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# Landscape Composition and Crop Border Vegetation Diversity Effect on Pollinators, Auxiliary Fauna, and Phytophagous Arthropods of Leguminous Cropland in Araba (Basque Country)

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**Abstract:** Many strategies and directives are starting to address the importance of an appropriate landscape for agricultural biodiversity, such as pollinators and auxiliary fauna. Therefore, it is necessary to identify which landscape features are more important for agricultural biodiversity conservation and the ecosystem services they offer, like pollination and pest control. Thus, the main objective of this study was to assess the effect of landscape composition, configuration, connectivity, and crop border vegetation on arthropod diversity. The arthropod community was sampled in eight legume crops located across a gradient of landscape complexity. Additionally, the border vegetation of each plot was characterized, and the surrounding landscape was analyzed at a small and a large scale. For the statistical analysis, Generalized Linear Mix Models and redundancy analyses were applied. Pollinators were positively affected mainly by landscape connectivity. Pest control agents were less influenced by the landscape and only before harvest were they positively affected by riparian forests. Finally, phytophagous arthropod richness increased with border vegetation diversity and cropland in the surroundings. In conclusion, in the leguminous crops of Araba landscape connectivity together with cropland extension in the surroundings should be considered to promote ES-offering fauna diversity.

**Keywords:** complexity; connectivity; biodiversity; ecosystem services; hedgerow

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## 1. Introduction

In 2024, the European Union (EU) approved a new law for Nature Restoration [1] in order to cease the accelerated biodiversity loss and ecosystem misfunctioning that have been occurring recently [2] due to anthropogenic landscape simplification [3] and a reduction in microhabitats for arthropods [4,5], among other causes. This law aims to restore 20% of the EU's land and sea ecosystems that are in bad condition for 2030 and 90% of all the areas in need for 2050.

In agricultural landscapes, food production depends on the supply of different ecosystem services (ES), such as pollination and pest control, both performed by mobile fauna that inhabit surrounding natural habitats. Thus, there is wide evidence that more ES are expected in agricultural areas with the presence of natural habitats in the landscape [6–10], like for example meadows or pastures [11,12] and native forests [12]. Similarly, increasing the heterogeneity within the plot [9,13–17] and adopting biodiversity-friendly measures like diversifying crop species or decreasing plot size [18] have also been observed to promote pollinator and auxiliary fauna community conservation and to increase yield. In addition to these measures, green infrastructure alone has also been claimed to be insufficient, suggesting that habitat connection should be equally important [12]. Therefore, agricultural landscapes must be multifunctional [19] and bioredundant [20] to guarantee food security.

For that reason, the Nature Restoration law (EU 2024/191) [1] considers the presence of agriculture in high-diversity landscapes as an indicator for agricultural landscape restoration and urges pollination conservation and agricultural landscape restoration.

However, there is a certain debate about how natural habitats could also function as reservoirs of pests and different phytophagous arthropods [21–23]. Similarly, landscape complexity and connectivity also play a crucial role in disease dispersal. For instance, although agricultural matrixes with a high diversity of crops have been proven to decrease aphid richness, they have also been observed to increase virus diseases [24]. The high variability of the interactions between the landscape and biodiversity makes local studies completely necessary to promote the local populations of pollinators and auxiliary fauna.

Therefore, the main objective of this study was to identify key features of the landscape to contribute to the knowledge of agricultural biodiversity and the ES they may provide in the province of Araba (Basque Country). For that purpose, the effects of landscape composition, configuration, and connectivity were assessed, as well as crop border vegetation, on arthropod functional groups of legume crops to evaluate biodiversity associated with two of the most important ES for agriculture, namely pollination and pest control. Legumes were selected as the crop because of their greater resource offer for different arthropod groups, especially when they are in flower [25,26]. Thus, landscape connectivity and configurational complexity, together with natural or semi-natural habitats like pastures, natural forests, or riparian forests, were expected to benefit these arthropod groups, which could lead to better pollination and pest control ES. On the contrary, phytophagous arthropods were expected to decrease in complex landscapes, due to the richer auxiliary fauna community.

## 2. Material and Methods

### 2.1. Survey Area

The sampling was carried out in the province of Araba in the Basque Country (northeastern of the Iberian Peninsula, Spain) (Figure 1a). In this province, the climate is Subatlantic- Mediterranean and there is a mixture of more intensive agriculture in a more simplified landscape and a more natural agriculture placed in a more natural and complex landscape. In the province of Araba, agriculture has great importance on the economy, as 92% of its land surface is under agricultural use [27]. The main management model in the province is intensive agriculture of potatoes, cereals, and diverse legumes, while organic farming still has little impact on the market since it only occupies 4.2% of the whole agricultural land [28]. Natural or semi-natural vegetation patches consist of *Quercus robur* and *Q. faginea* forests.

In total, 8 sites were sampled in May 2021 (before harvest) and 7 in August 2021 (after harvest, 1 of them was not harvested) to see the effect of the landscape when crops were present and when they were not. The sites were located in different landscape matrixes with different levels of naturalness. All the crops were leguminous, they were organically managed, and they followed a similar management calendar. Due to the low presence of organic farming in the province, it was not possible to select a single crop species for the whole study and different organic leguminous croplands were sampled: pea, vetch, lentil, and chickpea. For the same reason, not all crops were in the same phenological development state (4 of them were in flower, while 4 of them were not), which had to be considered when applying the models.

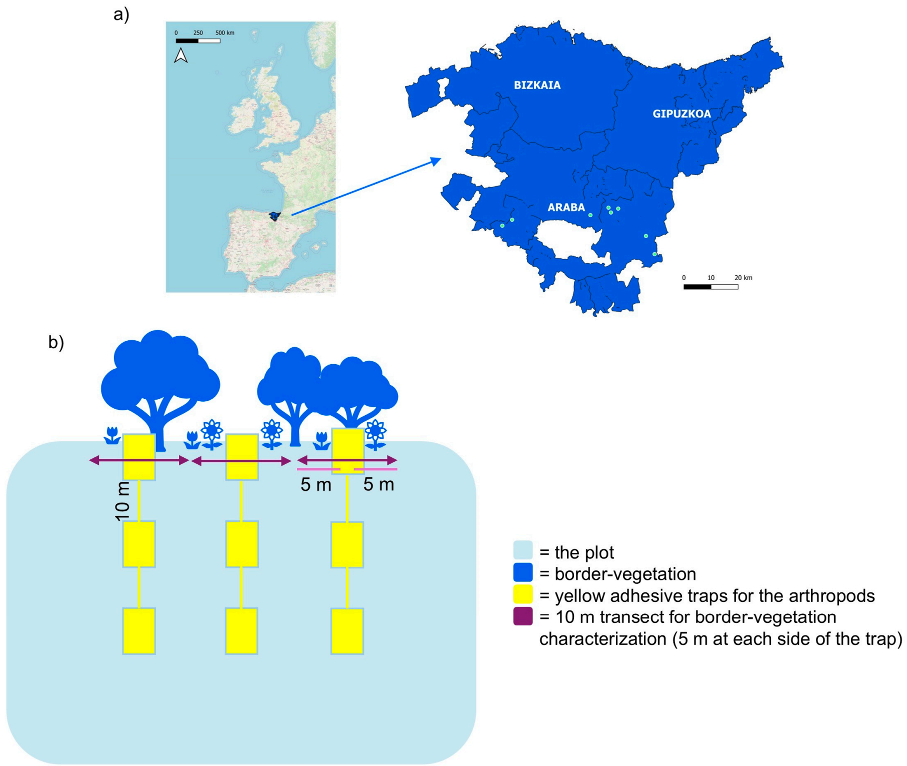


**Figure 1.** (**a**) On the left: map of Europe taken from © OpenStreetMap [29] with the Autonomous Community of the Basque Country (CABC) highlighted in dark blue; and on the right: map of the CABC with the eight sample plots colored in light green; (**b**) drawing of the sampling-design, where the location of the adhesive traps for the arthropods (yellow rectangles) and the transects for the border vegetation characterization (purple arrows) are displayed.

*2.2. Arthropod Sampling*

Arthropods were sampled before harvest (May 2021) and after harvest (August 2021). For that purpose, a plot of at least 1 ha was selected at each site and adhesive yellow traps of 10 × 25 cm were placed at a height of 1 m. Nine traps were set at each plot, forming 3 transects of 3 positions, the first one on the border vegetation, the second one at 10 m toward the center of the plot from the border, and the third one at 20 m toward the center of the plot from the border (Figure 1b). Between transects, a minimum of 10 m was left. The traps stayed in the field for 14 days. Arthropods were then identified at the family level at the laboratory using the following keys: Goulet and Huber (1993) [30], Oosterbroek (2006) [31], and Bellmann (2018) [32]. In addition, they were classified into 3 different groups depending on their functional role: pollinators (small pollinators and flower-visiting insects (according to Oosterbroek (2006) [31] and Bellmann (2018) [32])), predators and pest control agents (also known as auxiliary fauna), and phytophagous arthropods. It should be highlighted that as identifications were not conducted to the species level, generalizations for each family were conducted and "one single family"-"one single group" associations were made. For each group, richness (number of taxa) was calculated.

*2.3. Border Vegetation Characterization*

The border vegetation of each plot was only characterized in May 2021 by sampling 3 transects in each plot (Figure 1b). In each transect, the trap placed on the border was established as the center of the 10 m transect (5 m to one side and another 5 m to the other side) and 1.5 m width into the hedgerow. This vegetation transect was perpendicular to the transect of the arthropod traps. All the plants were identified to the smallest level possible, differentiating 5 strata (0–0.2 m, 0.2–1 m, 1–2 m, 2–5 m and >5 m) and giving each plant species a cover-value with a semi-quantitative scale (+ = 0–5%, 1 = 5–20%, 2 = 20–40%, 3 = 40–60%, 4 = 60–80%, 5 = 80–100%). This way, the Shannon diversity of border vegetation was calculated [33].

### *2.4. Landscape Analysis*

The landscape surrounding each plot was analyzed by the QGIS program 3.28.3 version [34] using the EUNIS vegetation layer as a base. For landscape composition pasture, natural forest (*Quercus* spp., mixed forests), riparian forest (*Populus* spp., *Fraxinus* spp.), and cropland percentage were calculated [12]. Moreover, for landscape complexity, the next indexes were calculated based on the same cartography: the richness of different land uses (S) and the Shannon diversity index of the different land uses (SHDI) [35,36]. Then, landscape configuration patch density (PD) and edge density (as the sum of all patch perimeters in the buffer) (EDG) [35,36] were calculated. Finally, for landscape connectivity, the Effective Mesh Size Index (EMS) was calculated [37]. Considering previous analysis with larger scales and seeing that only small arthropods were sampled and that larger ones (better dispersal abilities) like bees, hoverflies, or butterflies were not caught by the traps, for the landscape assessment, two scales were used: a small scale of a 500 m radius buffer and a large scale of a 1000 m radius buffer (Table 1) [6,12,38].

**Table 1.** A buffer of 500 m and 1000 m radius, percentages of pasture, natural forest, riparian forest and cropland, land-use diversity as the Shannon index of different land-uses (SHDI), land-use richness as the number of different vegetation types (S), patch density as patches per ha (PD), edge density as the sum of border perimeters (EDG), and Effective Mesh Size (EMS) for each site.

| Site | Buffer | Pasture | Natural Forest | Riparian Forest | Cropland | SHDI | S | PD | EDG | EMS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 500 | 0.00 | 0.67 | 0.71 | 87.76 | 0.54 | 8 | 0.19 | 181.73 | 0.01 |
| | 1000 | 0.17 | 1.08 | 1.41 | 94.07 | 0.30 | 6 | 0.08 | 121.66 | 0.03 |
| 2 | 500 | 0.00 | 0.07 | 2.32 | 96.26 | 0.19 | 4 | 0.13 | 168.03 | 0.02 |
| | 1000 | 0.47 | 9.89 | 2.50 | 84.41 | 0.60 | 6 | 0.08 | 162.48 | 4.36 |
| 3 | 500 | 0.00 | 0.00 | 0.00 | 98.10 | 0.11 | 3 | 0.04 | 55.01 | 0.00 |
| | 1000 | 0.00 | 0.00 | 2.03 | 94.75 | 0.27 | 7 | 0.06 | 104.38 | 0.07 |
| 4 | 500 | 0.00 | 19.97 | 2.21 | 48.72 | 1.58 | 11 | 0.67 | 556.28 | 4.64 |
| | 1000 | 3.39 | 30.43 | 1.27 | 48.47 | 1.35 | 10 | 0.16 | 165.39 | 51.88 |
| 5 | 500 | 28.00 | 14.50 | 0.00 | 52.24 | 1.24 | 10 | 0.61 | 434.19 | 15.68 |
| | 1000 | 26.56 | 20.24 | 0.07 | 45.49 | 1.33 | 9 | 0.49 | 433.96 | 72.44 |
| 6 | 500 | 4.03 | 28.19 | 0.19 | 33.56 | 1.92 | 15 | 0.40 | 429.65 | 9.91 |
| | 1000 | 18.39 | 35.07 | 0.29 | 20.83 | 1.51 | 8 | 0.25 | 283.29 | 75.21 |
| 7 | 500 | 0.00 | 0.00 | 1.65 | 95.08 | 0.23 | 3 | 0.09 | 133.24 | 0.01 |
| | 1000 | 0.78 | 13.46 | 2.44 | 75.95 | 0.89 | 10 | 0.16 | 165.39 | 7.26 |
| 8 | 500 | 4.54 | 23.50 | 2.11 | 45.04 | 1.41 | 9 | 0.31 | 283.41 | 12.23 |
| | 1000 | 4.36 | 36.56 | 1.49 | 44.55 | 1.27 | 8 | 0.13 | 192.54 | 71.71 |

### *2.5. Statistical Analysis*

Statistical analyses were performed with R program 4.2.2 version [39]. Generalized Linear Mix Models (GLMMs) were made with "lme4" package. First, the correlation between the different land uses and landscape complexity indexes was assessed to avoid autocorrelation effects. This way, the cropland percentage in 500 m and 1000 m buffer, riparian forest percentage in 500 m buffer, Effective Mesh Size in 500 m and 1000 m buffer, and border vegetation diversity were selected (Table 2). Pollinator, pest control agent, and phytophagous richness were defined as response variables. To select the explanatory variables avoiding autocorrelation, all the compositional, configurational, and connectivity variables at the two scales and border vegetation diversity were defined as explanatory variables. *Gamma* distribution was used for building the models, and due to the differences in the phenological development state of the crops, this was defined as a random factor (less developed vs. in flower). Additionally, trap position and sampling time were also defined as random factors. For each arthropod variable, the best models were selected (smallest AIC value). The same methodology was followed to assess the response of the most abundant taxa of each group to landscape features. These taxa were Empididae (pollinator), Muscidae (pest control), and Thysanoptera (phytophagous).

**Table 2.** Correlations between land uses and landscape complexity indexes at two scales: 500 m and 1000 m radius buffer. $R^2$ and *p* values are expressed. Land-use diversity (SHDI), land-use richness (S), patch density (PD), and edge density (EDG). *Statistically significant values.

| **Variables** | | **500** | | **1000** | |
|---|---|---|---|---|---|
| | | $R^2$ | *p* | $R^2$ | *p* |
| Cropland | Natural forest | −0.97 | <0.001 * | −0.93 | <0.001 * |
| | Riparian forest | 0.12 | 0.443 | 0.55 | <0.001 * |
| | Pastures | −0.66 | <0.001 * | −0.90 | <0.001 * |
| Effective Mesh Size | SHDI | 0.61 | <0.001 * | 0.89 | <0.001 * |
| | R | 0.65 | <0.001 * | 0.51 | <0.001 * |
| | EDG | 0.69 | <0.001 * | 0.95 | <0.001 * |
| | PD | 0.69 | <0.001 * | 0.83 | <0.001 * |

The cycle of the crop itself and the surrounding ones are factors to be considered in understanding the dynamics of the arthropod community [40]. Because of that, the interaction between the sampling moment and the explanatory variables was also analyzed, and GLMM models were made separately before and after harvest when the interaction was significant (using *Gamma* distribution and defining trap position and crop development (only before harvest) as random factors). However, since the community of the trapped pollinators was mainly composed of smaller pollinators or flower visitors and leguminous crops are mainly pollinated by bees and large pollinators [26], this group was not analyzed separately before and after harvest.

Finally, a Redundancy Analysis (RDA) was performed to observe the effect of the landscape variables on the community composition of each group.

## 3. Results

### *3.1. General Results*

In total, 11,639 arthropods were identified and 51 taxa were observed before harvest, in May. Among them, 17 taxa were classified as pollinators or small flower visitors, 17 as pest control fauna, and 17 as phytophagous. Meanwhile, after harvest (in August), 23,450 arthropods and 92 taxa were counted and identified: 32 taxa were classified as pollinators, 27 as pest control fauna, and 33 as phytophagous arthropods. Most of them were dipters and small hymenopters, together with some heteropters and coleopters (Table S1). Other important taxa (mainly for the pollinator group) like bees and butterflies, however, were not caught. When it comes to the vegetation, 172 species were identified in total.

### *3.2. Pollinators*

Among cropland percentage (negatively related to pastures and natural forests), riparian forests, landscape connectivity (represented by Effective Mesh Size), and border vegetation diversity, the best predictor for pollinator richness was Effective Mesh Size (EMS) in 500 m buffer (Table 3; Figure 2a). This variable had a positive relationship with pollinator richness. This landscape complexity variable is representative of the connectivity of the natural habitats and refuges in the surroundings of the site.

**Table 3.** The best Generalized Linear Mix Model with significant results ($p < 0.05$) for pollinator richness depending on different landscape parameters and indexes, at two scales (500 m and 1000 m radius buffers) and at both sampling moments. The following values are expressed: AIC value, Estimate, Standard error, T value, and $p$-value. *EMS* = Effective Mesh Size.

| | AIC | Variables | Buffer | Estimate | Std. Error | t Value | Pr |
|---|---|---|---|---|---|---|---|
| Pollinator richness | 125.6 | Intercept | | 0.36 | 0.1 | 3.74 | <0.001 |
| | | EMS | 500 | −0.00 | 0.00 | −3.28 | 0.001 |
| Empididae abundance (before harvest) | 177.3 | Intercept | | −0.13 | 0.06 | 2.08 | 0.038 |
| | | Cropland | 500 | 0.00 | 0.00 | 3.10 | 0.002 |
| | | EMS | 500 | −0.01 | 0.00 | −3.12 | 0.002 |

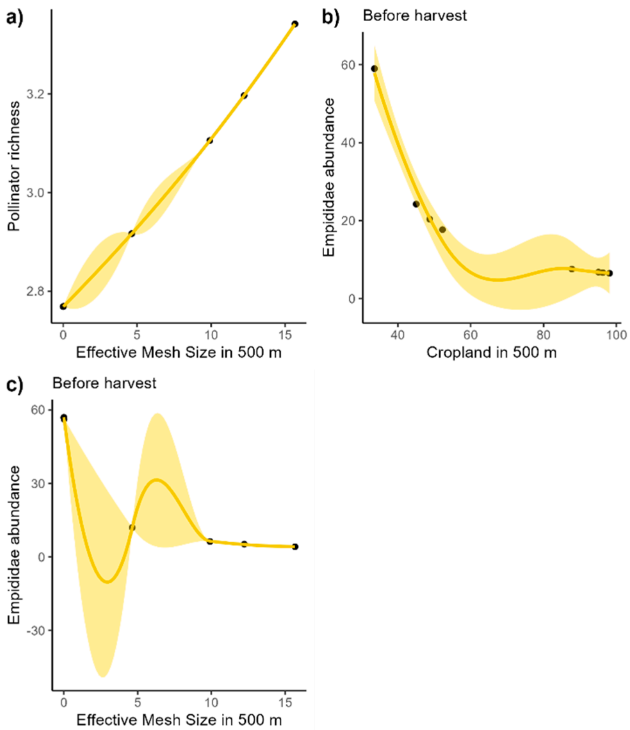


**Figure 2.** Relationship between pollinator richness and (**a**) Effective Mesh Size (ha) in 500 m buffer, representing the best Generalized Linear Mix Model for this variable. Relationship between Empididae abundance and (**b**) cropland in 500 m buffer before harvest, (**c**) Effective Mesh Size in 500 m buffer before harvest. Standard error is represented as a ribbon in light yellow.

The sampled pollinators were principally small Diptera and Hymenoptera taxa, as well as some Coleoptera. However, larger pollinators like bees and butterflies did not adhere to the traps. As the RDA analysis showed, the pollinator community was clearly differentiated by the sampling moment since the overlapping between before and after community composition is very small. Moreover, among the assessed landscape variables, the most influential one was the Effective Mesh Size in a 500 m buffer ($R^2 = 0.04$; $p = 0.002$) (Figure 3). Empididae was one of the most abundant pollinator families in both sampling moments and every site. The abundance of this family decreased with cropland percentage in the landscape before harvest (Table 3; Figure 2b. Moreover, the Effective Mesh Size also had a negative effect on their abundance (Figure 2c), although it was more subtle than cropland extension.

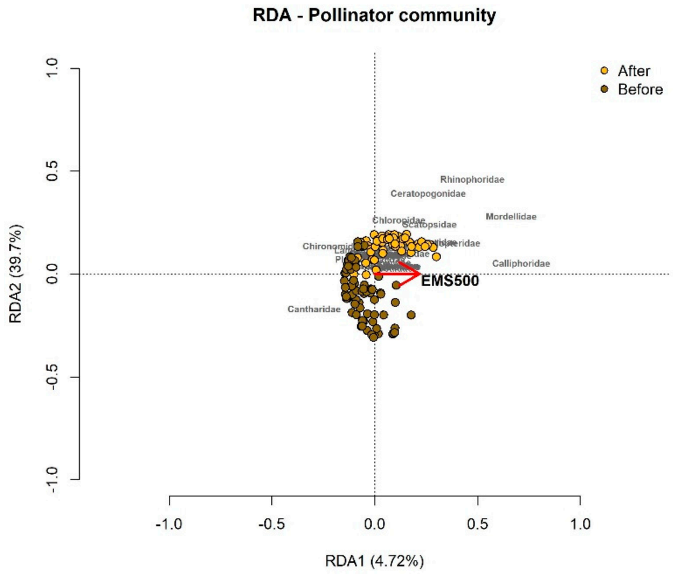


**Figure 3.** Redundancy Analysis (RDA) plot for pollinator community before and after harvest. The red arrow shows the most influential variable. EMS500 = Effective Mesh Size in 500 m buffer.

### *3.3. Pest Control Agents*

The riparian forest percentage in 500 m buffer (t = 2.62; $p = 0.008$) showed significant interactions with the sampling moment. Thus, when assessing this variable separating the sampling moment, it had a significant effect before harvest. This way, the best predictor for pest control agent richness was riparian forest percentage in 500 m buffer (Table 4; Figure 4) with a positive effect.

**Table 4.** The best Generalized Linear Mix Models with significant results ($p < 0.05$) for pest control agent richness and Muscidae family only before harvest, depending on different landscape parameters and indexes, at two scales (500 m and 1000 m radius buffers). The following values are expressed: AIC value, Estimate, Standard error, T value, and *p*-value. EMS = Effective Mesh Size.

| | AIC | | Buffer | Estimate | Std. Error | t Value | Pr |
|---|---|---|---|---|---|---|---|
| Pest control richness | 84.1 | Intercept | | 0.26 | 0.02 | 12.04 | <0.001 |
| (before harvest) | | Riparian forest | 500 | −0.03 | 0.01 | −2.16 | 0.031 |
| Muscidae abundance | −284.6 | Intercept | | 5.05 | 3.68 | 1.37 | 0.170 |
| (before harvest) | | EMS | 500 | −0.3 | 0.24 | −1.26 | 0.208 |

Similar to the pollinator community, the RDA analysis showed a clear separation between the community composition before and after harvest. Moreover, the most influential landscape variable was also the Effective Mesh Size in a 500 m buffer ($R^2 = 0.0098$; $p = 0.04$), although it explained a smaller part of the differentiation (1.76%) compared to the pollinator community (Figure 5). Among these families, only Muscidae showed as being affected by the assessed variables. However, even if the best GLMM (lower AIC value) included the Effective Mesh Size in a 500 m buffer as an explanatory variable, its effect was not significant (Table 4).

Among the landscape parameters that showed a significant effect on the richness of this group and Muscidae before harvest, both of them were defined at a 500 m buffer scale.

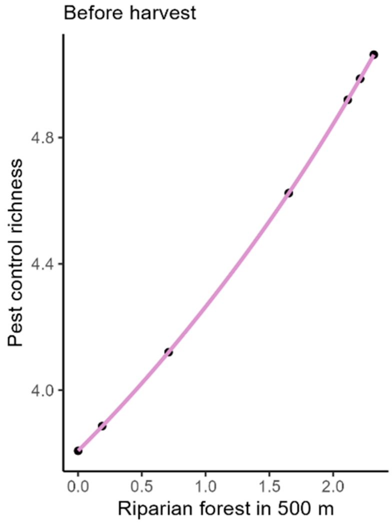


**Figure 4.** Only before harvest, the relationship between pest control agent richness and riparian forest percentage in 500 m buffer. Standard error is represented as a ribbon in light purple.

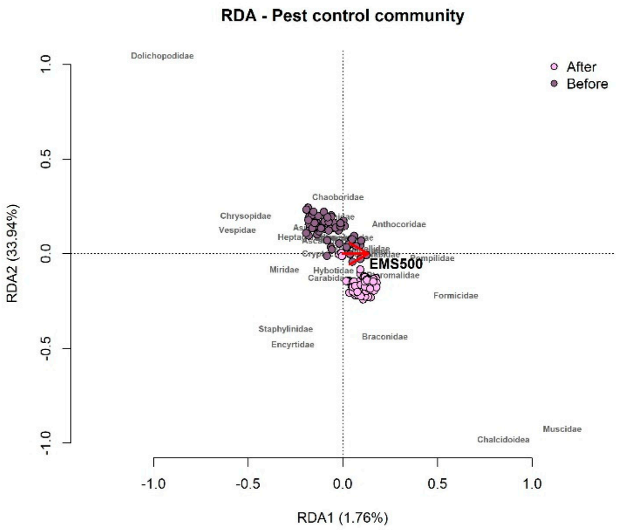


**Figure 5.** Redundancy Analysis (RDA) plot for pest control community before and after harvest. The red arrow shows the most influential variable. EMS500 = Effective Mesh Size in 500 m buffer.

### *3.4. Phytophagous*

Phytophagous richness was positively affected by cropland percentage in 500 m buffer (Table 5; Figure 6a) and border vegetation diversity (Figure 6b). Although the best GLMM also incorporated the riparian forest percentage in a 500 m buffer, this variable was not significant.

Border vegetation diversity showed interactions with the sampling moment ($t = 2.5$; $p = 0.012$). This way, harvest phytophagous richness also increased with border vegetation diversity (Table 5).

Finally, the RDA analysis showed that the phytophagous community was well differentiated by the sampling moment and that its composition was most affected by the border vegetation diversity ($R^2 = 0.03$; $p = 0.003$) (Figure 7 "Border-vegetation"). Thysanoptera was one of the most abundant taxa in the community, which showed a tendency to be more abundant with the increase in cropland in 500 m buffer (Table 5; Figure 6c).

**Table 5.** The best Generalized Linear Mix Model with significant results ($p < 0.05$) for phytophagous arthropod richness, depending on different landscape parameters and indexes. The following values are expressed: AIC value, Estimate, Standard error, T value, and *p*-value.

| | AIC | | Buffer | Estimate | Std. Error | t Value | Pr |
|---|---|---|---|---|---|---|---|
| Phytophagous richness | 135.2 | Intercept | | 0.33 | 0.05 | 6.50 | <0.001 |
| | | Cropland | 500 | −0.00 | 0.00 | −2.81 | 0.004 |
| | | Border vegetation diversity | | −0.05 | 0.02 | −2.76 | 0.005 |
| | | Riparian forest | 500 | −0.01 | 0.00 | −1.93 | 0.054 |
| Phytophagous richness (before harvest) | 61.2 | Intercept | | 0.30 | 0.02 | 14.73 | <0.001 |
| | | Border vegetation diversity | | −0.06 | 0.02 | −2.98 | 0.003 |
| Thysanoptera abundance (after harvest) | 176.2 | Intercept | | 0.07 | 0.02 | 4.03 | <0.001 |
| | | Cropland | 500 | −0.00 | 0.00 | 2.82 | 0.005 |

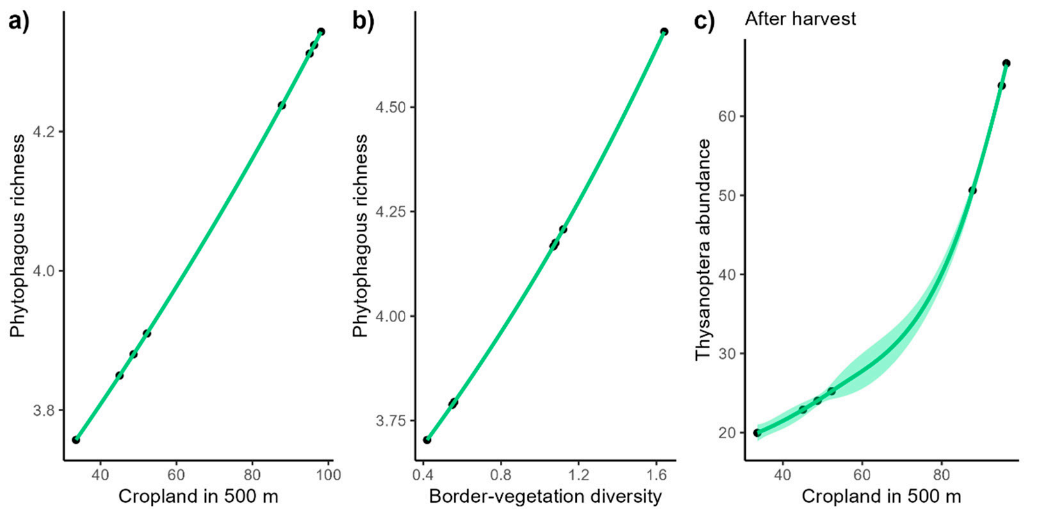


**Figure 6.** Relationship between phytophagous richness and (**a**) cropland in 500 m buffer and (**b**) border vegetation diversity. Relationship between (**c**) Thysanoptera abundance and cropland in 500 m buffer. Standard error is represented as a ribbon in light green.

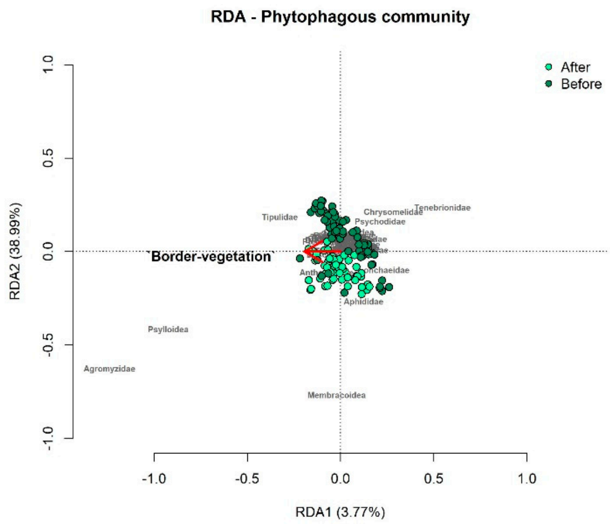


**Figure 7.** Redundancy Analysis (RDA) plot for the phytophagous community before and after harvest. The red arrow shows the most influential variable. 'Border vegetation´ = Border vegetation diversity.

## 4. Discussion

Spatial and temporal changes in a system can cause sudden changes in its biodiversity, affecting, at the same time, its functionality [41], which means that the dynamics of crops can shadow the effect of landscape complexity on the arthropod community [40]. In this study, the pollinator community was affected by the landscape, despite the presence of the crop. However, pest control and phytophagous arthropods were less affected by the landscape, suggesting that other factors must be affecting them at the same time.

### *4.1. Pollinators*

Different variables are known to be beneficial for arthropod richness, and especially for pollinators, such as overall landscape diversity and complexity [6–9], extensive meadows or pastures [11,12], the vicinity of the forest, woody elements and deadwood [8,9,11,12,42–44], and riparian forests [45,46].

In our study, among all, the best predictor for pollinator richness in the legume crops was found to be landscape connectivity. On the one hand, these results highlight the importance of natural habitats and resources being connected across the landscape matrix, even to a larger scale, to allow the dispersal of pollinators [12]; and on the other hand, they can be indicators of the importance of adopting small scale measures to promote this connectivity within the plot [9,13,16,17,42]. Therefore, not only is it important to promote habitats and resources for pollinators, but it is equally relevant to arrange them correctly to enable pollinators to disperse.

As expected, the proportion of intensive cropland extension on the landscape was not the best predictor for pollinator richness, even if a lower percentage of cropland in the landscape was representative of a higher percentage of pastures and natural forests. It is true that very intensive agricultural matrixes can be detrimental to the diversity of these arthropods, due to the loss and fragmentation of natural or semi-natural habitats [6,47]. However, considering that pollinator-friendly legumes took an important extension of the "intensive cropland" category on the buffers, such a negative effect was not expected to be observed. Legumes are mainly pollinated by bees and larger pollinators [26], which can be better competitors for these resources and do not depend on landscape naturalness as opportunistic or non-crop pollinators [48]. Since the pollinators we sampled were small, other crop pollinators like bees might have left the smaller pollinators to feed on poorer resources, such as small wildflowers in the borders [8]. This coincides with the results for Empididae, which was the most abundant pollinator family. Their abundance was lower when cropland extension was higher, which could indicate that this small Diptera family is more benefited by other natural habitats than by the crops themselves. This family, however, was, at the same time, slightly negatively affected by landscape connectivity, which could be a consequence of facilitated dispersal to more suitable habitats since this family is often associated with aquatic or highly humid habitats [49,50]. This highlights the importance of landscape complexity and natural vegetation for the richness of the pollinator community, even in crops with dense floral resources.

The 500 m radius buffer was observed to be best for landscape assessment for pollinator richness. Thus, to evaluate the features of the landscape and its suitability for hosting, a rich pollinator community using a buffer of a 500 m radius should be sufficient.

### *4.2. Pest Control Agents*

Several studies have proved that predators, pest control agents, or auxiliary fauna benefit from a higher complexity of the landscape [51–53], and there is wide evidence that borders increase in-farm biodiversity [6,9,17,54,55]. This way, a well-connected matrix [12] with natural habitats like pastures [56–58], for example, should be necessary to enhance pest control in crops. However, this study failed to prove a clear positive effect of landscape connectivity. This variable only influenced their community composition, but it did not promote auxiliary fauna richness. In addition, cropland extension did not have a negative effect on this group, and neither did landscape configuration and complexity indexes, contrary to what other studies show [13,59,60]. This lack of significance could be indicative of crops resulting in an important food source for pest control agents since they feed on the phytophagous arthropod community that grows on plants. Thus, other factors like crop cycle and pest dynamics should be considered to assess pest control arthropods.

Moreover, the presence of riparian forests in the landscape before harvest was identified as the only variable that had a positive effect on the pest control agent community. These habitats have been claimed to be refuges for auxiliary fauna since pest control services can be higher in crops near riparian forests [61,62]. Therefore, their conservation could be key for the promotion of pest control services in rural Araba and more studies should be made on these ecosystems.

Equally to the pollinators, this group was more related to the smaller scale. Therefore, it would be better to use the 500 m buffer for landscape assessment in relation to this group. However, more studies should be made about the interactions between the dynamics of pests and auxiliary fauna in crops and the landscape.

### *4.3. Phytophagous Arthropods*

There is a certain controversy on whether landscape complexity increases pest pressure or contributes to diminishing it. Some authors claim that natural habitats function as a source of phytophagous arthropods, causing heavier pest pressure and more damage to crops [22,23]. However, others suggest that the effects of this group decrease in complex landscapes due to a higher pest control or a higher availability of alternative resources for the phytophagous in the landscape [17,24].

In this case, cropland extension in the landscape was one of the drivers for phytophagous richness, which means that when the percentage of pastures and natural forests was higher, phytophagous richness was lower. This coincides with the latter authors. In addition, Thysanoptera abundance was also higher with cropland extension. Being potential pests of legume crops and other species of crops, it was expected to find an increase in this group with the increase in cropland [63].

Additionally, and similarly to auxiliary fauna, riparian forests also increased phytophagous richness. As said before, riparian forests are an important source of biodiversity [61,62,64]. Because of that, it is logical to observe an augment in phytophagous arthropod richness with their presence. Moreover, riparian forests in agricultural landscapes are commonly cut, so that the riparian habitat becomes limited to the stream flow and some associated vegetation. Consequently, the conservation of these forests could bring an increase in biodiversity in general.

At the same time, border vegetation diversity also contributed to a higher phytophagous richness due to two possible options: first, that a higher plant diversity hosted a higher phytophagous diversity, and second, that crops, being monospecific, could host a less diverse phytophagous community. This result should not be considered only as a threat to crop health but also as an opportunity for border vegetation to absorb part of the phytophagous community as an alternative food source, especially for native phytophagous when the vegetation is natural [65]. Thus, the controversy of these results could be related to the fact that phytophagous arthropods also depend on other factors that were not assessed in this study, like crop cycle and its structural complexity [66,67]. Because of that, more studies should be conducted on how phytophagous arthropod populations change depending on crop cycles and their interaction with the landscape in Araba.

Regarding the landscape scale, the smaller scale could be more appropriate, which suggests that the analysis of the nearest vegetation could be more important to assess this community and approach landscape evaluation and management. Since many of the phytophagous arthropods are very small and they might not be good dispersers [68], the adjacent vegetation would play an essential role in conditioning their presence or absence.

## 5. Conclusions

In closing, the Effective Mesh Size Index for landscape connectivity could be a key feature of the landscape as an indicator of the pollinator and pest-control arthropod communities in the leguminous cropland of the Mediterranean region of Araba. Therefore, sustainable agricultural management should consider this index to assess the conservation of biodiversity in agricultural contexts. Moreover, cropland extension for phytophagous arthropods, and riparian forests both for phytophagous and pest control agents could also be interesting indicators for their richness. Additionally, based on the present results, a radius of 500 m could be a good measure to evaluate landscape suitability for the assessed arthropod communities.

Thus, this work not only contributes to the knowledge of the arthropod communities in the agricultural landscape of Araba, but it is also a starting point for the introduction of landscape characteristics as a feature to be considered in agricultural management. Therefore, more studies should be made to advance the study of sustainable landscape designs.

All these results highlight the importance that landscape complexity and natural vegetation have for ES offering groups in an agricultural context. Therefore, the first step in the management of the leguminous crops of the region should be to analyze the landscape within the area in order to improve biodiversity conservation, which goes in line with a lot of sustainable strategies and with the focus of the recent Nature Restoration law (2024/191) [1] on agrarian landscapes. Moreover, more studies should be made on the real capacity of the fauna on ES delivery and on the production of the crops.

**Supplementary Materials:** The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/land13122128/s1: Table S1: Mean values of the assessed arthropod taxa abundance in each site before and after harvest.

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