# ROLE OF LANDSCAPE DIVERSITY FOR BIODIVERSITY CONSERVATION IN VITICULTURE: LIFE+ BIODIVINE'S RESULTS

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***Abstract***

Nowadays biodiversity loss is considered as a prior environmental issue. Agricultural landscapes are particularly concerned, mainly through the specialization and intensification of farming activities which lead, at a larger scale, to landscape simplification. Landscape management would be a good means to halt biodiversity loss, but large-scale studies remain rare. The life+ project BioDiVine aims to understand biodiversity dynamics and promote sustainable conservation actions at this scale in viticulture.

Seven demonstration sites, in France, Spain and Portugal, followed common protocols in order to quantify biodiversity in vineyard plots and evaluate its possible link with the surrounding landscape. In each area, arthropods were monitored on 25 selected plots, from 2011 to 2013. Arthropods were sampled by non-selective trapping stations set into vines and semi-natural habitats (2011) and exclusively inside vine plots (2012-2013). They were sorted out using the Rapid Biodiversity Assessment method. Then, abundance and richness indices were calculated. The landscape surrounding each trapping station (400m radius) was characterized through a GIS database. Then, indices such as proportion of semi-natural habitats have been calculated.

Semi-natural habitats show higher arthropods richness than vineyards, with a significant difference in richness values of 20 to 50%, depending on demonstration sites. On all French demonstration sites, a significant positive correlation was shown between the proportion of semi-natural habitats in a 400m buffer area and the arthropods richness inside the vine plot. These results support the action program of the BioDiVine project, which consists in encouraging landscape management actions such as planting hedgerows or restoring semi-natural elements connectivity. This can be an efficient way to support biodiversity and promote environmental-friendly wine production. Yet, these actions have to be collectively managed to reach their maximum efficiency, and require a huge coordination effort.

***Key Words: Biodiversity, GIS, landscape management, vineyard***

## 1 INTRODUCTION

The negative impact of human activities on species diversity and abundance is well described, and the major threat to biodiversity identified so far is the modification or suppression of natural habitats, mainly converted to arable or urban land (MEA 2005). Biodiversity is identified as a key factor for ecosystem functioning, and therefore for the quality of services it provides (Altieri 1999). Agriculture is particularly targeted, as its intensification during the last decades has led to a dramatic loss of semi-natural habitats and crop diversity in rural landscapes. This specialization at farm and landscape scales is an aggravating factor for biodiversity erosion (Burel 2004). What's more, it has been accompanied by an increase of the use of inputs (Leroux et al. 2008). Viticulture landscapes often follow this trend: on Appellation d'Origine Contrôlée (AOC) areas, vines are most of the time the dominant crop. Some farming practices in viticulture are intensive: French viticulture, occupying 3% of arable land, accounts for 15% of pesticide consumption (in value) (Butault et al 2011). But European vineyards, often old historical landscapes, have complex spatial configurations including non-productive areas that are opportunities for Agri-Environmental Schemes. Plots are often small and interstitial space available to maintain or promote biodiversity can be significant. Global landscape scale actions such as the conservation and restoration of semi-natural habitats and other landscape features and their ecological connectivity seem to be a relevant way to halt biodiversity loss. From 2011 to 2014, the BioDiVine program, funded by the European LIFE+ Nature and Biodiversity programme and the farmers associations, aims to evaluate and promote conservation actions in favor of biodiversity in viticulture landscapes. It encompasses seven vineyards as "demonstration sites" across France (Saint Emilion, Costières de Nîmes, Limoux, Bourgogne), Spain (Rioja, Penedes) and Portugal (Alto Douro) (Figure 1).

**Figure 1: The project's demonstration sites**

The two main work-packages of the project are:

- Quantifying biodiversity in viticulture landscapes (taxa monitored: arthropods, birds, inter-row flora, landscape composition)
- Encouraging the implementation of conservation actions such as introducing ground covers, hedgerows, restoring low walls, management of fallow plots.

The biodiversity monitoring aims to study the link between landscape features promoted by the project and their role for biodiversity enhancement. The results presented in this paper concern arthropods on French participating sites.

## 2 MATERIALS AND METHODS:

### 2.1 Traps used to sample arthropods

Arthropods were trapped in 2011, 2012 and 2013 by non-selective trapping stations composed of a "combi-trap" which combines chromatic attraction (yellow color of the funnel) and interception (transparent panels), and is mostly dedicated to flying arthropods, and a pitfall trap for ground-dwelling arthropods. Traps were filled with a 5% saline solution and some surfactant. 25 traps were set up per demonstration site and per year. Samples were collected weekly from April to June (total sampling duration: 10 weeks, 25 pairs of traps per site, total number of samples collected: 10 x 25 x 2 = 500). Arthropods were transferred from the saline solution of the traps into 70% ethanol jars, and stored at room temperature till sorting.

A yellow sticky pheromone trap was set up to complete the system, using 2µg *Lobesia botrana* sex pheromones dispensers. The number of *Lobesia botrana* (males) caught in the trap was recorded each week in the same period as biodiversity sampling. Pheromone dispensers were changed every second week.

### 2.2 2011 arthropods sampling: habitats comparison

In 2011, first year of the program, traps were located directly next to the five main landscape features (5 replicates each) present on each demonstration site (figure 2), in order to compare the "biodiversity levels" of those elements.


a) b) c)

**Figure 2: Examples of traps in different direct environments (habitats) in Saint Emilion: Forest edge (a), Hedgerow (b), Vineyard (c)**

### 2.3 2012 and 2013 arthropods sampling: effect of surrounding landscape

In 2012 and 2013, the effect of large-scale landscape composition was studied. Traps were located exclusively in the center of vine plots (> 1ha), in different landscape contexts, separated from each other by at least one kilometer (2 x buffer radius) to avoid overlapping of the 400m buffer area.

### 2.4 Landscape characterization

Land use around each sampling station (red point on figure 3) was recorded (digitized) into a GIS database, respecting a common protocol.

Elements were digitized at a displaying scale of 1/2500. All surface elements, linear elements, and point elements visible on aerial photographs (BD Ortho, 50 cm resolution) provided by the French Institute for Geographic Information (IGN) were recorded with ArcGIS 10.0 software, in a radius of 400m from the sampling point (Figure 3). Standard values for width of linear elements (roads…) were chosen in order to convert these into surfaces. Data recorded is the proportion of each landscape element in a 400m buffer area.

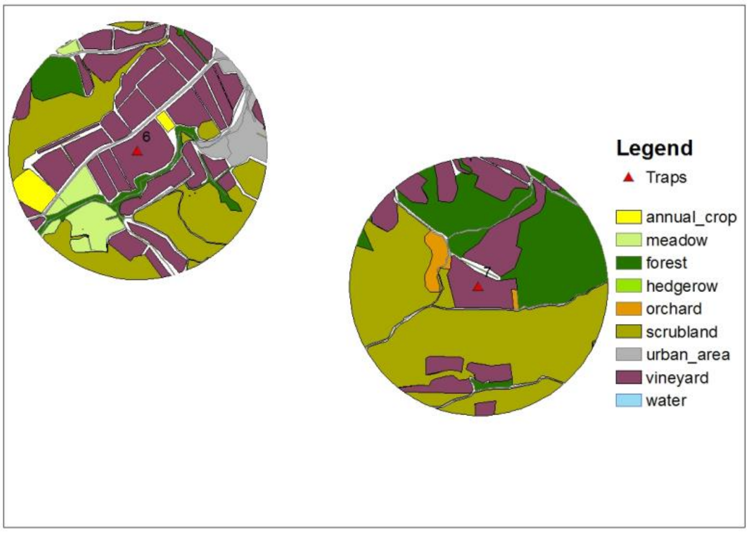

**Figure 3: Two traps and their digitized 400m radius buffer area (Limoux)**

### 2.5 Sample analysis

Arthropod biodiversity samples were analyzed using Rapid Biodiversity Assessment (RBA) (Oliver and Beattie 1993). This method substitutes morpho-types (MT) to species, each MT being a group of individuals which present similar morphologic characteristics (size, color, shape…). This method allows obtaining approximate values for common biodiversity indices such as:

- morpho-types richness (RMT) (which is in this case the number of MT identified in the sample). RMT can be considered as a good approximation of species richness and can be used for comparative studies (Krell 2004, Duelli and Obrist 2010).
- Abundance (total number of arthropods).

### 2.6 Statistical analysis

RMT of arthropods in different habitats collected in 2011 was compared using ANOVA. Habitat types (forest, hedgerow, park, riparian forest, vineyard, fallow) were considered as explanatory variables. When significant differences were detected, post-hoc comparisons using Tukey HSD test were performed.

RMT of arthropods collected in 2012 and 2013 was analyzed by Generalized Linear Mixed Models (GLMMs) (poisson distribution). Abundance of *Lobesia botrana* during the first flight period was analyzed by Linear Mixed Models (LMMs). The model structure for all variables included the respective proportions of urban area, forest, meadow and hedgerow, and landscape diversity in 400 m buffer areas. Then, RMT of arthropods were analyzed using the same model structure but with only three fixed effects: the total proportion of semi-natural habitats (fallow, hedgerow, forest and scrubland combined), the proportion of urban area and landscape diversity in a 400 m buffer area. For all these models, we defined year and site as random-effects to take into account replicated measures in identical sites (Zuur et al. 2009). All continuous variables were standardized before analyses (Grueber et al. 2011). Only significant variables and associated statistics (z and P-value) are shown in the Results and Discussion section. Statistical analyses were performed using R (R Project for Statistical

Computing release 2.15.2 http://www.r-project.org). We used the R-package lme4 for LMMs and GLMMs (Bates et al. 2011)

## 3 RESULTS AND DISCUSSION

In 2011, 85070, 55040, and 78322 arthropods were respectively collected in the denominations of Saint Emilion, Costières de Nîmes, and Limoux, distributed over the different habitats monitored. Habitats comparisons show significant differences between biodiversity levels of the main habitats present in the vineyards. Natural or semi-natural habitats (forests, hedgerows, scrublands …) are richer than vineyard or other crops (if present) in all demonstration sites. We found from 20% to 50% more RMT (richness) and from 50% to 100% more individuals (abundance) in semi-natural habitats than in vines. The richness in Saint Emilion (a) and abundances in Costières de Nîmes (b) are given as examples in figure 4.

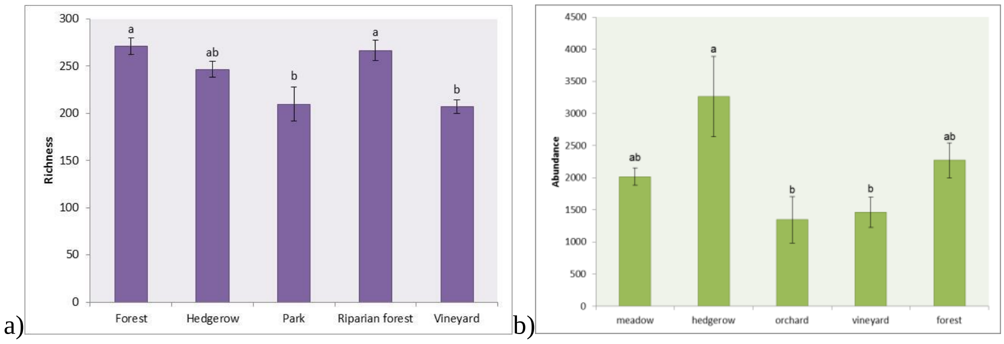

**Figure 4: levels of richness in the different habitats of Saint Emilion vineyard (a), and abundances in the different habitats of Costières de Nîmes vineyard (b), (2011)**
("Park" designates gardens often seen around the "châteaux" buildings)

All sub-categories of arthropods (orders) follow this general pattern (no order showing opposite trend). The contribution of semi-natural habitats in terms of general biodiversity is important, in all demonstration sites. This first step of the study allowed estimating values to determine the relative contribution of each element in terms of biodiversity, and can be used to promote and in some cases prioritize conservation actions. Hedgerows can be considered as an efficient means to reintroduce perennial habitats for fauna. The only exception being Saint Emilion "parks" (generally lawn with isolated trees), which are present in this landscape as numerous "islands" in a vineyard "sea", show a level in biodiversity closer to vineyards' than to natural elements'. Thus, they cannot be considered as ecological areas for now, but the plant structure and management of these park areas could easily be adapted in order to enhance their capacity to host high levels of biodiversity. In Costières de Nîmes, fruit orchards, that in our study are showing a very low level of biodiversity, could also be aimed at using similar actions as used for viticulture in order to complete the actions of BioDiVine. For example, mono-specific windbreaks could be replaced by more diverse hedgerows. Furthermore, the vine plots themselves showed higher levels of abundance and richness, which can be surprising considering high pesticides inputs of this crop. Far from being an observation comforting wine-growers in their current farming practices, this is considered an additional plea to encourage them paying attention to the plot's rich ecosystem.

In 2012 and 2013 (sampling stations located in vines only), between 43352 and 89374 arthropods have been collected and sorted depending on years and demonstration sites. The detail of values (abundances) is given in table 2.

**Table 2: Average number of arthropods analyzed per trap (10 weeks of sampling) and per year**

| Mean (±*Standart Deviation)* per trap | 2012 | 2013 |
|---|---|---|
| Bourgogne | 1408.68 (±*265.13)* | 1267.8 (±*466.48)* |
| Costières de Nîmes | 1787.48 (±*591.03)* | 3154.4 (±*1090.96)* |
| Limoux | 1666.32 (±*542.24)* | 1973.65 (±*612.1)* |
| Saint Emilion | 867.04 (±*257.14)* | 1190.56 (±*289.44)* |

These arthropods mainly belong to the following orders: Coleoptera (beetles, lady bugs …), Hymenoptera (bees, wasps, ants …), Diptera (Flies, mosquitoes…), and Heteroptera (true bugs). Values were very heterogeneous from one sampling station to another; therefore, the hypothesis of an influence of the surrounding landscape was tested.

2012 and 2013 values for all demonstration sites show a positive and significant correlation between the proportion of “semi-natural elements” and arthropods richness in a 400m buffer zone (figure 5).

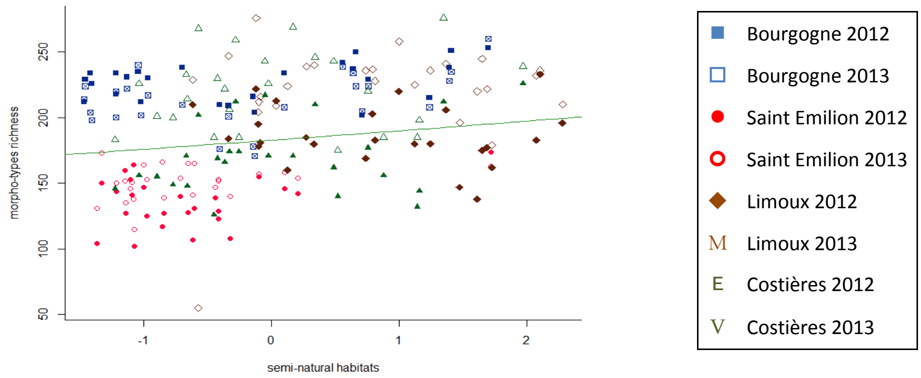

**Figure 5: Relation between semi-natural elements proportion in a 400m buffer area and total arthropods richness measured in each trapping station (10 weeks of sampling).**

This correlation shows the importance of presence of semi-natural elements to preserve biodiversity at this landscape scale. The preservation and extensive management of such existing elements or their restoration in areas where there is a lack can therefore appear as pertinent means to approach the European Union goal of “halting biodiversity loss” (Secretariat of the Convention on Biological Diversity 2003). However, this result does not allow determining a threshold value for a minimum proportion of semi-natural habitats (also referred to as Agro-Ecological Infrastructures, IAE) that could be used in environmental regulations. For instance, eco-conditionality of the CAP, and High Environmental Value (HVE) French certification are based on a minimum value of 4% of IAE.

Moreover, the GIS databases built in the BioDiVine project shows that in most cases, viticulture landscapes already contain much more than this threshold. Therefore, a 4% IAE minimum would be considered as too low to encourage viticulture farms to maintain semi-natural habitats since they often go over this value. The way of managing IAE could also be emphasized, in order to maximize the potential of IAE to host high levels of biodiversity.

Considering the pests insects monitored, a negative correlation between the quantity of *Lobesia botrana* caught during the first flight and the proportion of forests quantified in the 400m buffer zone is seen on all demonstration sites, in 2012 and in 2013 (forest’s proportion: $z = -2.413$, $P = 0.02$). This result has to be balanced by the fact that significant correlations exist between dominant landscapes features (there are no vines where forest is present). This result could more reflect a possible relation between the quantity of resources (vines) in the general landscape and the quantity of pest insect caught, instead of a possible direct effect of the presence of forests through biological control. In fact, if the presence of semi-natural habitats in farming landscapes could boost the quantity of biodiversity and, at the same time, the quantity of natural enemies, their final effect on pests’ populations remains hard to demonstrate (Sentenac 2011).

## 4 CONCLUSION

Arthropod biodiversity seems to be higher in vineyards plots surrounded by landscapes where semi-natural habitats are well present. This biodiversity is distributed among the different landscape elements with semi-natural habitats being richer than vines or other crops. The difference of richness levels is most of the time less than 50%. At the landscape scale, the presence of semi-natural habitats tends to support higher levels of arthropods biodiversity (as measured in the vine plots). These trends tend to show that managing landscape (maintaining existing semi-natural habitats, or implementing conservation actions where there is a lack) to preserve common biodiversity at the vineyard denomination scale could be an effective solution. This can be a sufficient argument to reinforce the policies which are set up across Europe. Nowadays, these results do not allow us to extrapolate up to a value for a minimum proportion of semi-natural habitats or to ideal landscape structure which could be relevant to use in legislation (CAP) or normative systems (HVE).

Implementation of conservation actions such as planting hedgerows, sowing ground covers inside plots or using uprooted fallow plots for biodiversity is also used in this project, and is still challenging. In fact, these actions can be perceived as constraints by the farmers, and without any strong proof of their usefulness in terms of functionality (particularly biological control), other advantages (air and water filtration, carbon sequestration, wood production…) often seem not sufficient to convince vine growers. The direct suppressive effect of ecological infrastructures on pest insects' abundance is not so easy to establish. This difficulty to identify and quantify the functional aspects (ecosystem services) of conservation actions makes incentive programs such as BioDiVine less attractive to vine-growers. It highlights the necessity to follow-up with research programs more oriented towards the functional side of biodiversity. However, in most vineyards semi-natural habitats are already well present: herbaceous ground cover and small hedgerows or bushes often present in the interstitial space between plots, which represents a high fraction of landscape (often > 10%) as plot units are often small. An extensive and adapted management of such areas (reduce the mown area and mowing frequency, the use of less impacting tools for pruning hedgerows …) could already contribute to preserve biodiversity without impacting too much wine-growers habits nor incurring additional costs. Awareness raise of these professionals to the existing richness of the vineyard landscape, the valorization of terroir not only as an "abiotic" (soil and climate) element but also as a living heritage (biodiversity) and the combination of agronomic and ecological sides of actions can be key aspects for the success of such programs.

The last point to highlight from BioDiVine's experience would be the importance of collective management of such programs, firstly to ensure reliability of actions (to create real ecological networks, hedgerows for instance often have to cross several wine estates), secondly to maintain motivation and willingness among professionals. So far, BioDiVine allowed implementing 15.4 km of hedgerows, 229 hectares of plots, 49 ha of environmental meadows.

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