



UNIVERSITÀ DEGLI STUDI DI PADOVA

Dip. Territorio E Sistemi Agro-Forestali

Dip. Agronomia Animali Alimenti Risorse Naturali e Ambiente

Corso di laurea magistrale in Scienze Forestali e Ambientali

Invasion of alien plants across heterogeneous agricultural landscapes

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ANNO ACCADEMICO 2016-17

Ringraziamenti

Alla mia famiglia per avermi sempre supportato e ascoltato

A Carlo Zanrosso e Pietro Castello per i viaggi fatti insieme e la musica

A tutti i miei coinquilini e compagni di stanza presenti e passati, in particolare:

Marta Teston, Pietro Maraschin, Maro Boscaro, Sebastiano Zaroni,

A Federico Vaona, Marta Teston e Chiara Tibaldo per avermi sopportato quando ero stanco

A Francesco Lami per avermi sopportato e seguito

A Mattie Loesche e Francesco Lami per tutto quello che abbiamo passato in Friuli

A Lorenzo Marini, mio supervisore

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Abstract

Invasive plant species are a serious and growing threat to native biodiversity in Europe. In agricultural landscapes this problem can also be influenced by the amount and configuration of seminatural land. Our aim in this study was to assess interactions between invasive and native plant communities and landscape composition using data collected in the Italian region of Friuli Venezia Giulia (North-Eastern Italy), in which land-use intensity gradients are fully represented. We selected 15 landscapes (circular buffers of 1 km of radius). In each landscape we performed 20 vegetation samplings in different habitat patches, both natural and seminatural, which represent the habitat diversity of the entire landscape.

Our main explanatory variable was seminatural habitat percentage (a proxy for land-use intensity) at both the 1 km radius scale and a larger 1,5 km radius scale. In a novel methodological approach, we modelled the species-habitat complex as a bipartite network, and correlated important network metrics such as nestedness and modularity with seminatural land amount. We also analyzed how the percentage of land around each sampling site (both seminatural and agricultural) influences species abundance for each group. Finally we assessed how community similarity changes with the distance between sampling sites for each major habitat type.

Introduction

1- Importance of alien plants across the landscapes

An alien species is a species introduced by humans – either intentionally or accidentally – outside of its natural past or present distribution. However not all alien species have negative impacts, and it is estimated that only between 5% and 20% of all alien species become invasive. Alien plant species that become invasive influence not only species richness and composition but also alter trophic interactions and ecosystem services (Levine et al. 2003; Vila et al, 2010). Alien species have common traits such as fast growth, self-compatibility and high seed output. They are often pioneer plants which colonize open spaces and disturbed -or human used- lands (Van Kleunen et al, 2015). Invasive species have the potential to dramatically alter land-uses and consequentially affect ecosystems functioning so, in some regions, biological invasions and changes in land-use are considered two of the major drivers of biodiversity loss (Wilcove et al. 1998). For example, invasion by pine trees in South-Africa fynbos has transformed many low stature shrublands into woodlands, which has led to increases in ecosystem biomass and water demand, and the consequent decrease in water availability exerting a great strain on the local human population (Le Maitre et al. 1996; Richardson and van Wilgen 2004). In California, the introduction of Eurasian annual grasses during colonial times has increased a positive grass-fire feed-back in shrublands, leading to a transformation of shrublands into grasslands (D'Antonio and Vitousek 1992; Keeley et al. 2005). Due to the increase in the movement of people and goods around the world, the opportunity for the introduction of species outside of their natural range is on the increase. For example within Europe the numbers of invasive alien species has increased by 76% between 1970 and 2007 (Lista Rossa della Flora italiana). Also climate change can influence the rate of spread of native and alien species not only between different countries or regions but also in a height gradient. In the Alps non-native species are spreading upwards approximately twice as fast as natives (Dainese et al, 2017). Non-native species have always traits facilitating their spread. A large proportion of native and non-native species seemed to be able to spread upwards faster than the current pace of climate change. In Italy there are 6711 plant species and 751 of them are naturalized alien species, with their number constantly

growing (Lista Rossa della Flora italiana). Given that situation, it is important to understand the drivers of alien species spread to make predictions and limit possible problems.

2- Local drivers

Factors affecting ecosystem vulnerability to invasions could be considered hierarchically, from the regional scale to the micro-site scale (Milbau et al. 2009). At a regional level (100–1,000 km) climate still remains the major driver of species distributions, including alien species (Ibáñez et al. 2009b). Plants are among the taxa most interested by this problem. At the local level (10–1000 m) ecosystem type is the most important factor influencing species composition. In particular, resource availability tells us where introduced species may succeed (Saunders et al. 1991). But it is at the intermediate landscape level (10–100 km) that the invasion process—species establishment, population growth and further spread—takes place (Theoharides and Dukes 2007). At that scale, abundance and richness of alien species are lower with higher elevations, lower light availability (closer canopy or high grass coverage, low nitrogen mineralization (shady and cool conditions) and a thick litter layer in woods. Habitat fragmentation is one of the most important causes of biodiversity decline (Pauchard and Alaback 2004). Also pastures (Pauchard and Alaback 2004) and agricultural land are good sources of alien species spread. Habitat fragmentation affects populations in various ways: first of all there is habitat loss but there is also less space for the species and less connectivity inside the landscapes. Also fragmentation can create border areas and ecotones. In that situation some plant species (often exotic) are harmful and frequently connected to anthropic habitats while other species are of natural interest. Habitat fragmentation (often caused by disturbs) creates patches of different habitats: the type of habitat, patch shape and their susceptibility to disturbs influences the alien species spread. The communities diversity depends on patch area and connectivity. More anthropized habitats are more connected to alien species entrance; also since alien species are pioneers and often annuals or ornamentals they can grow easily there. Little or narrow patches are more influenced by the surrounding habitat. Also important is the percentage of edge land of the patches. Edge habitats are subjected to the influence of both the inner part of each shape and the outer one. More connected patches can present communities more complex than even slightly less connected ones. In more isolated patches there are less plant

dispersion, less chances of recolonization from important species and the genetic exchanges are reduced. While the effect of climate and local effects are quite well studied large scale processes are less investigated.

3- Landscape drivers

From a conservation point of view, there is an increasing emphasis on the importance of managing the landscape to cope with the loss of biodiversity and to sustain natural resources (Lindenmayer et al. 2008). A right management of agricultural areas can promote the dissemination of native species preventing the spread of harmful exotics. In addition to the effects of fragmentation, other land use consequences also affect the incidence of invasive species. Land use directly affects the invasion process by modifying disturbance regimes and environmental conditions and by creating sources of propaguli in the landscape. Agricultural intensification, urbanization and development of transport networks are among the most explored land-use drivers of invasion. Regarding landscape composition many empirical studies have conducted multivariate analysis to assess the influence of the proportion of different land-uses on the local level of plant invasion in natural or semi-natural areas. Most studies have found a positive association between the percentage of urban land in the surrounding landscape and the level of invasion at a site (Borgmann and Rodewald 2005; Bartuszevige et al. 2006; Maheu-Giroux and de Blois 2007). Similarly, road density, frequency of road use and road improvement increases diversity of alien species in adjacent ecosystems (Tyser and Worley 1992; Parendes and Jones 2000; Gelbard and Belnap 2003). However, the influence of agricultural and grazing land on the level of plant invasion in adjacent natural areas is controversial (Pauchard and Alaback 2004; Borgmann and Rodewald 2005). This may be due to the fact that, as we describe in the following sections, the spatial variability on the local level of invasion is not only determined by landscape composition but also by landscape configuration.

4- Methodological approach

Historically, networks of seminatural land patches surrounded by a hostile matrix (usually represented by croplands) were the most studied network type (MacArthur & Wilson, 2001; Hanski, 1998). Also studied are the connections between single patches (or close groups) and the surrounding matrix, often incorporating the elements of landscape heterogeneity (Brudwig et al, 2017; Fischer and Lindenmayer, 2006). This “buffer-landscape” dichotomical

approach, however, is limited, as real-world matrices are not constituted by an uniform general habitat, but different ones that may influence species in different ways.

There is already a tool to overcome that limit: bipartite networks, which are already used to study mutualistic interactions (Bascompte & Jordano, 2007). Bipartite networks are networks in which two levels (types) of nodes (interacting entities) exist, and nodes of one level can only interact with nodes of the other level. Some well-studied examples include plant-pollinator and plant-seed disperser interactions (Bascompte et al, 2003). These networks could be easily used to model species-habitat interactions, with species being one node type and habitat patches the other.

Nestedness and modularity are among the most important network metrics (Fortuna et al, 2010). A species-habitat network, for instance, is nested if the less species-rich patches host a subset of the species hosted by more species-rich patches. Using nestedness we can also evaluate the importance of an area for conservation. In a highly nested system, species-poor patches only host common generalists, while species-rich patches are the only ones to also host rare specialists, so they would be the only priority in preservation. In a non-nested network, on the other hand, more patch types will have to be protected if the aim is to conserve the entirety of species in the system.

Modularity measures the strength of division of a network into subset called modules, and gives information about connections in the system. Species and patches that are part of the same module interact with each other more strongly than species and patches in other modules. Once again, this has conservation implications: in a highly modular network, an anthropic impact is likely to affect only species and patches of the impacted module, while such an impact in a non-modular network is likely to have significant ripple effects on the whole system.

5- Aim of the thesis

The aim of this thesis was to study interactions between land use intensity and plant species diversity and habitat use inside agricultural landscapes. We selected 15 landscapes in the Udine plain (Friuli-Venezia Giulia), and carried out floristic surveys in 20 habitat patches for each one. First of all we studied the connections between the percentage of seminatural land (a proxy for land use intensity) and species richness, nestedness and modularity calculated

respectively for native species, exotic species, and all of them pooled. We also analyzed how the percentage of land around each sampling site (both seminatural and agricultural) influences species abundance for each group. Finally, we assessed how community similarity changes with the distance between sampling sites for each major habitat type.

Material and methods

1- Site selection

The sampling activity was carried out in the province of Udine, in the Friuli Venezia Giulia region, in north-eastern Italy, because of the high landscape diversity that can be found there. The region is characterized by an average annual temperature of 13°C and an average annual rainfall of between 1100 mm and 1600 mm. The most frequent crops are maize, soybean, winter cereals (mostly barley and wheat) and grape. We worked only in the southern area of the province, which is dominated by flatland, small hills, agricultural landscapes and small woods. We selected 15 sampling sites within circular buffers of 1 km in diameter. Other, larger buffers (1,5 km in diameter) were centered on the original ones. The landscape analysis was made on both buffer types to assess landscape influence at different spatial scales (Fig. 1).

We selected the sites along a gradient of land use intensification expressed by seminatural habitat cover and by the configuration of seminatural habitat patches inside the sites (the ratio between perimeter and area).

Sites were selected in QGIS (ver. 2.18), using a 2013 Friuli soil use shapefile, working on a scale of 1:20000. Adjustments were made to the 2013 file by comparing it with 2017 google satellite images.

2- Vegetational analysis

Sampling of plant communities in all 15 sites was carried out between May 15th and July 5th. We did 20 vegetational analysis in each sampling area (fig 4), trying to have a uniform pattern and also to respect the variety and abundance of habitats in each area. We used a 300m square grid superimposed to the buffers to evenly distribute the sampling points. Adjustments were made to ensure that the number of sampling points in each habitat type was proportional to the habitat type relative abundance in the each buffer, that sampling points were close to roads (for easy access) and that at least 5 sampling points in each site were in seminatural areas, to always be able to compare them with agricultural ones. In each area we collected specimens of every species of vascular plant in a square-shaped area of 10 m², and preserved them for later identification by pressing and drying them in newspaper pages; we also estimated the abundance (soil coverage from each specie in 10 m²) of each species in the sites. In total 300 plots were sampled (Tab. 1)

Tab.1 Habitat and plots

Habitat	number of plots	Habitat	number of plots
Woods	73	Poplars	13
Mais	71	Alfalfa	7
Grapes	36	Rapeseed	4
Meadow	26	Wooden colture	3
Barley	19	Pea	2
Hedgerows	14	Orchard	2
Sunflowers	14	Olive groves	2
Wheat	13	Blue tansy	1

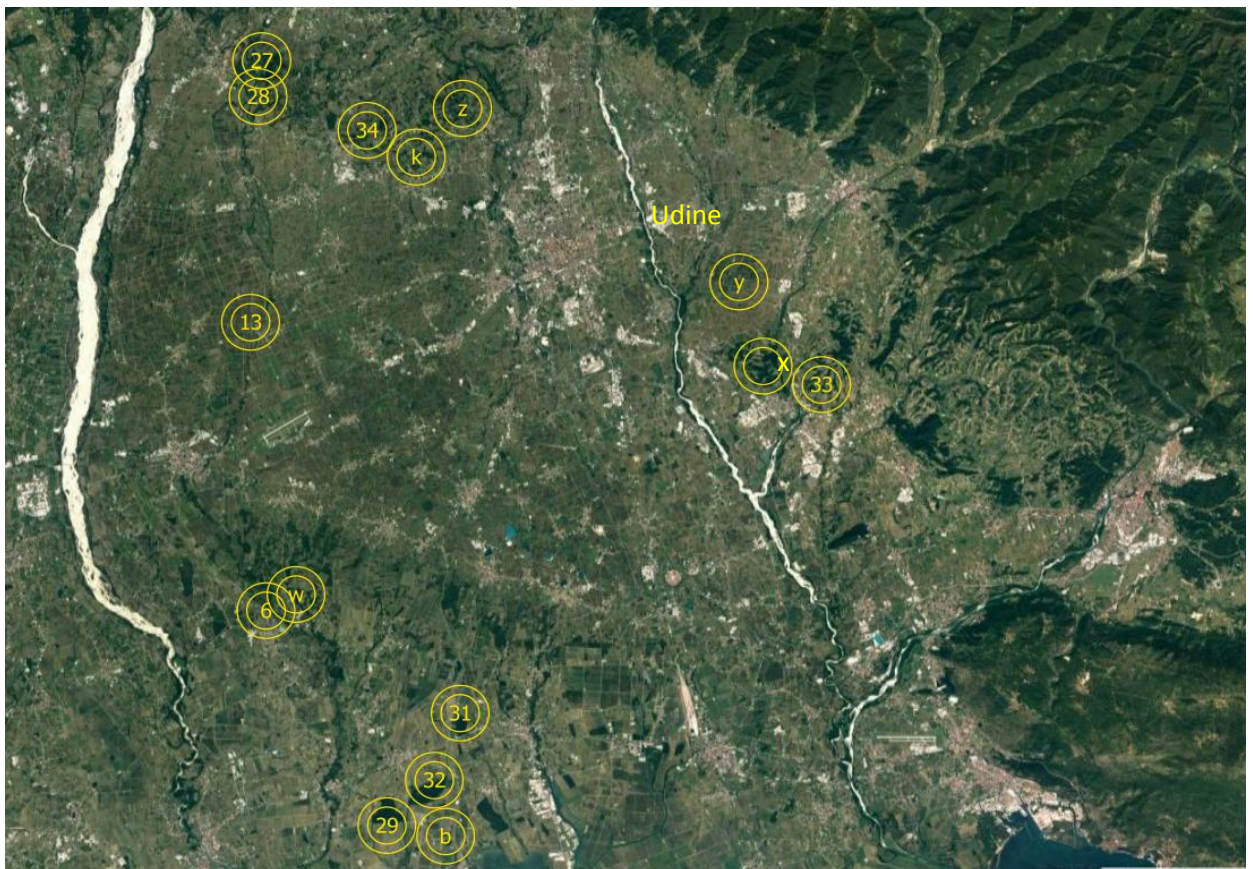


Fig. 1 Sites position and names

After collecting datas on the field we organized them in a database with informations about the species, the sampling points in which they were collected and their abundance. Nomenclature and taxonomy followed Poldini (2002) and Pignatti (1982). Exotic or native status was classified according to the national inventory (Celesti-Grapow et al. 2009).

3-Data analysis

3a-Geographical analysis

First of all, using QGIS (ver. 2.18), we made maps of the seminatural areas (hedgerows, meadows and woods) for both the sampled landscape (1 km of radius) and the surrounding buffer (1,5 km radius). For each site (landscape) we calculated the total area of seminatural habitats using the QGIS “\$area” function. In the figures 2 and 3 are shown sites with different percentage and configuration of seminatural land.

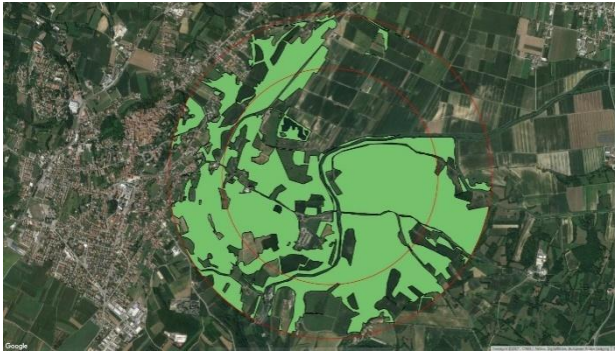


Fig. 2 Example of a site with a high percentage of seminatural land



Fig. 3 Example of a site with a low percentage of seminatural land

Additionally, we made two buffers with a radius of 250 m and 500 m respectively, centered around each sampling point, and calculated the percentage of seminatural habitats around each one. We also calculated the percentage of cropped area around each seminatural sampling point in a radius of 250 m from each point (fig 5).



Fig.4 Seminatural areas and sampling points in one of the landscapes

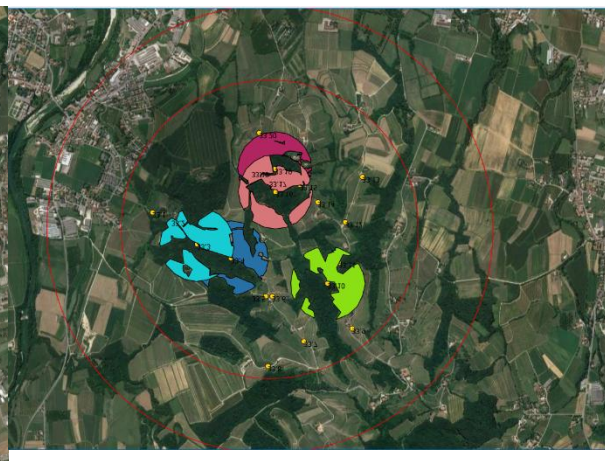


Fig.5 Crop areas around seminatural sampling points in one of the landscapes

3b-Species analysis

Analysis was carried out separately for native and exotic species. We calculated abundance in each site, as well as the absolute and average number of species inside all the sites without counting the main crop in cropped sites .

3c-Regression between species number and landscape composition

For each sampling area we correlated the richness of native species, exotic species and all species with the amount of seminatural areas at both spatial scales (1 km and 1,5 km of radius buffers).

3d-Nestedness and modularity

The nestedness and modularity analysis was carried out using the “weighted NODF” and “computeModules” functions in the “bipartite” package, respectively. We calculated the nestedness of native plants, exotic plants and all the species together for each sampling point in each landscape. We carried out a regression analysis between the nestedness and the percentage of seminatural land in each sampling area. R^2 values were used to explain the variance given by the model.

3e-Decay of similarity with distance

Beta-diversity was correlated to geographical distance to investigate the potential different distance-decay of similarity between native and exotic species. To perform the analysis on beta-diversity we used regression on distance matrices (MRM). The similarity was calculated with the formula $1 - BC$ (where BC is the Bray Curtis dissimilarity index), using the “vegdist” function (method: “bray”) of the R package “vegan”. The response matrix was the beta-diversity matrix and the explanatory matrix was the geographical distance matrix (distance in meters between each pair of sampling sites obtained from the sampling point coordinates). MRMs were conducted for each response variable separately using a linear model for a possible non-linear relationship. Tests of statistical significance were performed by permutation ($n=999$, $P<0.05$). The MRM analyses were conducted using R statistical software with “MRM” function in the “ecodist” package. R^2 values were used to enucleate the variance explained by the model.

To analyze the difference of decay of similarity with distance between native and alien species we used the R difflpe function of the package “simba”.

Results

1. Species richness, seminatural area and habitat distribution

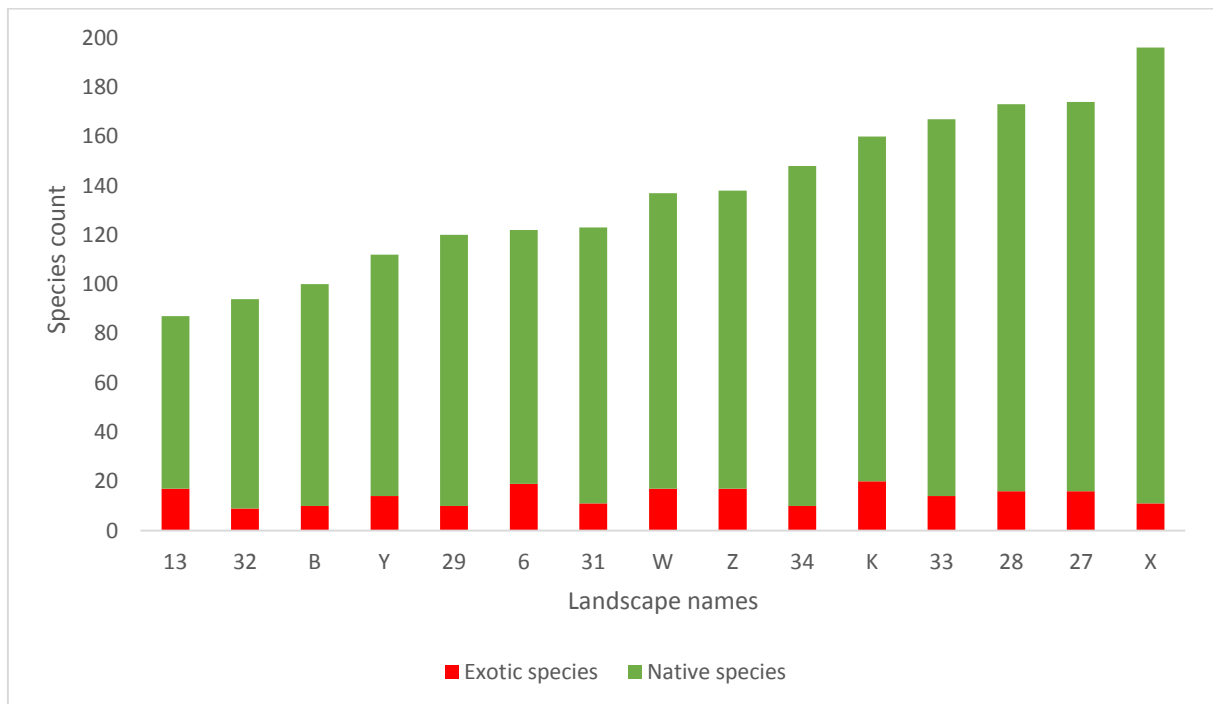


Fig 6 Total number of species in each site

Native plants have a higher species-richness than exotic ones in all the sites (fig 6).

Buffers of 1 km of radius have a percentage of seminatural land going from 3.6% to 60% (fig 7) while buffers of 1,5 km of radius range from 2.16% to 50% (fig 8).

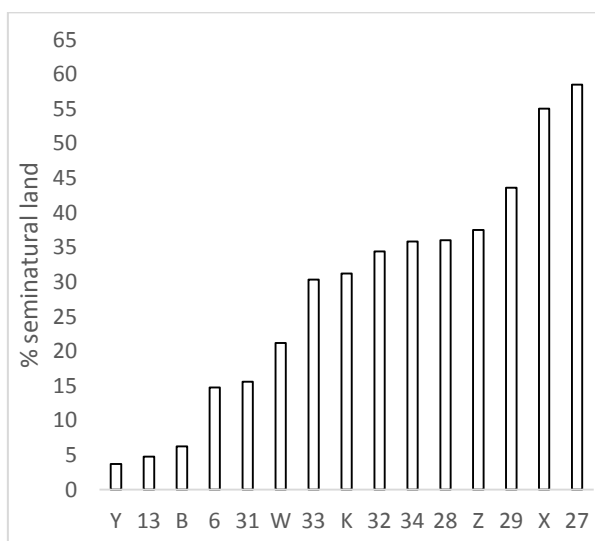


Fig. 7 Percentage of seminatural land in each landscape (1km radius)

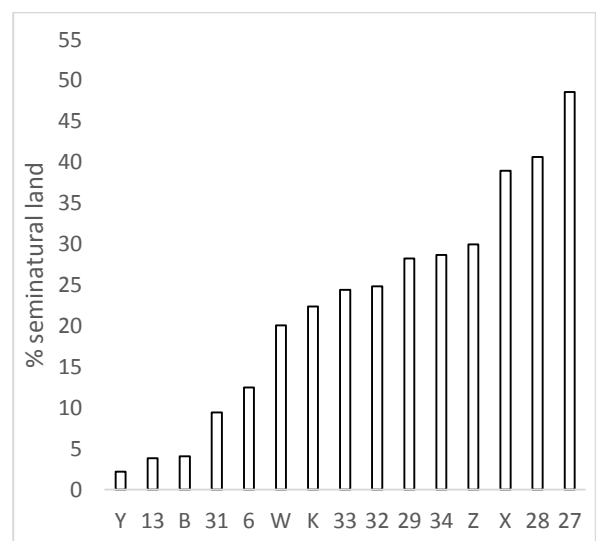


Fig. 8 Percentage of seminatural land in each landscape (1,5 km radius)

We also checked the habitat distribution within all the landscapes counting the habitat frequency and then observing the distribution of exotic and native species in each site

Tab. 2 Area and percentage of seminatural land for each site

Site	Seminatural area (m ²) - 1 km radius	% seminatural land 1 km radius	Seminatural area (m ²) - 1,5 km radius	% seminatural land 1,5 km radius
Y	115365.614	3.672201546	153284.077	2.168526093
13	148941.46	4.740953918	270855.715	3.831824525
B	195731.897	6.230339786	285582.206	4.040161755
31	488381.793	15.54567529	665496.172	9.414844923
6	462672.168	14.72731251	880867.643	12.46172796
W	664369.464	21.14753685	1419194.684	20.0774977
K	979932.595	31.19222328	1580457.073	22.35889382
33	952343.2	30.31402556	1724905.883	24.40242646
32	1079745.265	34.36935924	1754217.204	24.81709682
29	1370046.288	43.6099278	1995312.411	28.22789629
34	1125634.259	35.83005129	2025599.777	28.65637487
Z	1178305.154	37.50661795	2119053.007	29.97846762
X	1728723.728	55.02698531	2753979.382	38.96083838
28	1131211.428	36.00757809	2873195.56	40.64740223
27	1837655.631	58.49439547	3435212.558	48.59831637

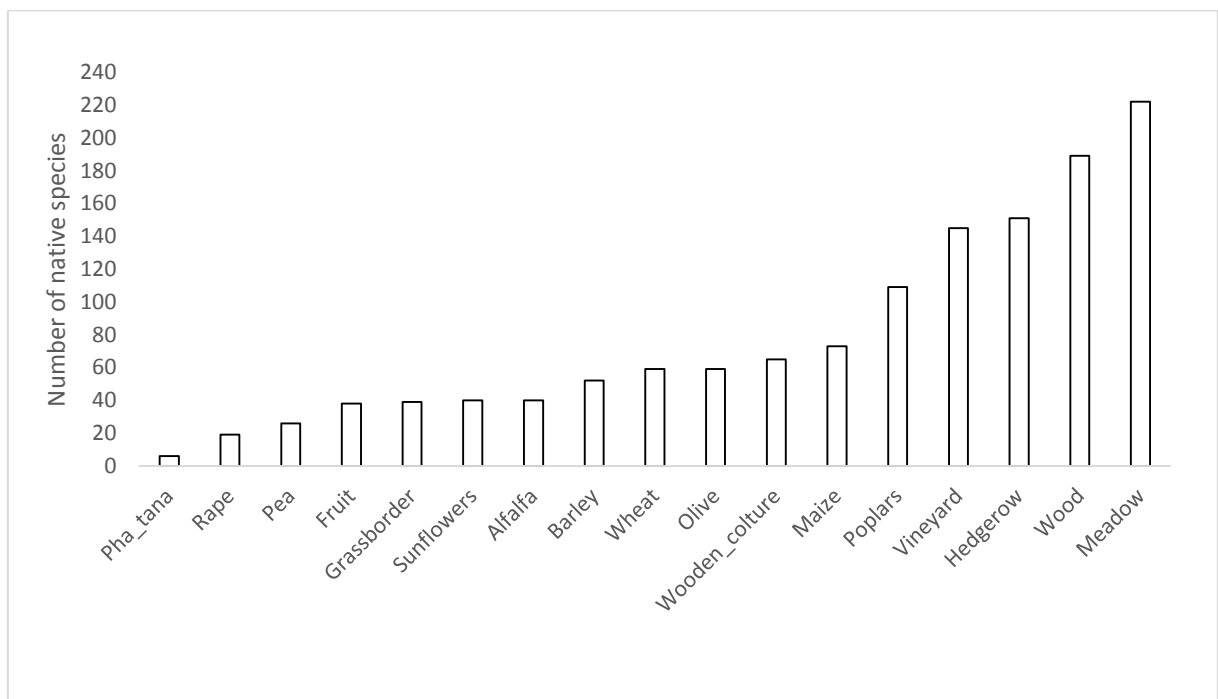


Fig 9 Number of native species for each habitat

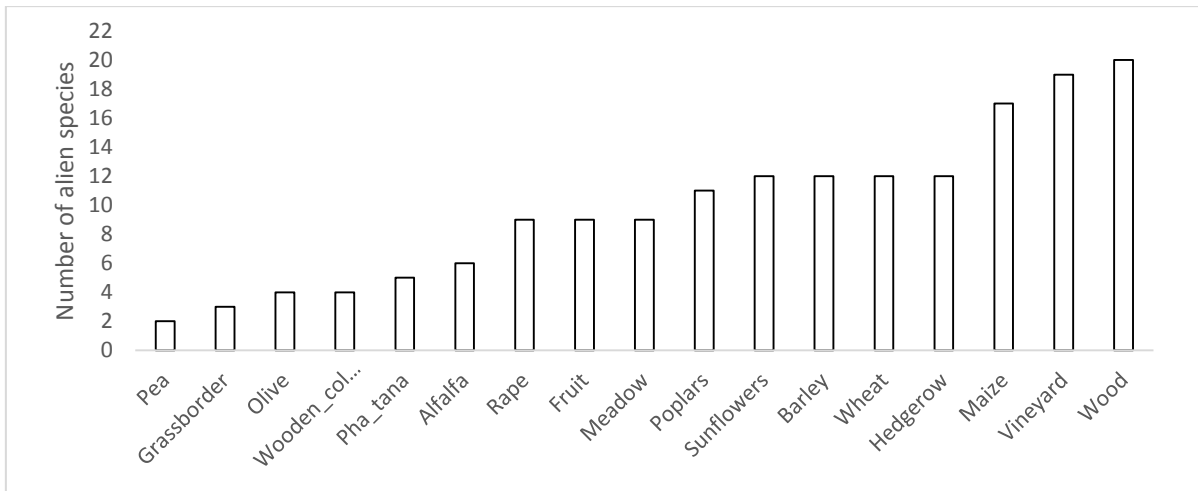


Fig 10 Number of exotic species for each habitat

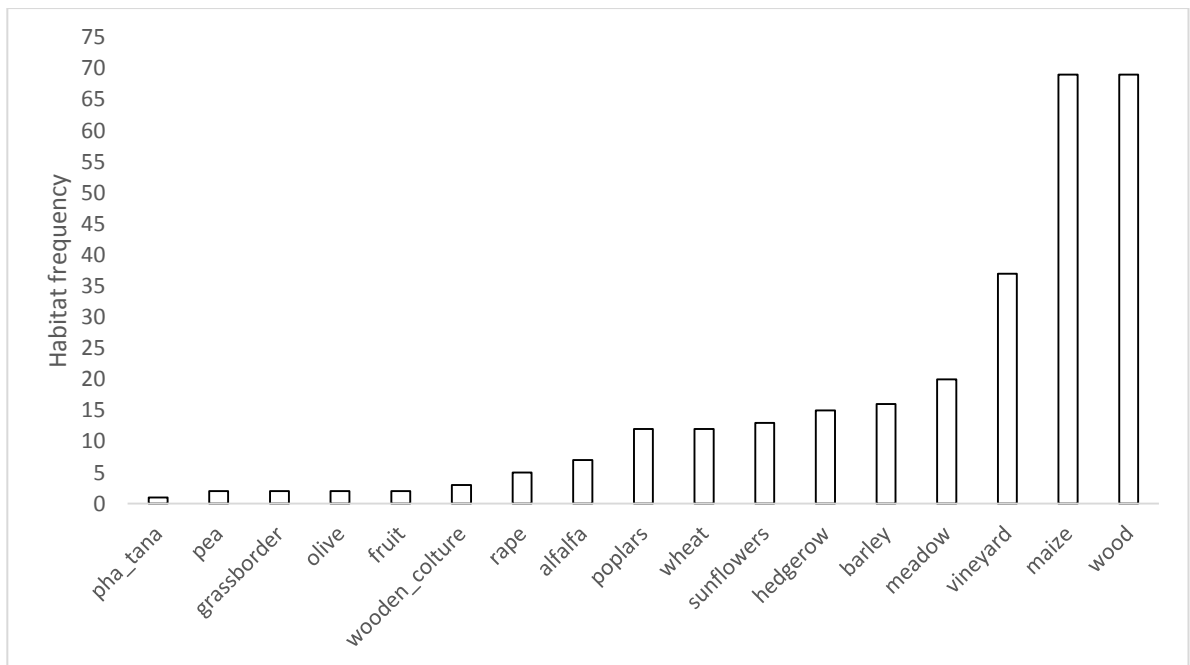


Fig 11 Habitat and their frequency (pha_tana is *Phacelia tanacetifolia*)

The most abundant sampled habitats are woods and maize fields (Fig. 11), followed by vineyards, meadows, hedgerows, winter cereals and oil crops. Less abundant habitats have also a lower number of species. Seminal habitats have a higher number of native species (Fig. 9): meadows have the highest number of native species, as expected since the high biodiversity of permanent fields, often lean; then there are woods (many plantal woods are habitat protected by UE) and then hedgerows, which are a shelter for many species in landscapes dominated by biodiversity-poor croplands. The number of alien species is higher in winter crops, hedgerows, maize fields, vineyards and woods (Fig. 10).

2. Influence of seminatural habitat abundance on species richness

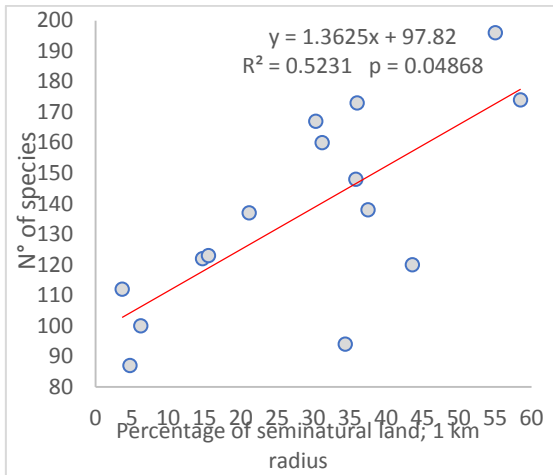


Fig 12 Species richness VS percentage of seminatural land in the landscape (n=15)

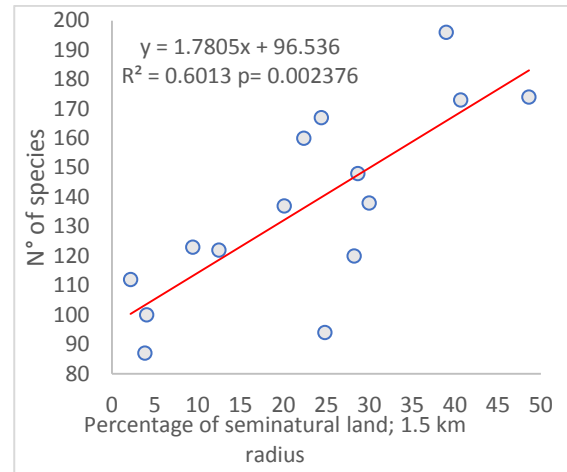


Fig 13 Species richness VS percentage of seminatural land in the landscape and buffer area (n=15)

With an higher percentage of seminatural land the total number of species increases. The positive correlation with species richness is significant for both the 1,5 km buffer and the 1 km buffer, but is more marked for the first one (figg 12-13).

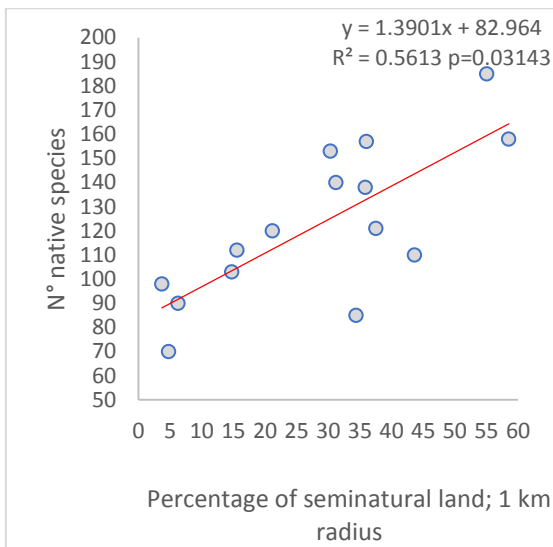


Fig 14 Native species count VS percentage of seminatural land in the landscape area (n=15)

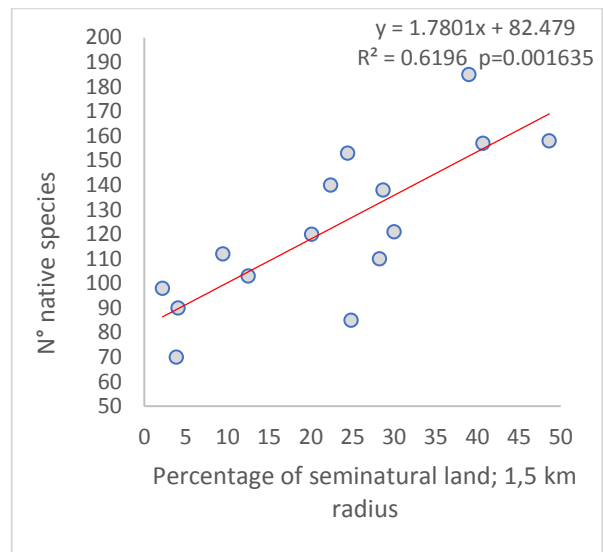


Fig 15 Native species count VS percentage of seminatural land in the landscape and buffer area (n=15)

With a higher percentage of seminatural land the total number of native species increases (figg 14-15)

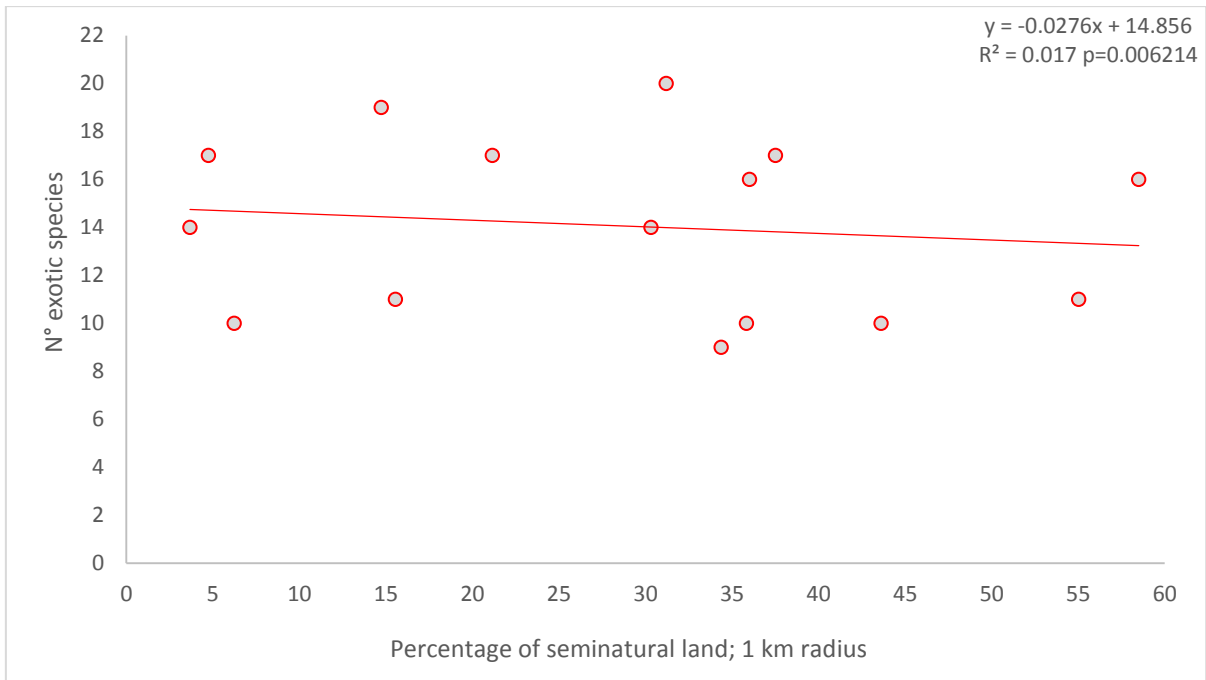


Fig. 16 Exotic species count VS percentage of seminatural land in the landscape area (n=15)

Since the number of alien species is low (fig 16), we used the percentage of alien species on the total of plant species, instead of species richness .

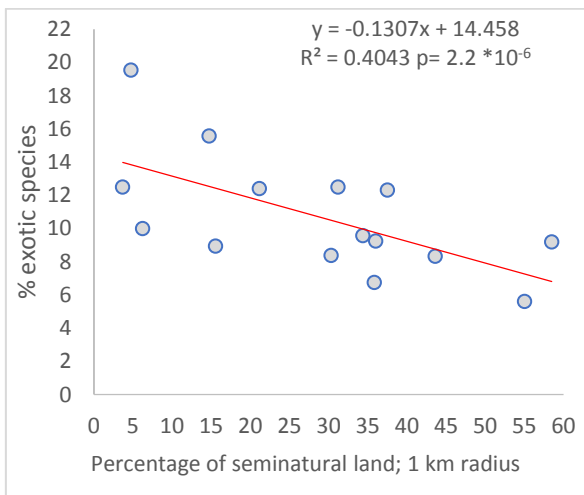


Fig 17 Percentage of exotic species VS percentage of seminatural land in the landscape area (n=15)

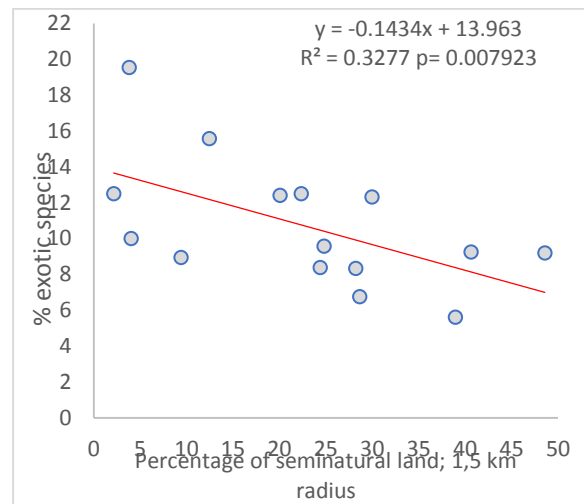


Fig 18 Percentage of exotic species VS percentage of seminatural land in the landscape area and buffer (n=15)

The amount of exotic species, which are connected to anthropic activity, is inversely correlated with the percentage of seminatural land in the landscape, more markedly for the 1,5 km than for the 1 km buffers (figg 17-18).

3. Nestedness

Higher percentages of seminatural habitats in the landscape are generally thought to be linked to higher system complexity and richness (especially for native species). For that reason both the NODF nestedness index and the modularity were calculated separately for natives, exotics and all species combined.

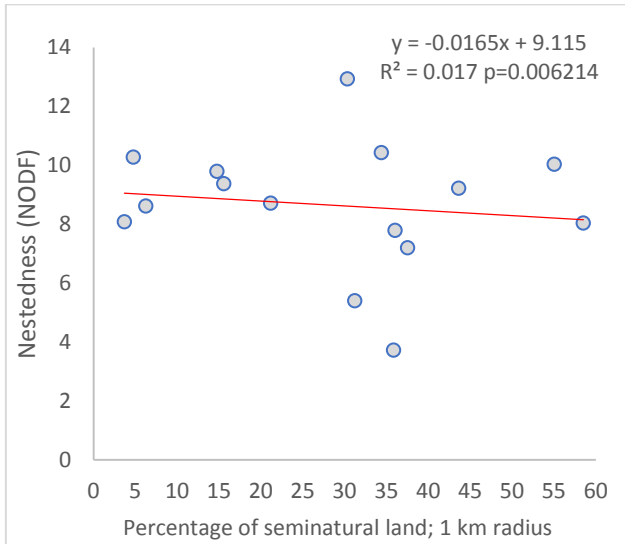


Fig 19 Nestedness VS percentage of seminatural land in the landscapes(n=15)

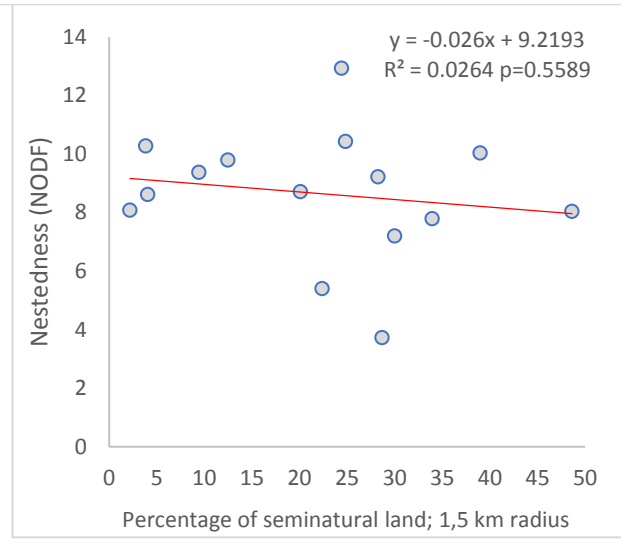


Fig 20 Nestedness VS percentage of seminatural land in the landscapes and buffer areas(n=15)

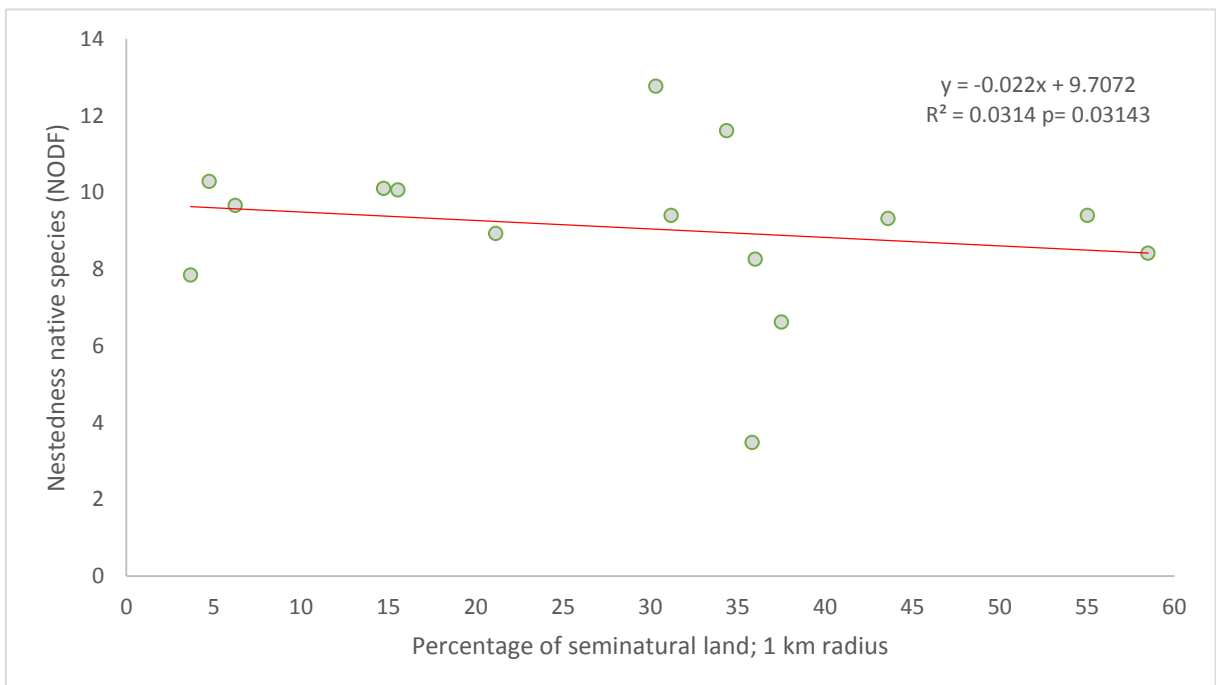


Fig 21 Nestedness of native species VS percentage of seminatural land in the landscapes (n=15)

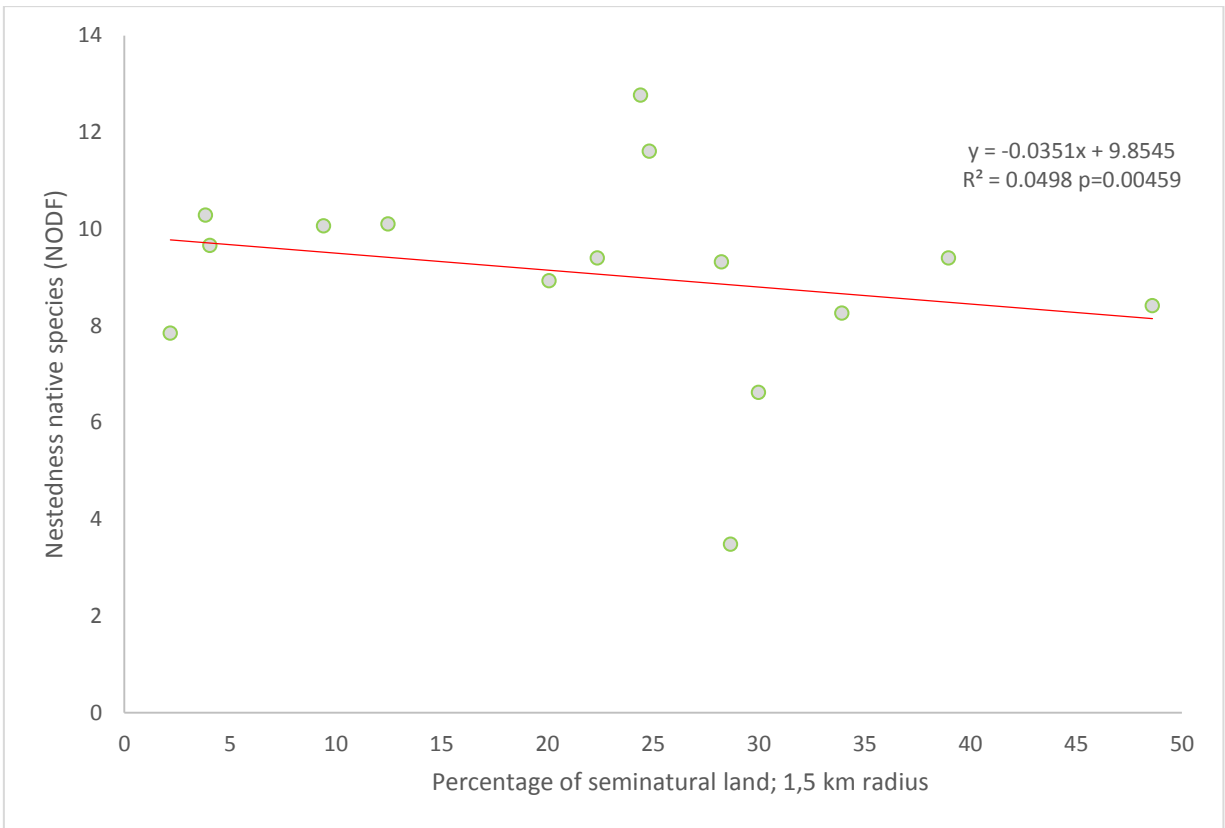


Fig 22 Nestedness of native species VS percentage of seminatural land in the landscapes and buffer areas (n=15)

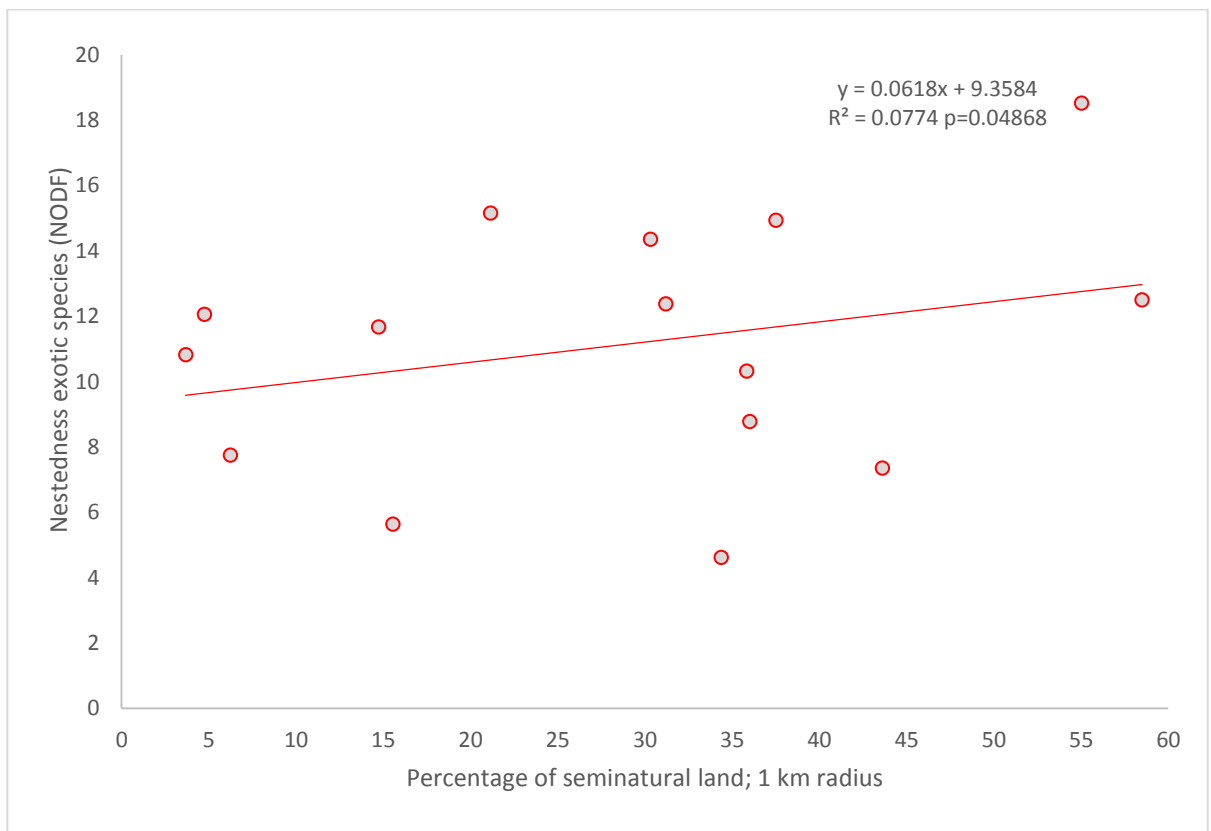


Fig 23 Nestedness of exotic species VS percentage of seminatural land in the landscapes (n=15)

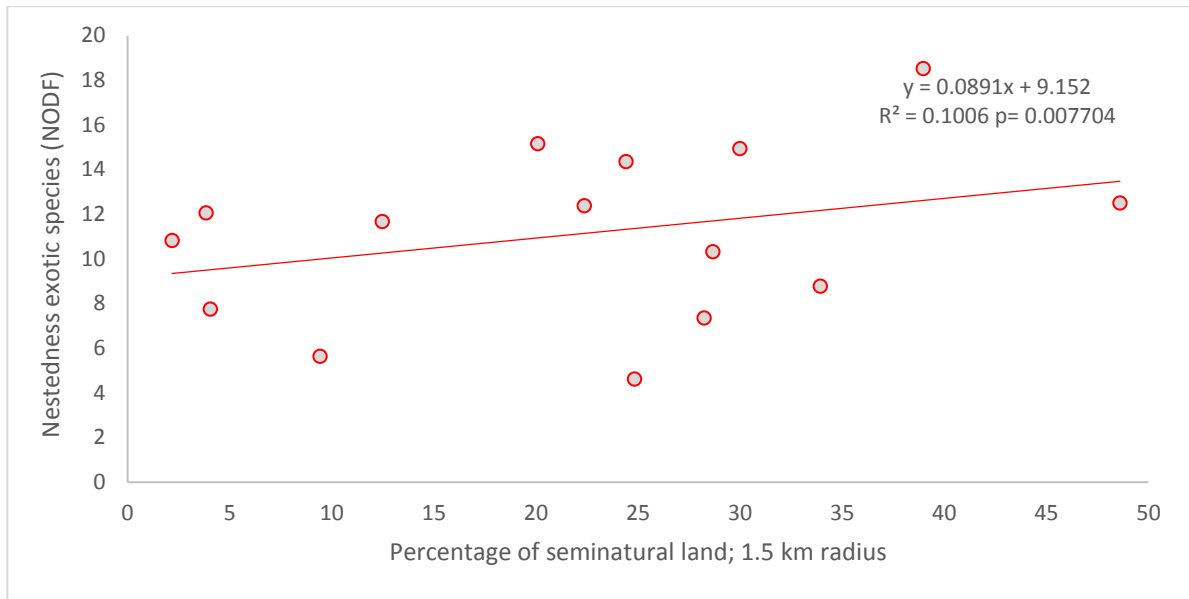


Fig 24 Nestedness of exotic species VS percentage of seminatural land in the landscapes and buffer areas (n=15)

As for the NODF index, increasing the percentage of seminatural land the nestedness of all plants and of native species decreases slowly (figg 19-20-21-22), with the effect being more marked for native species alone. On the other hand, the nestedness of exotic species increases (figg 23-24). All of these trends are stronger for the 1,5 km than for the 1 km buffer (figg 20-22-24).

All of these correlations are rather weak ($R^2 \leq 0.1$) and not always statistically significant, such as in the case of the decrease of nestedness of all the plants species in the 1,5 km buffer.

4. Modularity

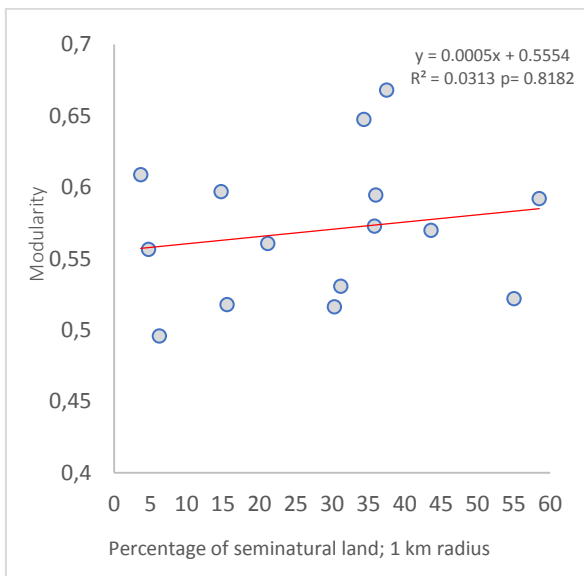


Fig. 25 Modularity VS percentage of seminatural land in

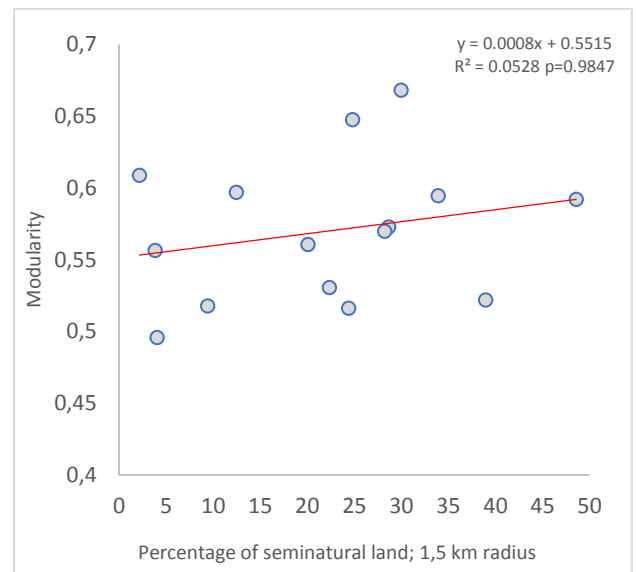


Fig. 26 Modularity VS percentage of seminatural land in

the landscapes (n=15)

the landscapes and buffer areas (n=15)

Considering all the species, the modularity slowly grows with the percentage of seminatural land, with more influence if we consider the larger 1,5 km of radius area: landscape and buffer (fig 25-26). The correlation between modularity and percentage of seminatural land is weak and not statistically significant ($R^2 \leq 0.1$; $p > 0,05$).

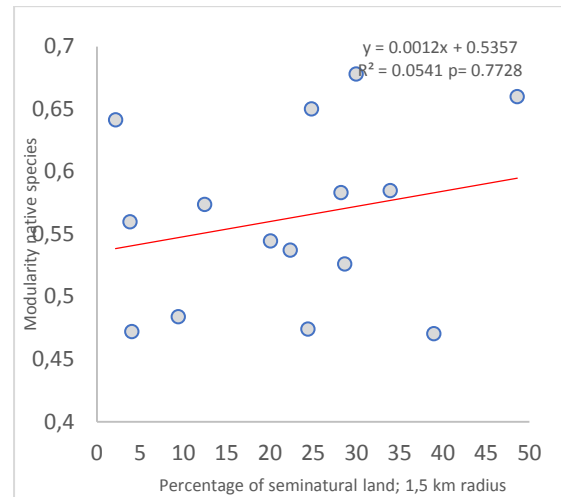
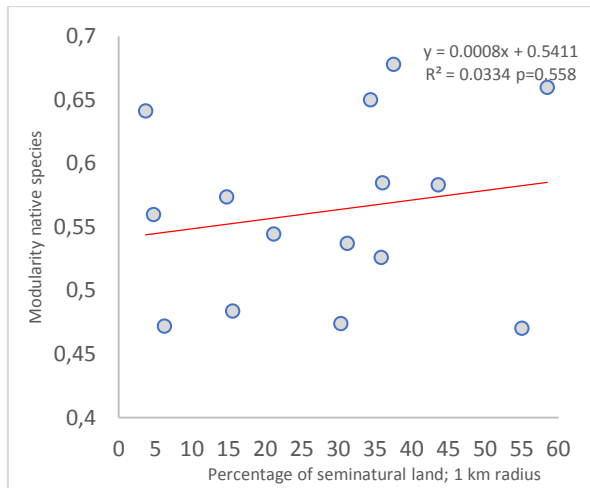


Fig 27 Modularity of native species VS percentage of seminatural land in the landscapes (n=15)

Fig 28 Modularity of native species VS percentage of seminatural land in the landscapes and buffers(n=15)

The modularity of native species slowly grows with the amount of seminatural land (fig 27-28) with a rate similar to the one of all the species but still not significant ($R^2 \leq 0.1$; $p > 0,05$). The larger spatial scale (landscape and buffer) still shows a higher growth rate of the modularity.

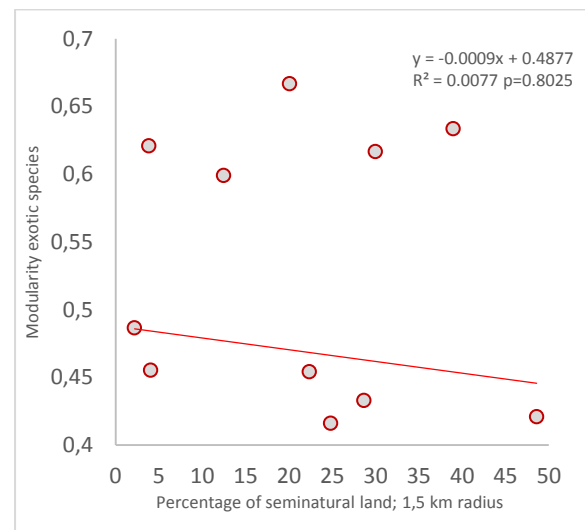
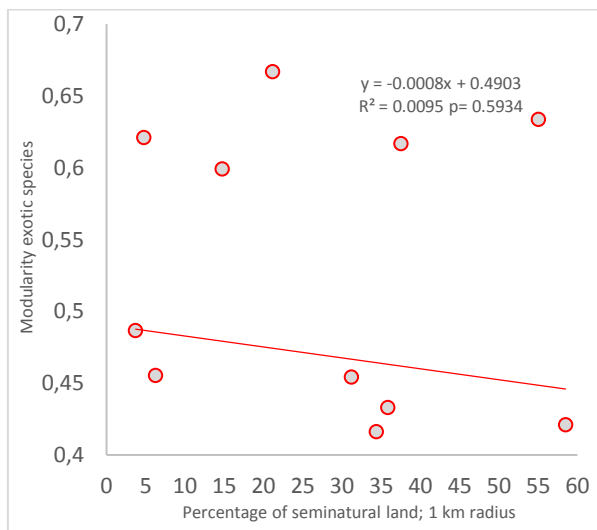


Fig 29 Modularity of exotic species VS percentage of seminatural land in the landscapes (n=15)

Fig 30 Modularity of exotic species VS percentage of seminatural land in the landscapes and buffers(n=15)

Exotic species show an opposite, but still not significant ($R^2 \leq 0.1$) trend (fig 29-30). A higher amount of seminatural habitats in the landscape means less space for alien species who have less connections between themselves.

5. Analysis on the local area around each sampling point

To elucidate the interactions between the species in each sampling point and the surrounding area we also analyzed how the species richness for exotics, natives and all plants changes with the composition of the immediate surroundings (local scale) (Tab.

Tab. 3 Local area analysis scheme

Species	Sampling point	Surrounding area (buffer)	Buffer radius (m)
Exotic	Seminatural habitats (Wood or meadow or hedgerow)	Seminatural habitat	500
Natives	Seminatural habitats	Seminatural habitat	500
Exotic	Seminatural habitats	Seminatural habitat	250
Natives	Seminatural habitats	Seminatural habitat	250
Exotic	Seminatural habitats	Crop habitat	250
Natives	Seminatural habitats	Crop habitat	250
Exotic	Crop habitats (not seminatural ones)	Seminatural habitat	250
Natives	Crop habitats	Seminatural habitat	250

In each case we considered both all the species and only the species with an abundance > 0,5%.

5.1 Sampling points in seminatural habitats

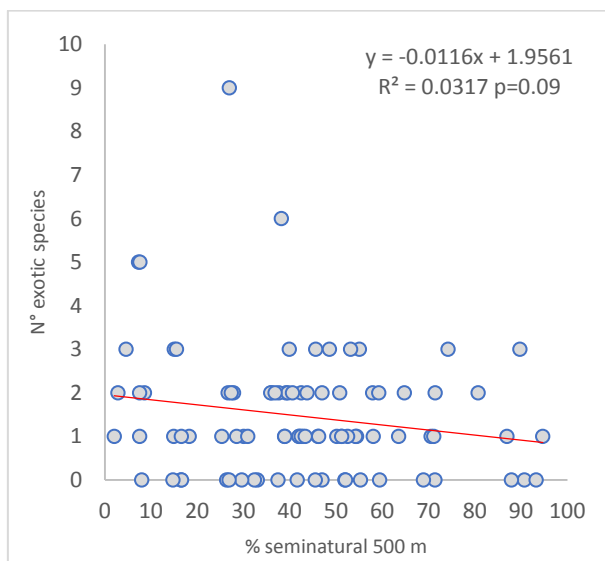


Fig 31 N° alien species VS percentage of seminatural land in a 500 m radius from each point (n=88)

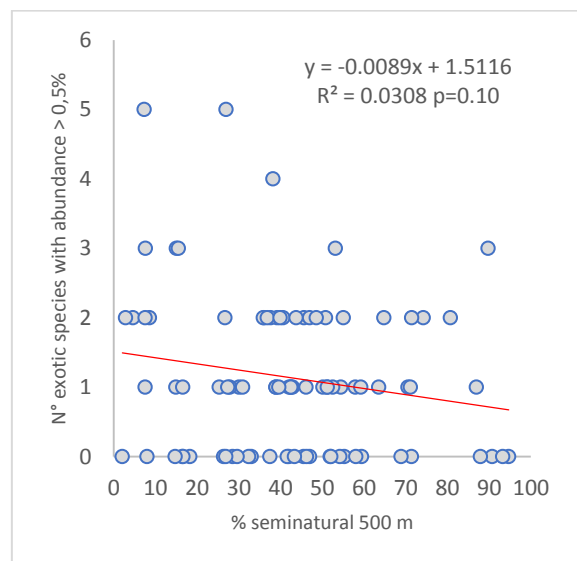


Fig 32 N° alien species with abundance > 0,5% VS percentage of seminatural land in a 500 m radius from each point (n=88)

Increasing the percentage of seminatural land in a buffer of 500 meters around seminatural sampling points, the number of alien species decreases but not in a significant way (fig 31-32), while the number of native species increases (fig 33-34). The trends are stronger if we consider all the species (fig 31-33).

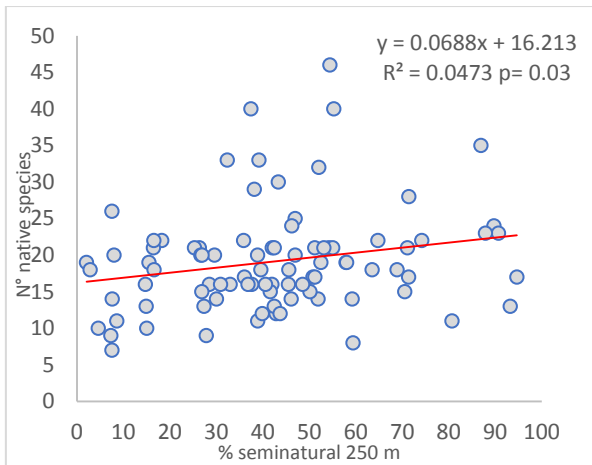


Fig 34 N° native species VS percentage of seminatural land in 500 meters from each point (n=88)

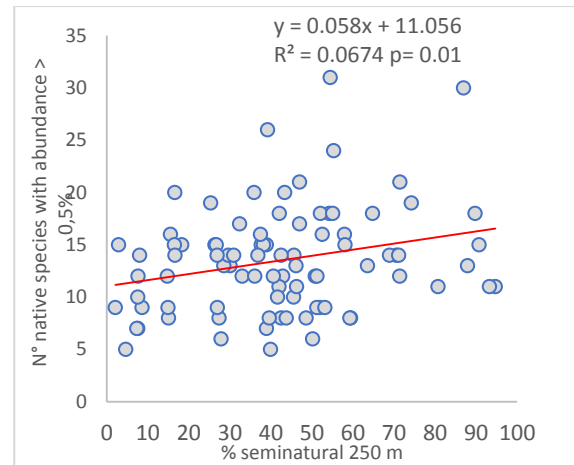


Fig 35 N° native species with abundance > 0,5% VS percentage of seminatural land in 500 meters from each point (n=88)

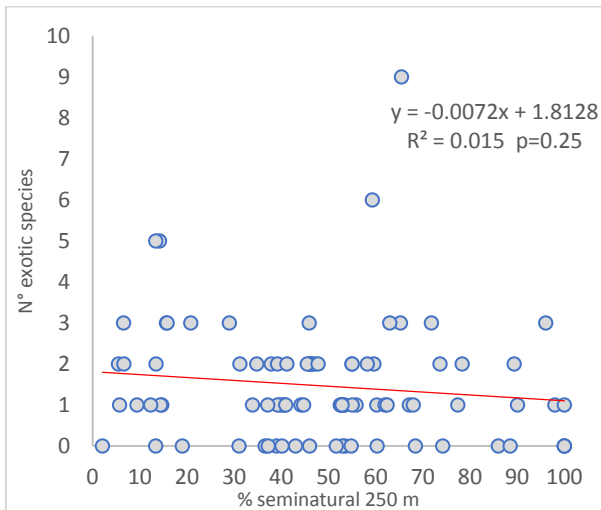


Fig 36 N° exotic species VS percentage of seminatural land in 250 meters from each point (n=88)

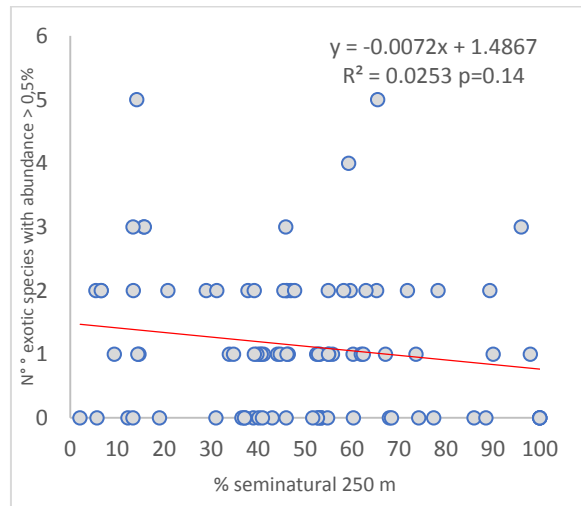


Fig 37 N° exotic species with abundance > 0,5% VS percentage of seminatural land in 250 meters from each point (n=88)

The trends are similar in a 250 m buffer: the number of species decreases too (fig 36-37-38-39), even though the rate of decrease for exotic species is lower (fig 36-37) and the rate of increase for native species is higher (fig 38-39) than the bigger buffer (fig 34-35). Additionally, the rate of decrease for exotic species is higher if we consider only species with

an abundance > 0,5% (fig 37), while the rate of increase for native species is higher (but not statistically significant) if we consider all species (fig 39).

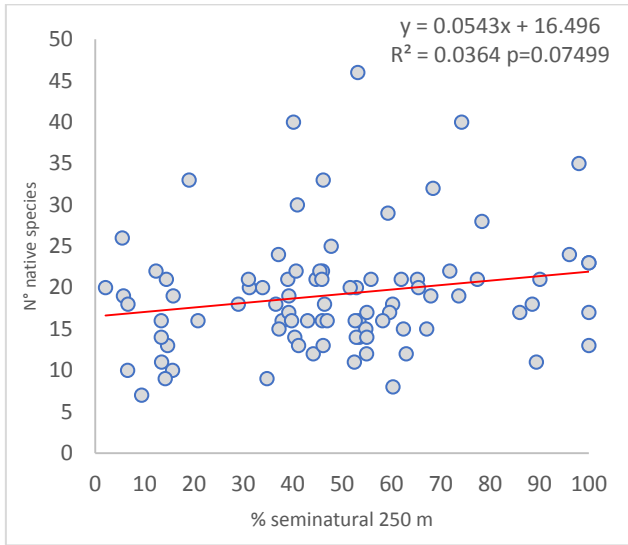


Fig 38 N° native species VS percentage of seminatural land in 250 meters from each point (n=88)

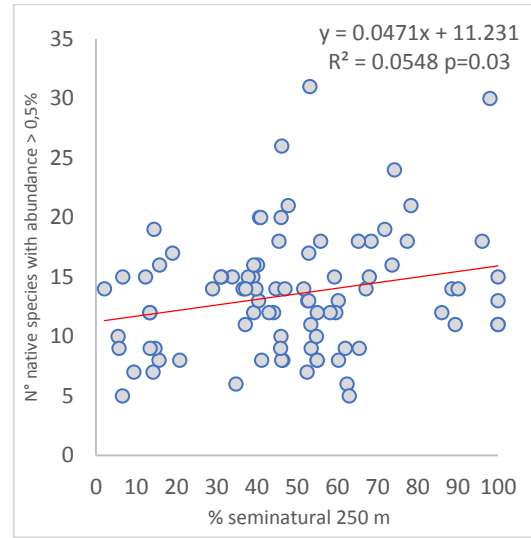


Fig 39 N° native species with abundance > 0,5% VS percentage of seminatural land in 250 meters from each point (n=88)

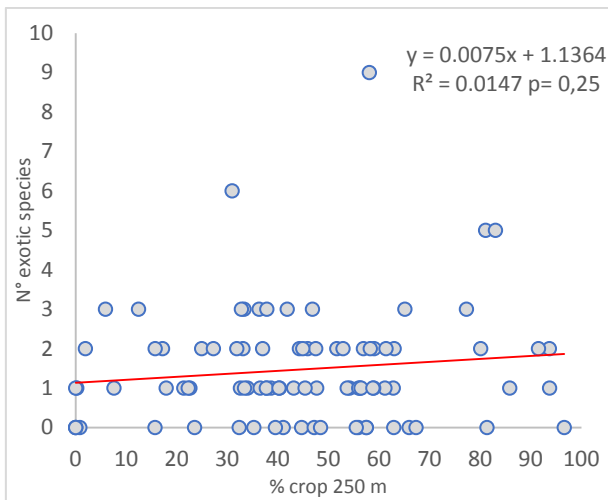


Fig 40 N° exotic species VS percentage of not seminatural land in 250 meters from each point (n=88)

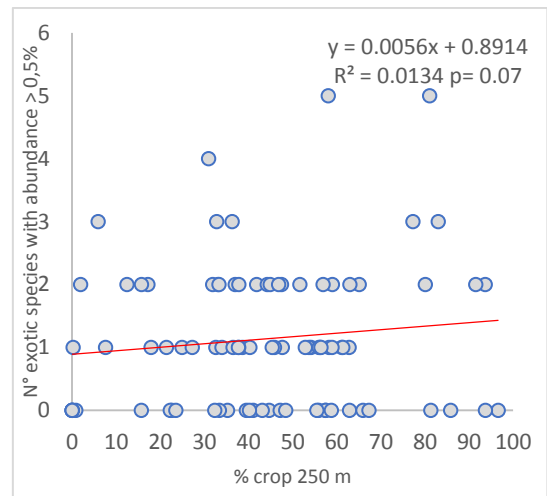


Fig 41 N° exotic species with abundance > 0,5% VS percentage of not seminatural land in 250 meters from each point (n=88)

Conversely, increasing the percentage of crop land in a buffer of 250 meters around points in a seminatural habitat the number of alien species increases (fig 40-41), while the number of native species decreases too (fig 42-43). The rate of increase for alien species is higher (fig 40) if we consider all the species (but not statistically significant), while the rate of decrease for native ones is higher if we consider only the species with an abundance > 0,5% (fig 43).

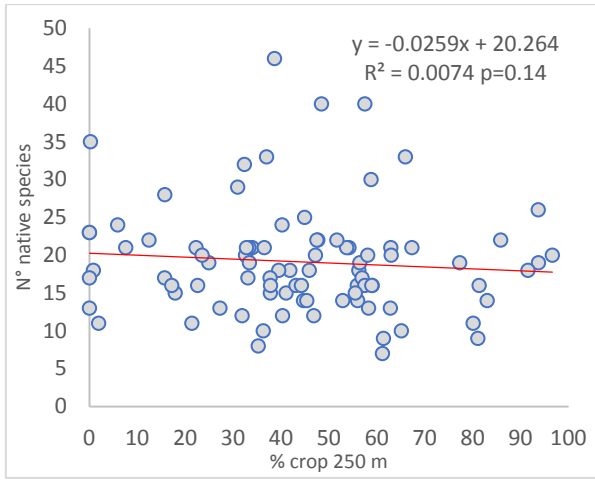


Fig 42 N° native species VS percentage of not seminatural land in 250 meters from each point (n=88)

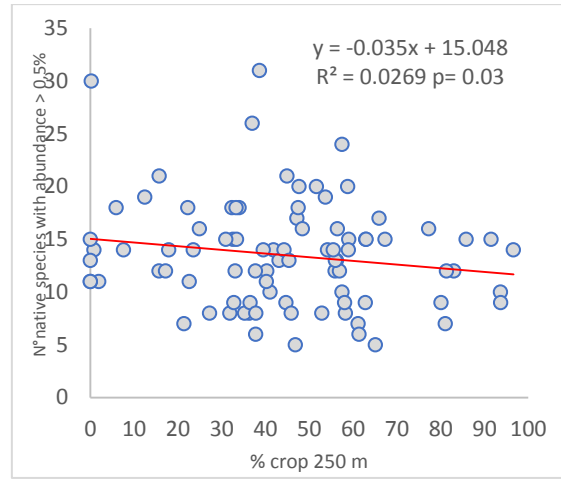


Fig 43 N° native species with abundance > 0,5% VS percentage of not seminatural land in 250 meters from each point (n=88)

5.3 Sampling points in crop habitats

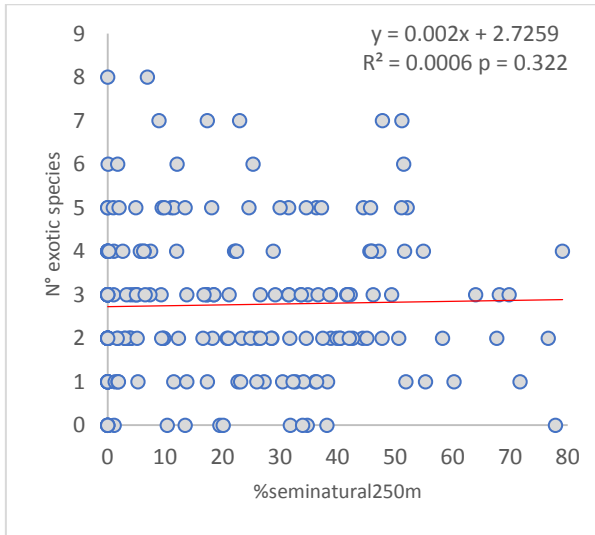


Fig 44 N° exotic species VS percentage of seminatural land in 250 meters from each point (n=201)

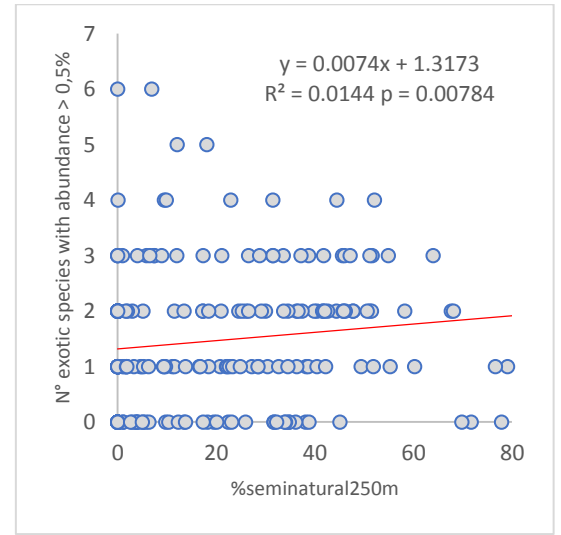


Fig 45 N° exotic species with abundance > 0,5% VS percentage of seminatural land in 250 meters from each point (n=201)

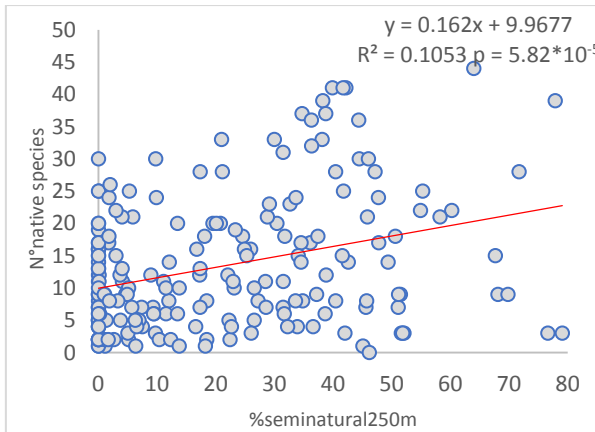


Fig 46 N° native species VS percentage of seminatural land in 250 meters from each point (n=201)

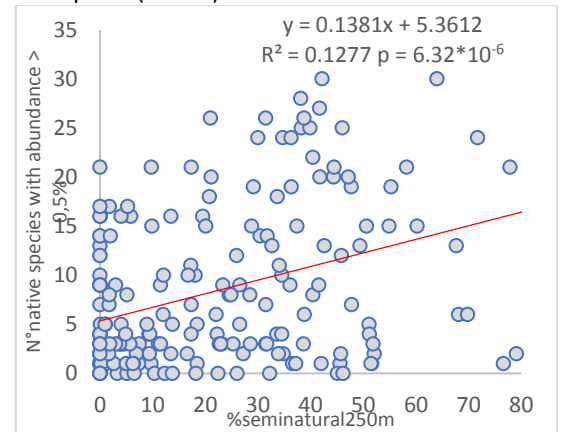


Fig 47 N° native species with abundance > 0,5% VS percentage of seminatural land in 250 meters from each point (n=201)

The highest recorded percentage of crop habitats around seminatural sampling points is 96%, while the highest recorded percentage of seminatural habitats around crops is 79%. Since crop lands usually host only a few species in addition to the crop itself, the number of species – both exotic and native, but only the latter in a statistically significant way – increases with the amount of seminatural habitats surrounding cropland sampling points (fig 44-45-46-47).

The rate of increase is higher if we consider only species with an abundance higher than 0,5%.

6. Decay of similarity with distance

For each habitat with more than 12 sampling points, we calculated how the community similarity between sampling points decreases with the geographical distance between them.

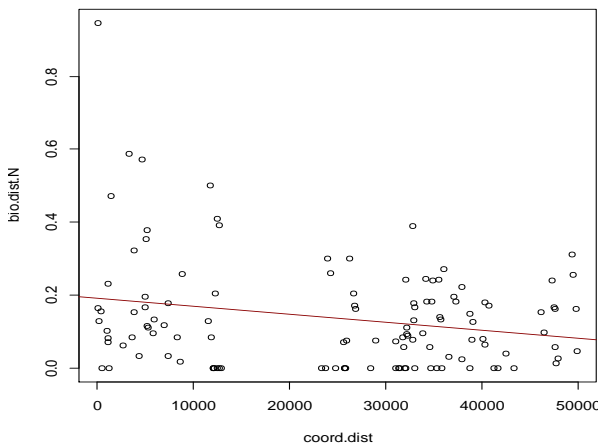


Fig 48 Decay of species similarity with distance in barley; native species
Slope -2.20E-06 p 0.19019 R² 0.053149

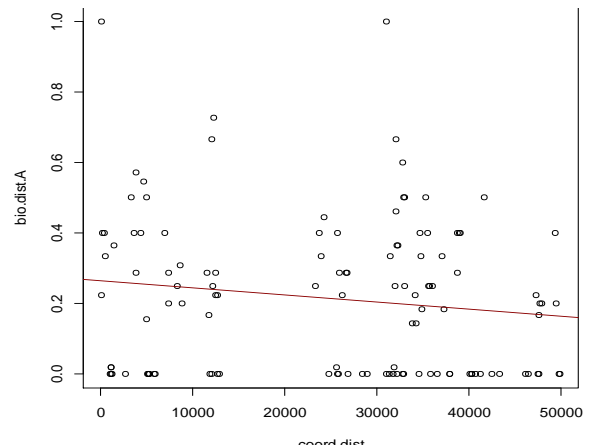


Fig 49 Decay of species similarity with distance in barley ; exotic species
Slope -2.03E-06 p 0.108108 R² 0.20668

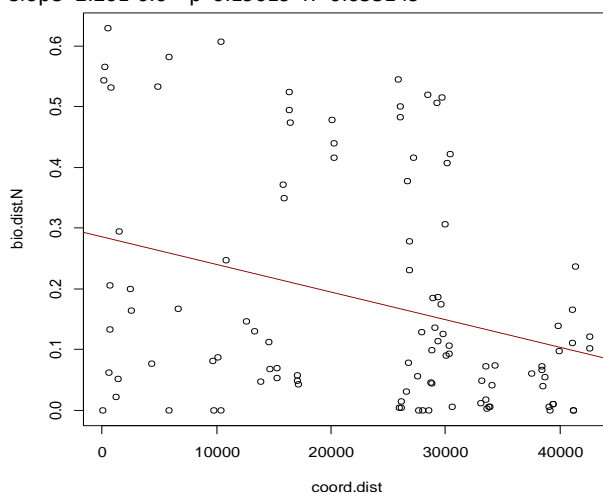


Fig 50 Decay of species similarity with distance in hedgerow; native species
Slope -4,49E-06 p 0,007007 R² 0,095511

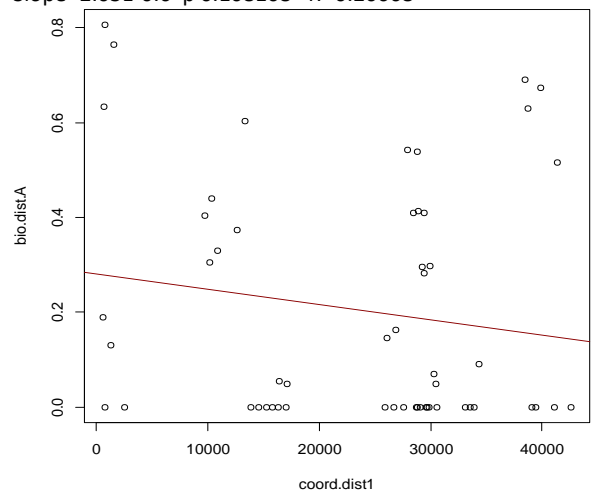


Fig 51 Decay of species similarity with distance in hedgerow ; exotic species
Slope -3,25E-06 p 0,145145 R² 0,025184

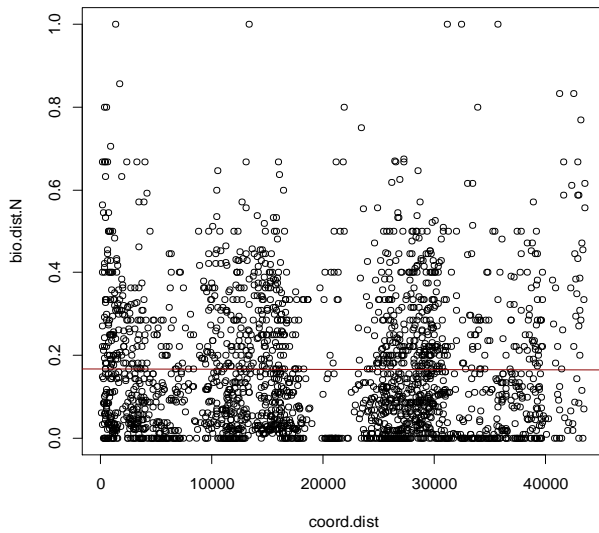


Fig 52 Decay of species similarity with distance in maize;
native species
Slope $-6,27E-09$ p $0,98999$ R^2 $2,92E-07$

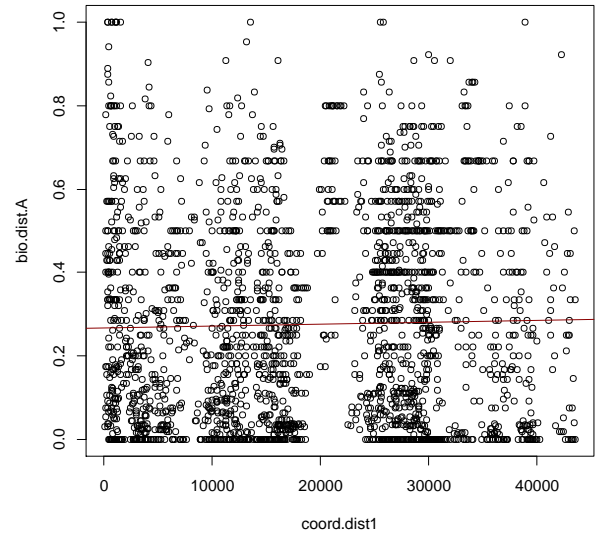


Fig 53 Decay of species similarity with distance in maize;
exotic species
Slope $0,00019$ p $0,053053$ R^2 $0,010058$

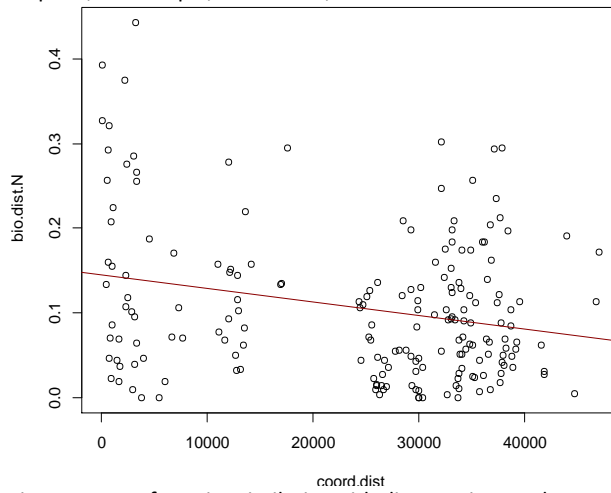


Fig 54 Decay of species similarity with distance in meadows;
native species
Slope $-1,61E-06$ p $0,003003$ R^2 $0,063434$

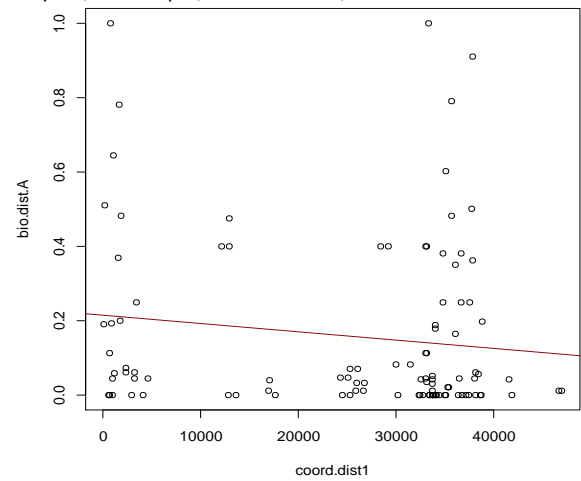


Fig 55 Decay of species similarity with distance in meadows;
exotic species
Slope $-2,26E-06$ p $0,143143$ R^2 $0,018729$

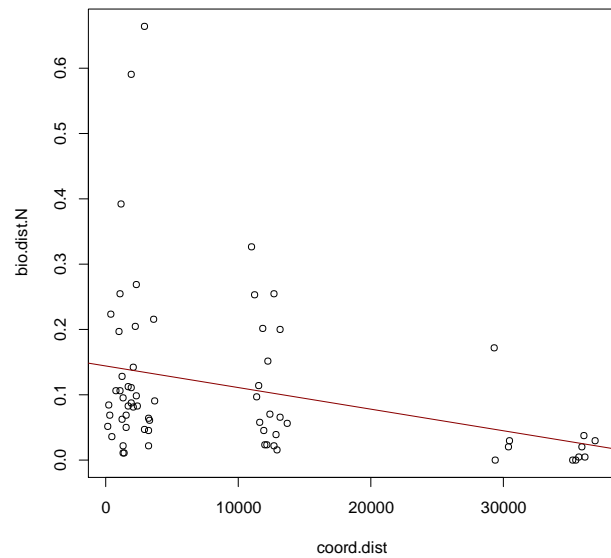


Fig 56 Decay of species similarity with distance in poplars;
native species
Slope $-3,33E-06$ p $0,056056$ R^2 $0,095686$

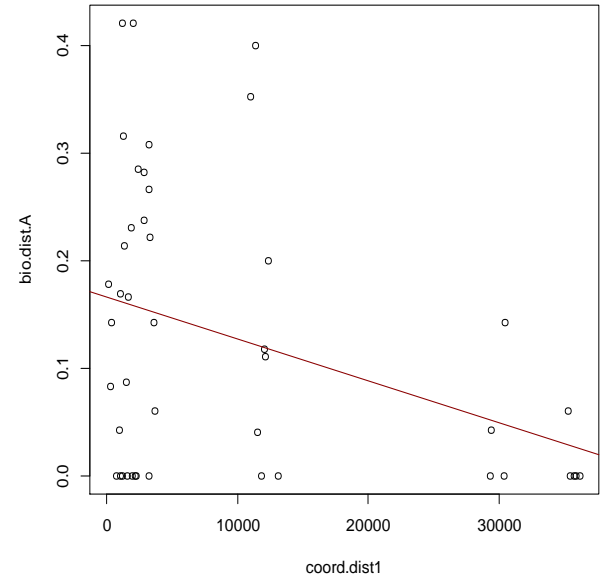


Fig 57 Decay of species similarity with distance in poplars;
exotic species
Slope $-3,90E-06$ p $0,098098$ R^2 $0,132167$

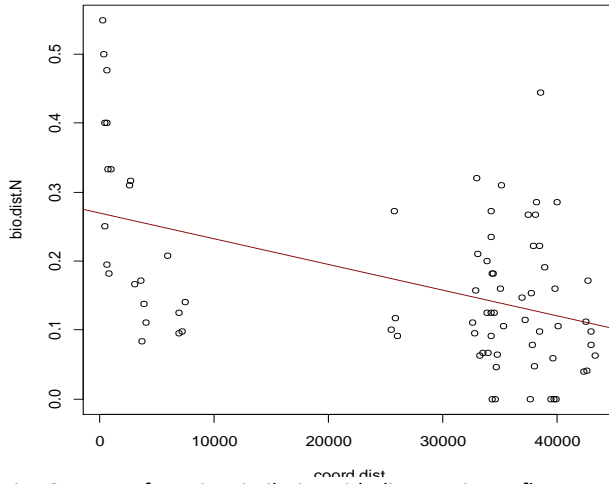


Fig 58 Decay of species similarity with distance in sunflowers; native species
Slope $-3,74E-06$ p 0,001001 R^2 0,225539

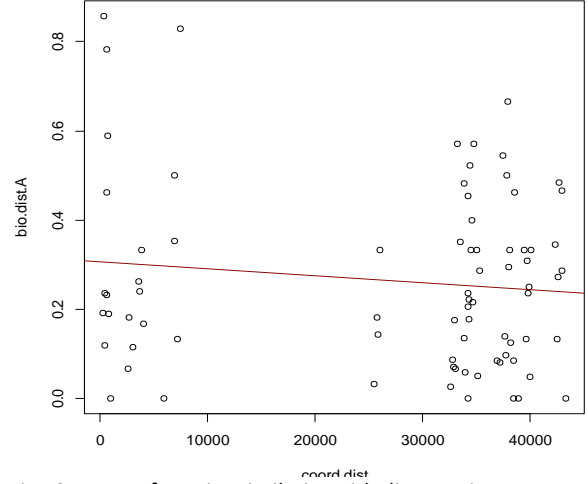


Fig 59 Decay of species similarity with distance in sunflowers; exotic species
Slope $-1,57E-06$ p 0,218218 R^2 0,014623

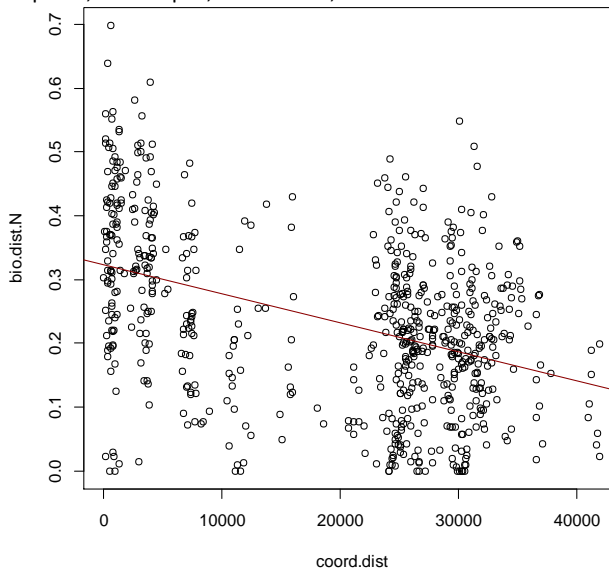


Fig 60 Decay of species similarity with distance in vineyard; native species
Slope $-3,92E-06$ p 0,001001 R^2 0,172316

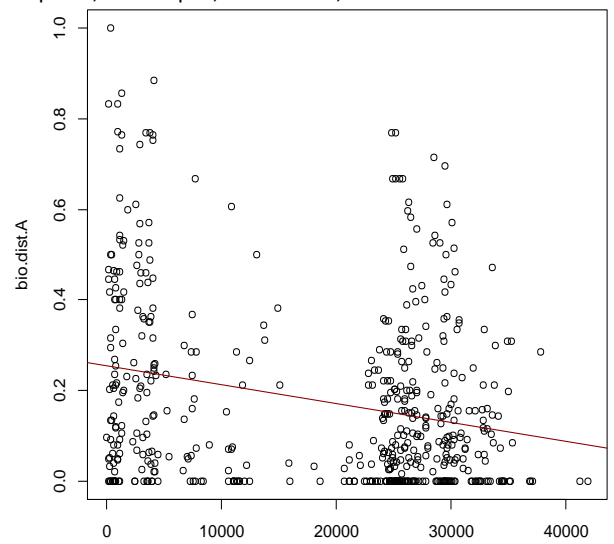


Fig 61 Decay of species similarity with distance in vineyard; exotic species
Slope $-3,88E-06$ p 0,002002 R^2 0,06898

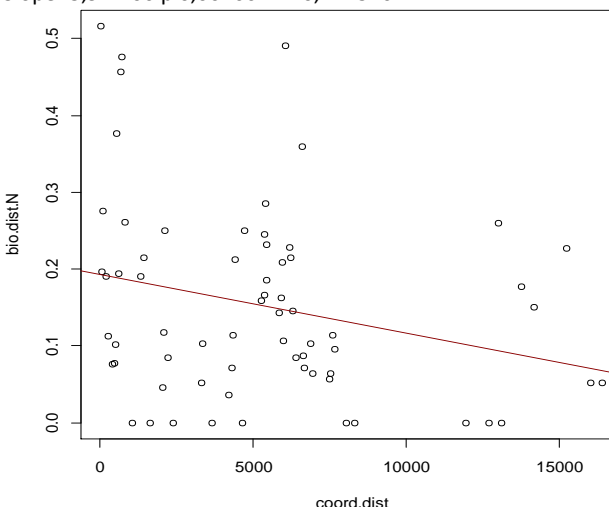


Fig 62 Decay of species similarity with distance in wheat; native species
Slope $-7,64E-06$ p 0,146146 R^2 0,067706

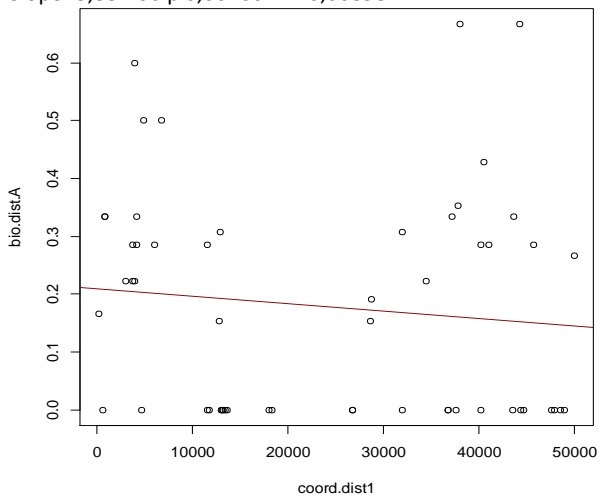


Fig 63 Decay of species similarity with distance in wheat; exotic species
Slope $-4,67E-06$ p 0,001001 R^2 0,050371

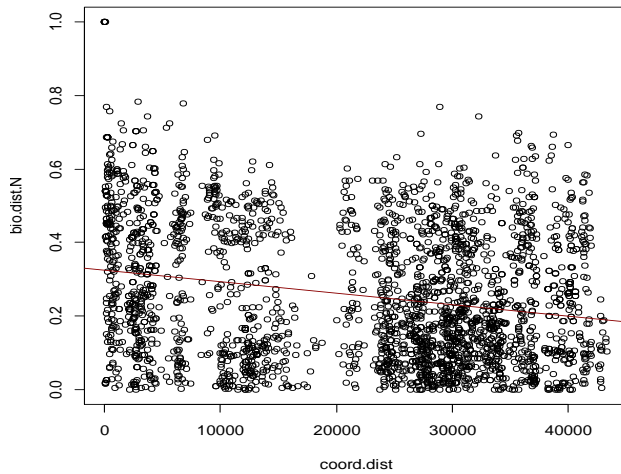


Fig 64 Decay of species similarity with distance in wood;
native species
Slope $-2,58E-06$ p 0,01001 R^2 0,026174

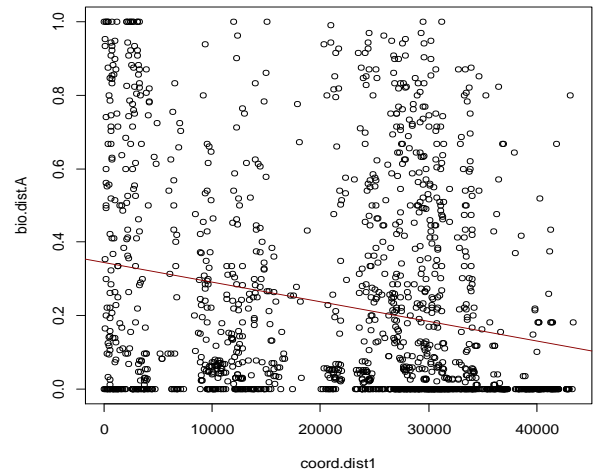


Fig 65 Decay of species similarity with distance in wood;
exotic species
Slope $-4,67E-06$ p 0,001001 R^2 0,050379

Tab.4 Habitat frequency and decay of species similarity

habitat	frequency	NativeSlope	pnative	R^2 native	AlienSlope	palien	R^2 alien
barley	16	$-2.20 \cdot 10^{-6}$	0.019	0.05	$-2.03 \cdot 10^{-6}$	0.108	0.020
hedgerow	15	$-4.49 \cdot 10^{-6}$	0.007	0.095	$-3.25 \cdot 10^{-6}$	0.145	0.025
maize	62	$-6.27 \cdot 10^{-9}$	0.990	$2.92 \cdot 10^{-7}$	$1.85 \cdot 10^{-5}$	0.053	0.010
meadow	21	$-1.61 \cdot 10^{-6}$	0.003	0.063	$-2.26 \cdot 10^{-6}$	0.143	0.019
poplars	12	$-3.33 \cdot 10^{-6}$	0.056	0.096	$-3.90 \cdot 10^{-6}$	0.098	0.132
sunflowers	13	$-3.74 \cdot 10^{-6}$	0.001	0.225	$-1.57 \cdot 10^{-6}$	0.218	0.014
vineyard	37	$-3.92 \cdot 10^{-6}$	0.001	0.172	$-3.88 \cdot 10^{-6}$	0.002	0.069
wheat	12	$-7.64 \cdot 10^{-6}$	0.146	0.068	$-4.67 \cdot 10^{-6}$	0.001	0.050
wood	73	$-2.58 \cdot 10^{-6}$	0.010	0.026	$-4.67 \cdot 10^{-6}$	0.001	0.050

Decay of species similarity with distance is statistically significant for native species in all of the considered habitats except maize and wheat while alien species show a statistically significant decay of similarity only in vineyard, wheat and wood habitats. Regarding native species the higher decay of similarity with distance appears in wheat fields, followed by hedgerows and then vineyards. Alien species show a more similar decay of similarity with distance between different habitats and the highest decay rate are in maize fields, wheat fields and poplar cultures. (figg from 48 to 64)

[Tab.5](#) slope difference between native and exotic species

Habitat	Frequency	Slope difference (Native-Exotic)	p
Barley	16	$-5.68 \cdot 10^{-7}$	0.384
Hedgerow	15	$-1.31 \cdot 10^{-6}$	0.306
Maize	62	$-5.05 \cdot 10^{-7}$	0.180
Meadow	21	$1.18 \cdot 10^{-6}$	0.265
Poplars	12	$8.51 \cdot 10^{-7}$	0.288
Sunflowers	13	$-2.58 \cdot 10^{-6}$	0.121
Vineyard	37	$-3.84 \cdot 10^{-6}$	0.297
Wheat	12	$-2.07 \cdot 10^{-6}$	0.505
Wood	73	$2.19 \cdot 10^{-6}$	0.001

Additionally, it was shown that the distance decay of similarity of alien species is higher than the one of the natives in poplar stands, woods and meadows; however, the difference in the distance decay of similarity between exotic and native species is significant only for woods.

Discussion and conclusions

The amount of seminatural land in agricultural landscapes greatly influences wild plant species richness and composition. Seminatural habitats have a higher number of native species: meadows have the highest number of native species, as expected given the high biodiversity of permanent fields; then there are woods (planitial woods are a SIC habitat in north Italy) and then hedgerows which for many species represent shelters interspersed in the biodiversity-poor areas represented by crops. The distribution of alien species is connected to the human use of soil so there is a higher number of species mostly in winter crops, hedgerows, maize fields.

The seminatural land (meadows, hedgerows and wood habitats) percentage increases the abundance of species, and in particular the abundance of native ones, while the percentage of exotic species decreases, as they are connected to anthropic soil use since they are generalist and often pioneers. The abundance of exotic species isn't influenced by seminatural land amount, but their percentage is. Exotic species often occupy ecological niches created inside disturbed habitats and open spaces created by disturbs. In undisturbed habitats the more specialized native species already occupy and available space and niches. The increase rate of all the species with the percentage of seminatural land is higher than the one of only the native ones. We can see a stronger influence of the landscape at the larger scale (1,5 kilometers of radius instead 1 km).

Natives are more species-rich than exotics, forming more diverse communities and correlating strongly with seminatural habitat amount.

There are only weak correlations between the amount of seminatural habitats in each landscape and nestedness or modularity of the plant community. Nestedness of native plants (and all of the species) tends to be negatively correlated with the amount of seminatural habitats. Within a landscape with a higher percentage of seminatural land it is more likely to find an higher variety of habitat types and consequently an higher variety not only of native species in general, but also of different habitat specialists, resulting in unique assemblages and lower nestedness. On the other hand, the nestedness of exotic species increases. That is probably unrelated with the poroportion of specialist exotic species (exotic species tend to be mainly more generalist by definition) and simply linked to the lower diversity of exotic species in these landsapes which makes more likely for the species

in one point to be a subset of the species in the surrounding area. This might explain why the correlation is less significant for exotics than for natives. The opposite trend is true, but not statistically significant, for modularity and its correlation with seminatural habitat abundance (positive for natives, negative for exotics). It means that with a bigger amount of seminatural land there are less connections between the exotic species communities in the landscapes. Once again the trends are stronger for the larger landscape scale (1,5 km)

Responses are similar at lower spatial scales (250 m and especially 500 m of radius), with native species richness in seminatural habitats responding positively to seminatural habitat abundance and negatively to cropland abundance, while the contrary is true for exotics in the same habitats.

In cropland habitats, both exotic and native species richness is positively correlated with seminatural habitat percentage in the surrounding small-scale areas (250 and 500 m), with the native plants' response being stronger.

Decay of species similarity with distance is statistically significant for native species in all of the most commonly found habitat types (barley fields, hedgerows, meadows, poplar coltures, sunflower fields, vineyards and woods) while alien species show a statistically significant decay of similarity only in vineyard, wheat and wood habitats.

Regarding native species the higher decay of similarity with distance appears in wheat fields, followed by hedgerows and then vineyards.

Alien species show a more similar decay of similarity with distance between different habitats and the highest decay rate are in wheat fields and woods.

The distance decay of similarity of alien species is higher than the one of the natives in poplar coltures, woods and meadows.

The difference between exotic and native species decay of similarity is significant only for woods.

According to our data, it can be concluded that seminatural habitats can influence plant communities inside agricultural landscapes in many ways, and differentially for native and exotic species. A landscape with high amounts of seminatural habitats will host a more diverse (both in terms of species richness and beta-diversity) native plant community, while also being more resistant to the invasion of alien species. This suggests that correct

landscape management can have a significant positive impact on the preservation of biodiversity and on the limitation of damage caused by harmful exotic species.

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