatment is most harmful to these plant communities. Also, data documenting the impact of edge management on both the plant and insect community diversity would be strong evidence advocating for a change in current field edge management practices.

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Appendix A:

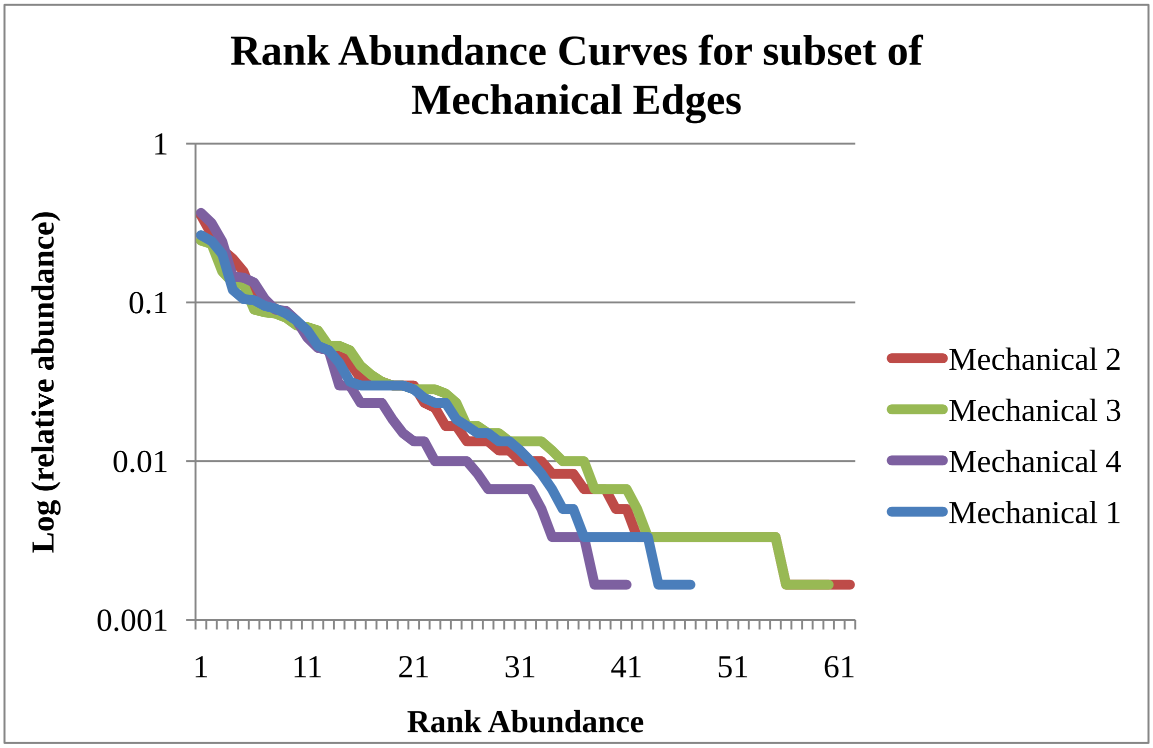

Figure 4. Rank abundance curves for subsets of the mechanically treated edges.

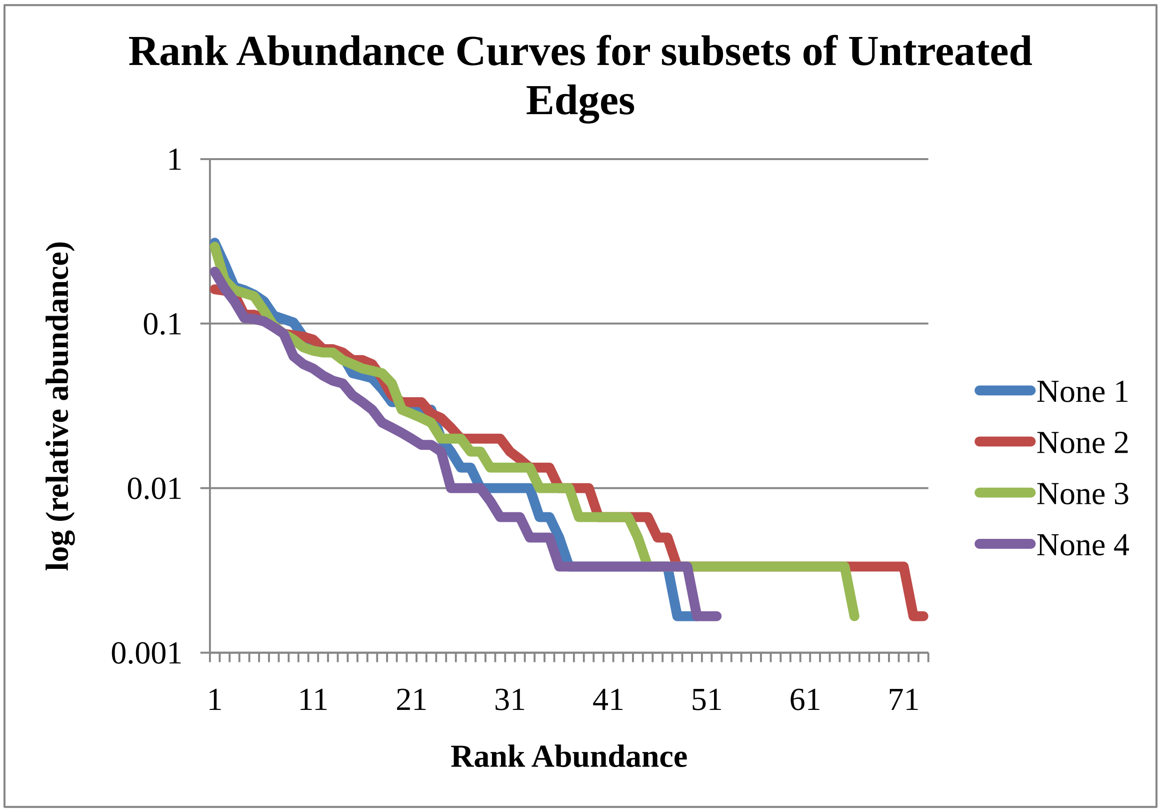

Figure 5. Rank abundance curves for subsets of the untreated edges.

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Agro Paris Tech (Summer 2010)
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Research Assistant
-assisted with field data collection in crop field edge biodiversity project
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Penn State Weed Ecology Lab (Spring 2008)
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-processed soil samples and identified weed seedlings

Agrecol Afrique (Spring 2009)
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