Quantification of ecological services for sustainable agriculture

7th Framework Programme Theme KBBE.2012.1.2-02
Managing semi-natural habitats and on-farm biodiversity to optimise ecological services
Collaborative Project

Deliverable D3.3

Scientific Analysis and assessment of SNH performance

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This deliverable relates to Task 3.5 Data analysis

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Data for this task was collected by all case study partners in Task 3.2.

Content

1 Aims and structure of the report

The present report addresses the deliverable D3.3 on scientific analysis containing an assessment of performance of semi-natural habitats (SNH) on ecosystem services (ES). It is related to objective 3.1 of WP3 which aims at evaluating the role of SNH for the control of pests by natural enemies, the pollination and other key services on a representative number of crops and semi-natural habitats in farms in 15 case studies across Europe with standardized and simple methods. We first report countrywide the results of investigated key services pollination and pest control for all case studies. The second part reports on additional ecosystem services and disservices that were investigated in selected case studies.

2 Report on measured key ecosystem services pollination and pest control

2.1 Introduction

Among the multiple provisioning and supporting ecosystem services (ES) that contribute to crop production in agro-ecosystems, animal-mediated pollination and natural pest control represent key services of paramount economic importance (Oerke 2005; Gallai et al. 2009). Insect pollination increases and stabilizes the yield of more than three quarters of the world's most important food crops (Klein et al. 2007; Aizen et al. 2009). Pest control is estimated to occur mainly through natural enemies (~50%) and host-plant resistance (~40%) and much less through pesticides (~10%) (Pimentel & Burgess 2014). The concept of agro-ecosystems in which multiple ES are optimized while anthropogenic inputs are minimized could represent a substantial step towards a more sustainable agriculture (Bommarco, Kleijn & Potts 2013). Elements in the landscape that are managed in an environmentally friendly way – semi-natural habitats (hereafter SNH) – such as hedgerows, flower strips, fallow land or extensively managed meadows, offer resources vital for populations of beneficial organism in agro-ecosystems (Pywell et al. 2006; Klein et al. 2012), and could potentially increase their service delivery via resources such as shelter, suitable microclimates, over-wintering sites and food (Jeanneret et al. 2003; Sardiñas & Kremen 2014). The importance of such landscape mediated resource effects on arthropods is relatively well documented in scientific literature (e.g. Shackelford et al. 2013). Mobile, predominately wild animals accomplish both pollination and natural pest control. Responses of these mobile ecosystem services providers to above semi-natural habitats is likely depending on the composition of the landscape and the amount, quality and configuration of resources distributed at landscape scale (Scheper et al. 2013; Jonsson et al. 2015). Complex landscapes (i.e. with more structure, smaller patch sizes and large amounts of semi-natural habitats) have been found to support more diverse populations of natural enemies (Bianchi, Booij & Tscharntke 2006), which are positively related to improved service delivery (Letourneau et al. 2009; Vergara & Badano 2009). The efficiency or strength of ecosystem services may therefore depend on the landscape composition (Holzschuh et al. 2007).

The provision of insect pollination and natural pest control by several existing habitat types was measured in six economically important cropping systems, several farming intensities and four European agro-climatic zones in 15 case studies (7 for the pollination ES and 8 for the pest control ES). General description of methods used have been made available in D3.1, and are completed at case study level in this report.

2.2 Results from pollination case studies

2.2.1 Italy

2.2.1.1 Introduction

According to the United Nations, during the last 50 years the world population raised from 3.4 to 7.4 billion people and 9.7 billion are expected by 2050 (United Nations. Department of Economic and Social Affairs. Population Division 2015). In this context of increasing demand, the decline in yield growth per incremental unit of external inputs promoted compensatory land conversion to agriculture despite the risk of further undermining the essential ecosystem services on which they rely (Garibaldi et al. 2011). The global area occupied by agricultural crops expanded by ~ 23% from 1961 to 2006, with the largest proportion of this increase attributed to pollinator-dependent crops (Aizen et al. 2008). Even though the major staples of the human diet do not require insect pollinators, around one-third of global food production comes from crops that are to some extent dependent on them (Kearns et al. 1998; Klein et al. 2007). Simultaneously, many studies have reported worldwide declines in insect pollinators as a consequence of habitat losses or fragmentation, land use changes and modern agricultural practices, highlighting the multiple risks of these declines in terms of crop production, food security and ecosystem stability (Allen-Wardell et al. 1998; Kearns et al. 1998; Steffan-Dewenter et al. 2005; Biesmeijer et al. 2006; Potts et al. 2010). This situation has caused concern among scientists, policy makers and the general public about possible imbalances between pollination service needs and supplies.

The present work aims at evaluating the current status of pollination, and its implications in terms of crop production, trying to disentangle how landscape context affects the pollination service delivery. The chosen model crop is sunflower -- Helianthus annuus L. --, an economically important crop in the E.U., which was historically considered as a highly self-incompatible crop, but that nowadays -- with the use of current commercial cultivars -- is claimed to be highly self-fertile.

2.2.1.2 Results

Cross-pollination dependence of sunflower

As some plants were found damaged, in total, 189 isolated heads and 191 hand supplemented heads belonging to 25 focal fields (17 in 2014 and 8 in 2015) were included in the analysis.

Seed set was strongly affected by pollination treatments, with the percentage of fully developed achenes of heads that were isolated from any visitor being significantly lower than of those heads that were hand pollinated. Pollination treatments also influenced oil content of achenes, with hand pollinated plants showing greater contents than bagged plants. Year was not significant either for seed set or oil content and thus was removed from the minimal adequate models.

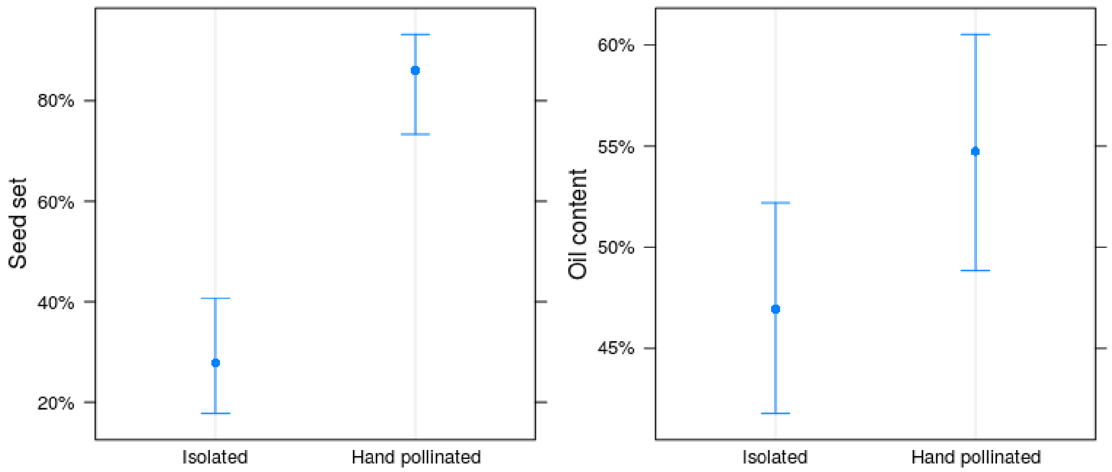

Fig.1 Cross-pollination dependence of sunflower for seed set -- % of fully developed achenes -- and oil content -- % of dry weight --. Dots represent the least-squares means of the GLMM (beta error distribution) averaged over the levels of cultivar. Bars represent the confidence intervals at the 95% level.

Pollination deficit

In order to quantify pollination deficit in terms of productivity, plant-level measures were pooled at plot level for each of the pollination treatments -- 'Open' and 'Hand pollinated' --. As all plants from one plot were destroyed, our final number of plots included in the analysis was 83 (belonging to the previously mentioned 25 fields).

Seed set was significantly affected by pollination treatment, with hand pollinated plants showing on average 2.4% more filled achenes than open ones, revealing a rather low, but significant, pollination deficit. Oil content of filled achenes was not significantly affected.

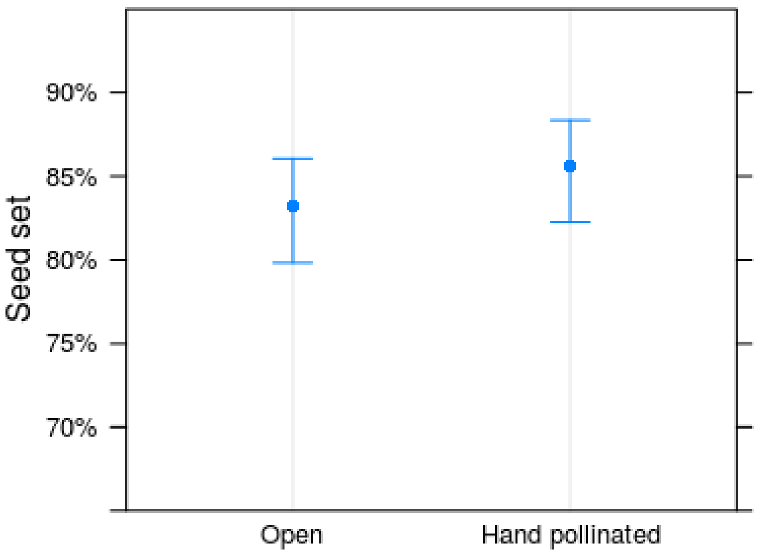

Fig. 2 Effect on seed set -- % of fully developed achenes -- of pollination treatment. Dots represent the least-squares means of the GLMM (beta error distribution) averaged over over both years. Bars represent the confidence intervals at the 95% level.

Local and landscape SNH influence on pollination service

In order to test how the local and landscape SNHs influenced pollination service delivery, we used only data from 2014. The seed set increase of sunflower due to insect mediated cross-pollination -- understood as a proxy of pollination success -- was calculated as the averaged value of seed set of open plants present in each plot minus the baseline level due to within-head selfing of that specific cultivar (estimated via the isolated plants).

There were very poor evidences supporting that the proportion of woody areal SNH (WA) present in the landscape had an effect on pollination service, while this was significantly affected by the proportion of herbaceous areal SNH (HA), herbaceous linear SNH (HL) and woody linear SNH (WL): pollination service delivery increased with the proportion of WL elements, whereas was negatively affected by the proportion of HA and HL. Regarding the type of adjacent SNH, 'woody SNH' resulted in reduced seed set compared to 'grassy SNH' and 'no SNH/control'.

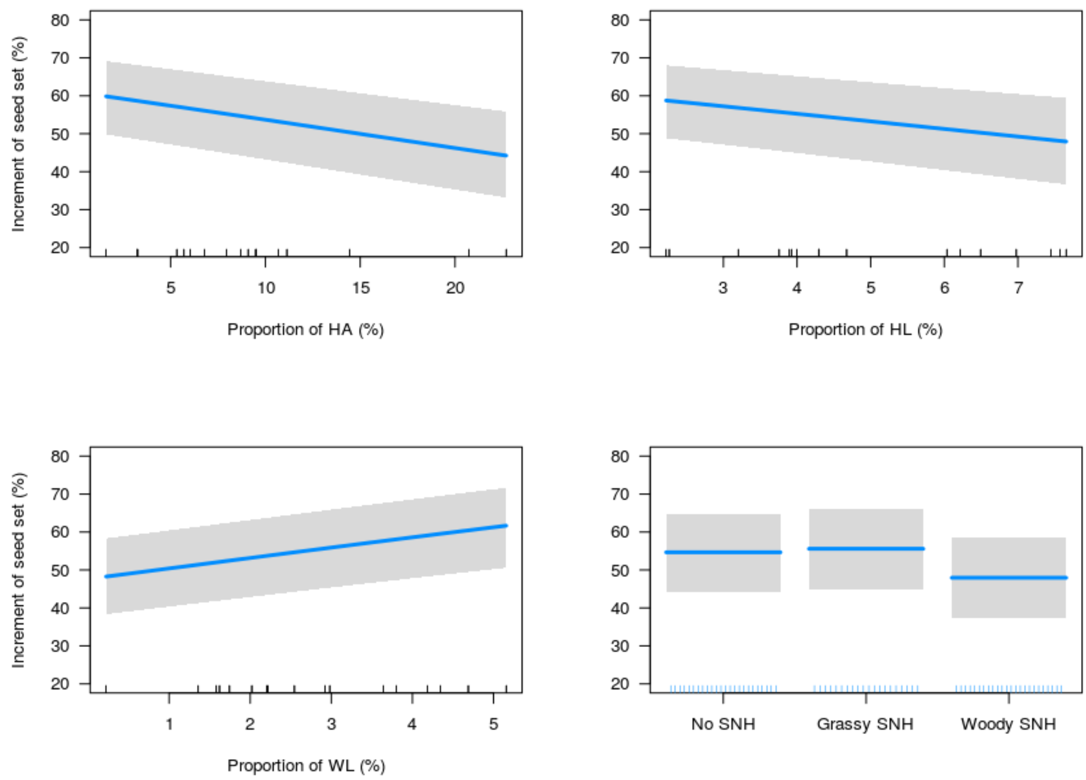

Fig. 3 Effect of local and landscape SNHs on pollination success. Mean increment of seed set -- % of fully developed achenes --. Results are based on GLMM (beta error distribution). Solid lines show predicted values, grey ribbons are upper and lower confidence intervals at the 95% level. Plots are constructed holding all other variables constant in their median value for numeric variables and most common category for factors.

2.2.1.3 Conclusion

This study reveals that:

Currently-in-use sunflower cultivars are still greatly dependent on cross-pollination events and those events are exclusively driven by sunflower visitors -- mainly honey bee --. At least up to date, there are not clear evidences of pollination deficits inducing important yield losses. The amount of SNHs exerts contrasting influences depending on their type. We hypothesize that co-flowering SNHs reduce pollination service delivery through a direct competition for pollinators. The presence of an adjacent SNH do not necessarily exerts a positive influence on service provision, as pollinator dynamics work at greater scales. Moreover, it negatively affect yields in their vicinities in the case of hedgerows through resource competition with the crop.

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2.2.2 Hungary

2.2.2.1 Introduction

Sunflower is the most important oil crop in Hungary, and its acreage has been increased by 50% in the last decade. Insect pollination plays a crucial role in the success of growing this crop. Honeybees and other pollinators can contribute to approximately 5-25% of the yield depending on the varieties (or hybrids). Semi-natural habitats (SNHs) can enhance pollination service by providing alternative source of nectar and pollen for the insect pollinators. We investigated sunflower pollination to clarify the contribution of the SNHs to this ecosystem service.

2.2.2.2 Materials and methods

In 2014 and 2015, 18 + 18 sunflower field were assessed with variable amount of SNHs within their 1km neighbourhood (Fig. 1). In both years six fields had woody adjacent habitat, six fields had herbaceous adjacent habitat, while six fields had not any adjacent SNH.

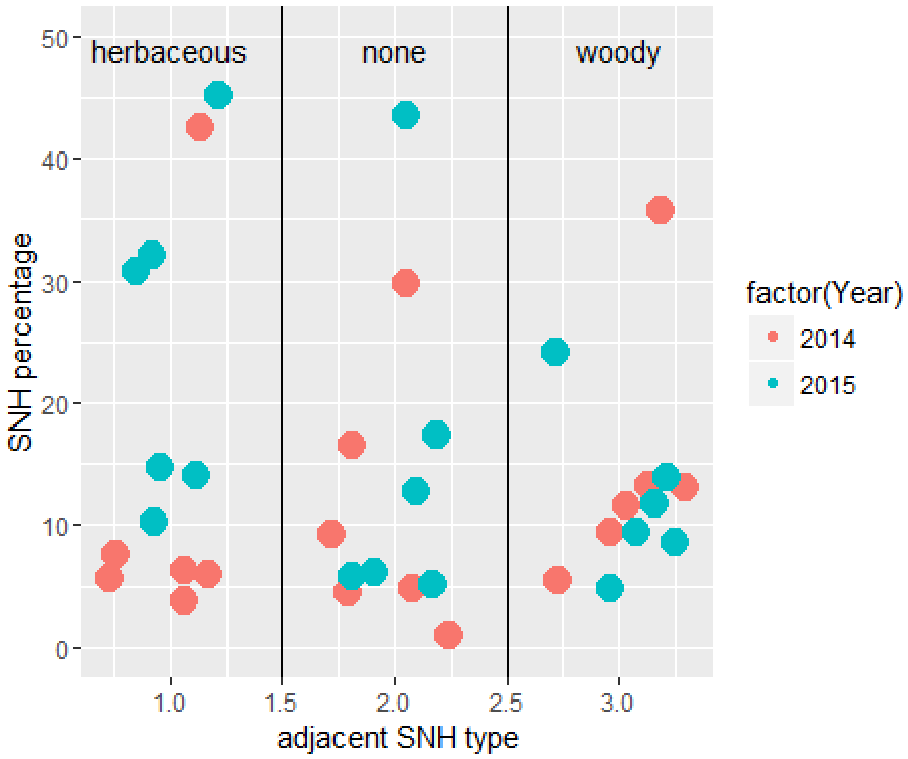

Fig. 1. Proportion of semi natural habitats within 1km neighbourhood of the investigated sunflower fields, Jászság, Hungary, 2014-2015

Open and isolated sunflower heads were selected at 2-25-50-75m from field edges in two transects. The isolated heads were covered by net to avoid ecosystem service of insect pollination. After harvest, the fertile and infertile achenes were separated and the fertility rate was determined on head level by measured the number of fertile and infertile achenes. The number of fertile achenes was calculated by measuring the weight of 50 or 100 fertile achenes and the total weight of the fertile ones. Ecosystem service of insect pollination was considered as fertility of open heads minus fertility of isolated heads.

Moreover, hand pollinated heads were also investigated in 34 fields to assess pollination deficiency. Pollination deficiency was calculated as fertility of hand pollinated heads minus fertility of open heads [on field level].

2.2.2.3 Results

I. Pollination deficiency

There was no pollination deficiency in the sunflower fields of 2015 (p=0.166), as well as for the pooled two years data (p=0.051) (Fig 2.). However, in 2014, the hand pollinated heads had higher fertility rate with 4.7%, (p=0.001).

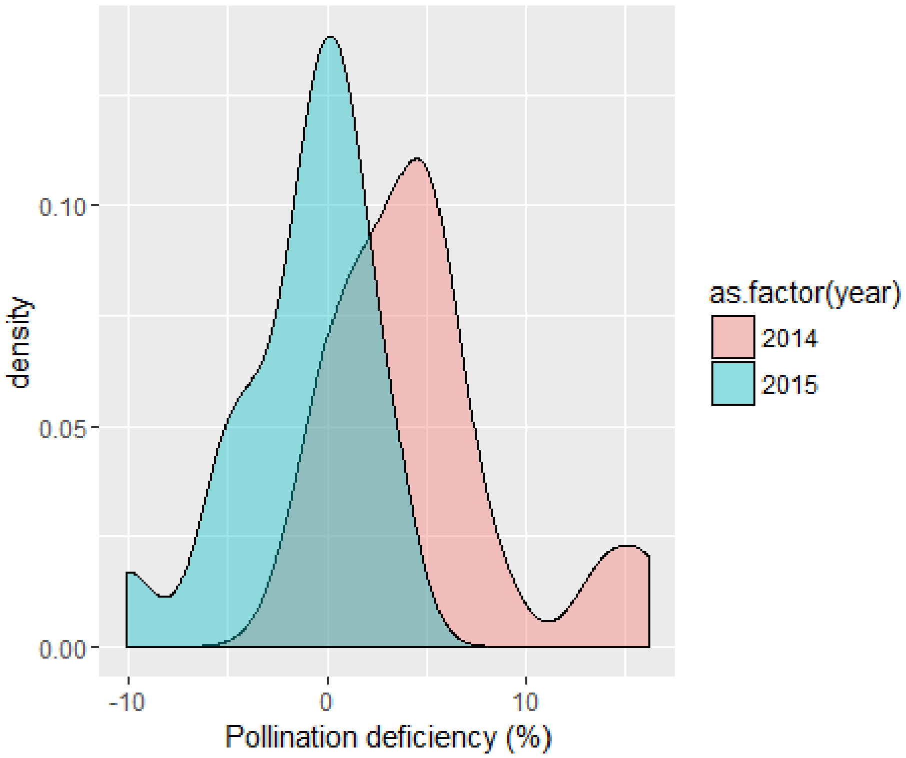

Fig. 2. Smoothed histogram (density plot) of the pollination deficiency of investigated sunflower fields, Jászság, Hungary, 2014-2015

II. Pollination as ecosystem service

The insect pollination service, i.e. the difference between the fertility of the open and isolated heads, were averaged at 7.5% and ranged from -3.21% to 27.57% in the 36 investigated fields (Fig 3.). However, the contribution of SNHs within 1km to pollination could not have been justified (p=0.09), i.e. more SNH are within the investigated landscape sectors did not resulted in higher ecosystem service levels (Fig 3.).

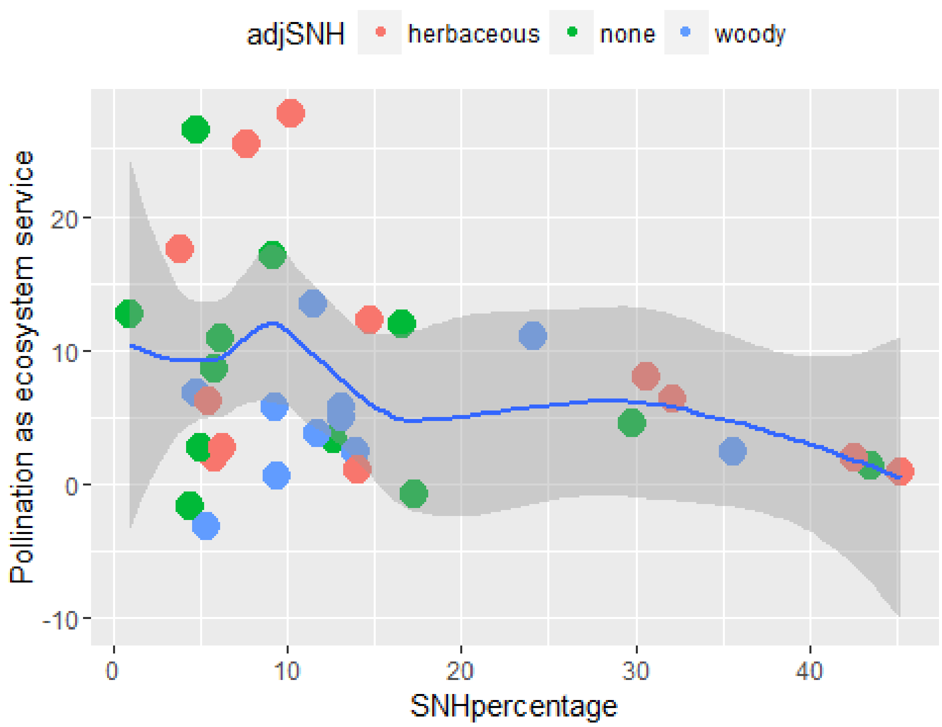

Fig 3.Effect of proportional SNH area within 1km (in %) on insect pollination in sunflower fields with adjacent herbaceous (salmon), woody (blue) SNH or without adjacent SNH (green), Jászság, Hungary, 2014-2015

Moreover, the type of the adjacent SNHs and the distance from them (2, 25, 50 or 75m) did not affect the pollination levels (Fig 4., p=0.37 and p=0.38, respectively for the type and distance) in sunflower.

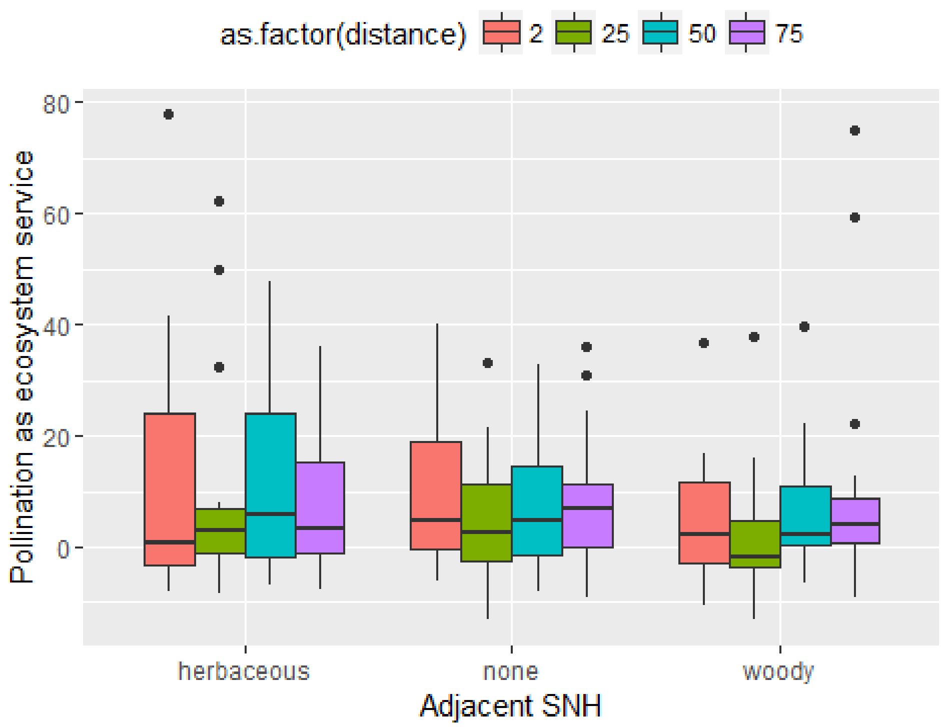

Fig 4. Effect of the adjacent SNH type and the distance (2, 25, 50 or 75m) from these SNHs on insect pollination as ecosystem service in sunflower fields, Jászság, Hungary, 2014-2015

2.2.3 Germany

Authors: Sonja C. Pfister, Jens Schirmel, Martin H. Entling

2.2.3.1 Introduction

Pumpkin (Cucurbita maxima) is a suitable study plant for pollination services because it is obligate cross-pollinated by insects and has local economic value. Although cucurbits have a long flowering period (on average 72- 80 days), the single flowers have only a short lifetime (6 hours – 1 day), so rapid and effective pollinator visits are vital to crop yield.

2.2.3.2 Methods

- Single visit deposition (SVD) of honey, bumble and halictid bees (2015)
- Pollen-yield-dose-response investigations using handpollination (2014 & 2015)
- Video recording of pollinators of female pumpkin flowers in 18 fields (3 times * 4 distances * 15 min = in total 180 min per field) (2014): bee visits and handling time (H)
- Measurement of pollen delivery to female pumpkin flowers in 18 fields (2 times * 4 distances * 4 stigmas = in total 32 samples per field)(2014)

2.2.3.3 Results

Bumble bees were the most efficient pollinators (SVD = 3369 grains; H = 12 seconds), followed by honey bees (SVD = 582; H = 144) and halictid bees (SVD = 45; H = 191) (Fig. 1 A). To produce a marketable fruit, a flower required > 500 pollen grains on its stigma and fruit mass increased up to an accumulation of c. 3000 pollen grains (Fig. 1 B). After accounting for realistic handling times and time of day to reach full pollination every female flower need 3.5 bumble, 12 honey or 190 halictid bee visits (between sunrise and ~11:00 am). Crop yield is most sensitive to declines in bumble bees, because either 15 honey bees or 1030 halictid bees are required to replace the service of each individual bumble bee.

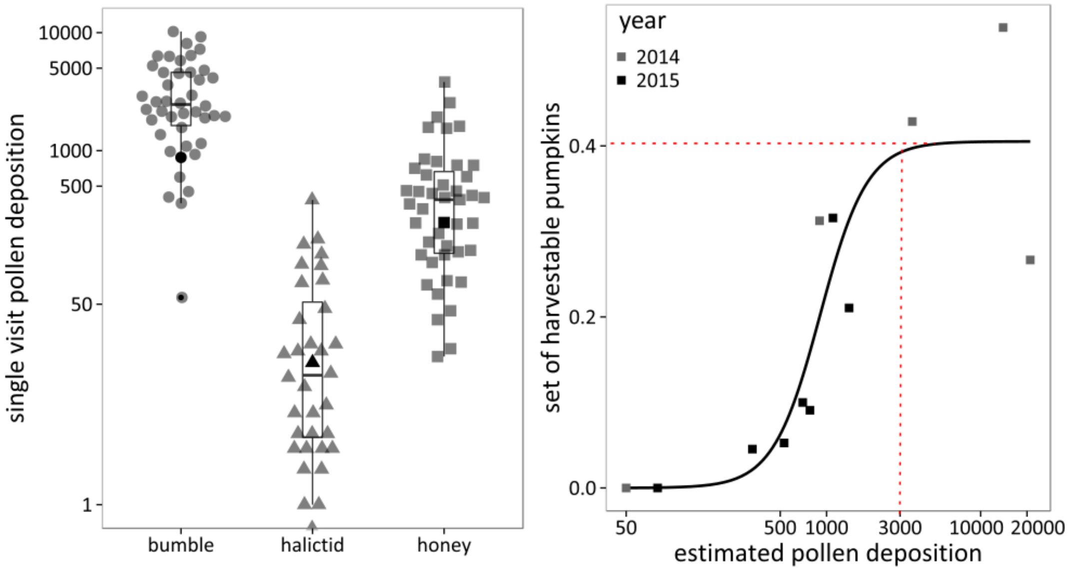

Fig. 1 A) Single visit deposition of bumble bees (circle: 3369 ± 2473, n= 41), halictid bees (triangle: 45 ± 76, n= 33) and honey bees (square: 582 ± 752, n= 43) in 2015. The boxplots display the medians and quartiles. The small black circle marks an outlier. The black symbols mark the calculated pollen deposition of an average bumble (877), halictid (16) or honey bee (246) with realistic handling times and time of day.

B) Fruit set of harvestable pumpkins increased with pollen deposition based on the hand-pollination results from 2014 (grey squares) and 2015 (black squares) (y =phi1/(100*(1+e^((-(log10(pollen)-phi2)/phi3)))) ; phi1 = 40.52, t8 = 7.53, p < 0.001; phi2 = 2.958, t8 = 36.5, p < 0.001; phi3 = 0.1525, t8 = 1.77, p= 0.111; R2= 0.79). With around 3000 deposited pollen grains the saturation level (phi1/100=0.4052) is reached (red dashed lines).

In total we observed 2100 bee individuals in all 18 fields in 2014: 79% honey bees Apis mellifera (1664), 14% bumble bees (282, mainly Bombus terrestris agg., some B. lapidarius) and 7% halictid bees (154). At maximum 33147 pollen grains were delivered to a stigma, on average 11600 (± 5680, n = 551). Pollen delivery significantly increased with the number of bumble bee visits, but was not significantly related to the visits of all pollinators, honey or halictid bee visits (Fig. 2 A), although honey bees were much more abundant than bumble bees. At the extant abundance of bumble bees (on average 250 bumble bees per ha and day) and pumpkin cultivation (9 ha in 1 km radius) there is no pollination deficit in our study region.

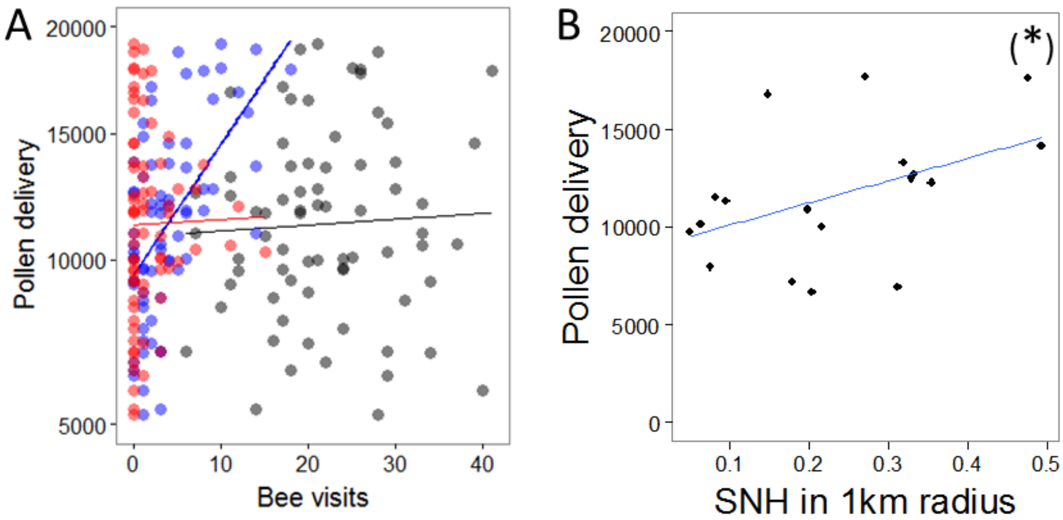

Fig. 2 A) Pollen delivery significantly increased with the number of bumble bee visits (blue, $t_{140} = 2.6$, $p = 0.01$), but was not related to the visits of all pollinators ($t_{140} = 0.71$, $p = 0.48$, $R^2 = 0.19$), honey (black, $t_{140} = -0.09$, $p = 0.93$) or halictid bee visits (red, $t_{140} = -0.31$, $p = 0.76$). B) Pollen delivery tended to increase with proportion of seminatural habitats in 1 km radius ($t_{16} = 2.0$, $p = 0.059$, $R^2 = 0.16$).

Pollen delivery tended to increase with proportion of seminatural habitats in 1 km radius (Fig. 2 B), because bumble bee visits also increased with proportion of seminatural habitats in 1 km radius (Fig. 3 A). Further bumble bees preferred pumpkin fields with adjacent open habitats (crop, herbaceous field margin) over fields adjacent to woody habitats. Nevertheless bumble bee visits tended to be more common in landscapes with high proportions of SNH in general and of woody linear habitatsin particular ($t_{16} = 1.9$, $p = 0.08$). In contrast, seminatural habitats had no significant effect on honey bee visits (Fig. 3 B).

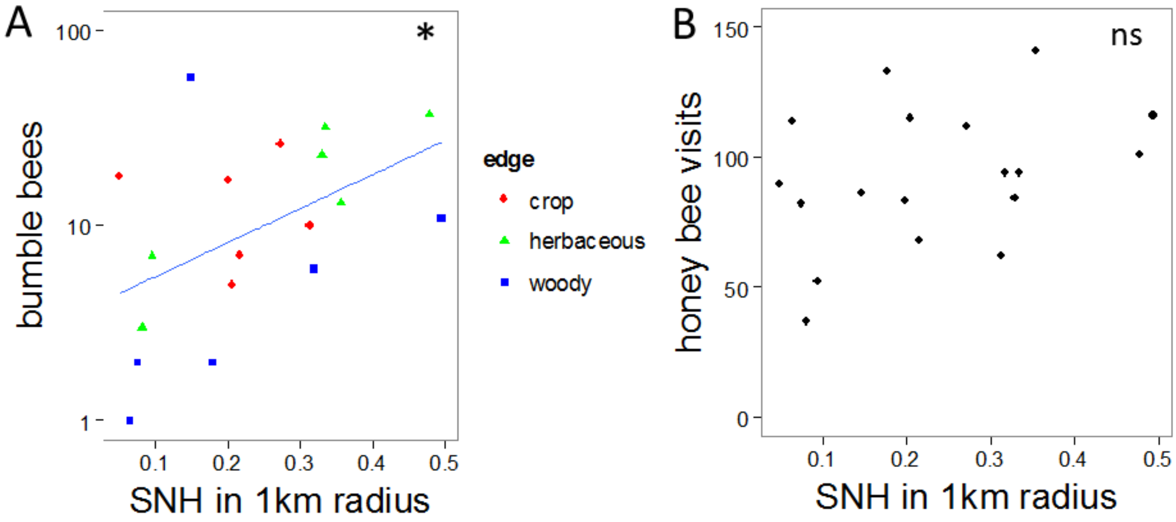

Fig. 3 A) Bumble bee visits to female pumpkin flowers increased with the proportion of seminatural habitats in 1 km radius ($t_{16} = 2.3$, $p = 0.04$, $R^2 = 0.19$) and was higher in fields adjacent to open habitats than in fields adjacent to woody habitats ($F_{2,14} = 1.4$, $p = 0.02$, $R^2 = 0.33$). B) Honey bee visits were not related to proportion of seminatural habitats in 1 km radius ($t_{16} = 1.5$, $p = 0.14$).

Conclusion

Especially bumble bees are important pollinators of pumpkin. Farmers should preferably support wild bumble bees, because commercial bumble bee hives can transfer diseases to local honey, bumble and other wild bee populations. Seminatural habitats enhance the abundance of bumble bees and the delivery of pollen. Herbaceous seminatural habitats are the best habitats adjacent to pumpkin fields, but on the landscape scale both woody (especially linear) and herbaceous seminatural habitats have positive effects. Especially, farmers should provide perennial herbaceous elements such as wildflower strips composed of species that flower throughout the vegetation period, and that provide nesting sites to bumble bees through the undisturbed soil surface and through the presence of small mammal burrows.

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2.2.4 Switzerland

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2.2.4.1 Introduction

The explicit and implicit aims of creating ecological focus areas (EFAs) and implementing greening measures in European agro-ecosystems include the promotion of regulatory ecosystem services (ES) to sustain crop production in conventional cropping systems (European Union 2014; Ekroos et al. 2014). However, it remains poorly explored to what extent these goals are achieved with current policy measures. Here, we address the question of influences of SNH on ecosystem services questions focusing on pollination in winter oilseed rape Brassica napus L. (hereafter OSR), which is amongst the most important food, fodder and biofuel crops worldwide. Although OSR is considered to be mainly wind pollinated, recent studies have shown that the contribution of animal-mediated pollination to yield can be considerable (Bommarco, Marini & Vaissière 2012; Hudewenz et al. 2013). Thus, there is high potential for ecosystem management measures to promote pollination in conventional OSR production. To investigate the effect of adjacent EFAs and landscape-scale greening measures on pollination in OSR, we tested the following interrelated hypotheses:

1. The local establishment of two commonly implemented types of EFAs (sown wildflower strips and hedgerows) enhances pollination service delivery in adjacent OSR crops.
2. The effectiveness of these adjacent EFAs in promoting pollination is reinforced by increasing the share of greening measures implemented at the landscape scale.

2.2.4.2 Results

Adjacent EFAs and landscape-scale greening measures driving ES providers and ES

The number of OSR flower visits by wild pollinators in focal fields tended to increase with 'landscape-scale greening measures' (Fig. 1a). This increase was, however, dependent on the local presence of an EFA adjacent to the focal field, with higher flower visitation by wild pollinators in the presence of a wildflower strip or a hedgerow as compared with no adjacent EFA, as shown by the nearly significant effect of the interaction between both explanatory variables (Fig. 1a). Honey bees, on the other hand, did not show any significant response to the tested explanatory variables. Furthermore, both the presence of an adjacent EFA and landscape-scale greening measures increased the effect of insect pollination on seed set in focal fields (Fig. 1b). Seed set driven by insect pollination was on average 10% higher when the focal field was adjacent to a flower strip and 4% higher when it was adjacent to a hedgerow compared with no adjacent EFA; furthermore, it increased from 7% at low (6%) to 18% at high (26%) proportions of greening measures in the landscape (Fig. 1b). However, there were no significant interactive effects of adjacent EFAs and landscape-scale greening measures on insect pollination (Fig. 1b).

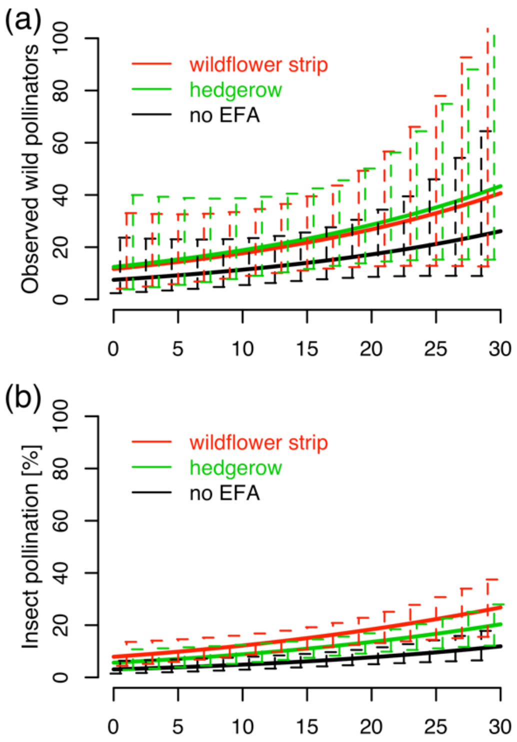

Figure 1 Effects of landscape-scale greening measures and adjacent EFA (wildflower strip (red), hedgerow (green), and no EFA (black)) on (a) number of observed wild pollinator, (b) increase of seed set driven by insect pollination (%), (c) number of predatory ground beetles, (d) predation on pollen beetle (black) and pollen beetle parasitism (grey). Predicted values 95% confidence interval for the investigated gradient (6–26%) of landscape-scale greening measures (n = 18 fields). Where no differences between adjacent habitat types occurred, only the average values for all three habitat types is shown.

2.2.4.3 Conclusion

Agriculture has to meet the growing demand for food while minimizing negative impacts on biodiversity and ecosystem functioning. It is hoped that the implementation of greening measures helps to achieve this goal by promoting farmland biodiversity and ES that sustain high and stable crop yields. Our results suggest, however, that beneficial effects of greening measures on the regulatory ES insect pollination in conventional OSR production become relevant only at increases in proportions of greening measures–much higher than the currently required 5% greening measures in the EU. However, the agricultural landscapes studied here did not comprise highly simplified and cleared landscapes largely lacking any greening elements or other semi-natural habitats. Regulatory ES may be restored and considerably enhanced already at lower increases in greening measures implemented in such landscapes. Our findings of beneficial effects of local and landscape-scale implementation of EFAs and other greening measures on important regulating ES may help to encourage farmers to implement them. Further research is needed to investigate how EFAs and other greening measures can be improved to make them more effective in achieving their multiple goals. Future studies should especially consider trade-offs and synergies at large scale between ES provision, food production and biodiversity conservation needs.

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2.2.5 Netherland

2.2.5.1 Introduction

QUESSA aims to quantify ecosystem services and will focus on sustainable agriculture with high quality production. Special focus is on pollination and natural control of pests. The Dutch case study will quantify and demonstrate the capacities of field margins in landscapes in supplying adequate pollination and natural control of pests in pear orchards. The goal is to provide breakthroughs in the management and produced ecosystem services for integration in sustainable, highly productive commercial integrated fruit production.

Pollination by honey bees, bumble bees and other pollinators is an ecological service of major importance. Fruit set and fruit quality is positively influenced by successful pollination. In order to quantify the impact of farm and landscape structure on provisioning of this service we aim at answering the following questions.

Main questions concerning pollination:

- Is there a pollination deficit at all?
- Does insect pollination contribute to seed forming in pears?
- Is pollination influenced by the adjacent SNH?
- Is pollination influenced by % SNH in the surrounding landscape?

Main questions concerning abundance of pollinators:

- Which pollinators are abundant in pear orchards?
- Is the abundance of pollinators influenced by the adjacent SNH?
- Is the abundance of pollinators influenced by the distance from the adjacent SNH?
- Is the abundance of pollinators influenced by % SNH in the surrounding landscape?

2.2.5.2 Methods

To test for the pollination deficit we evaluated the effect of additional hand pollination. Treatments were: C=control, E=extra pollen.

To test for the actual contribution of pollinators on seed forming in pear fruits we evaluated open pollination versus bagging of flowers. Treatments were: A=open pollination, B=bagged flowers.

All observations were done in 18 pear orchards (main cultivar: Conference) in the Netherlands. The orchards were under conventional/IPM crop protection management. Six focal fields bordered a woody linear (WL) semi-natural habitat (SNH), six bordered an herbaceous linear (HL) SNH and another six bordered no SNH and a crop instead (CO). In each orchard each treatment was applied at 4 different distances from the adjacent SNH (3, 11, 19 and 27 m). As response variable we used the presence of seeds in the fruit. This is an indicator of successful pollination.

As an additional indicator of fruit quality we measured the fruit diameter and the average sugar content in 2015. These parameters will be evaluated later on.

Observations on pollinators were done on sunny and dry days during flowering of the pear trees. This was done on all focal fields at each of the 4 distances by 10 min observations on a determined number of open flowers. At nine orchards we did additional observations by walking 50 m transects and noting all observed pollinators. Whenever possible we followed individual insects in their flower visiting behaviour. Here we will present the data on the 10 min observations.

2.2.5.3 Results

Pollination

There is a pollination deficit

Here we compare the number of seeds in fruits for treatment C (control) and E (extra hand pollinated). In both years the hand pollinated pears had significantly more seeds.

	C	E		
2014	0.35 ± 0.33	3.02 ± 0.78	T< 0.01	***
2015	0.14 ± 0.15	0.93 ± 0.51	T< 0.01	***

There is an actual contribution of insect pollination on seed forming in pears

We compare the number of seeds per fruit in treatment A (open pollination) and B (bagged flowers). In both years the open pollinated flowers developed significantly more seeds in fruits.

	A	B		
2014	0.42 ± 0.37	0.15 ± 0.16	T< 0.0027	***
2015	0.17 ± 0.14	0.06 ± 0.06	T< 0.0013	***

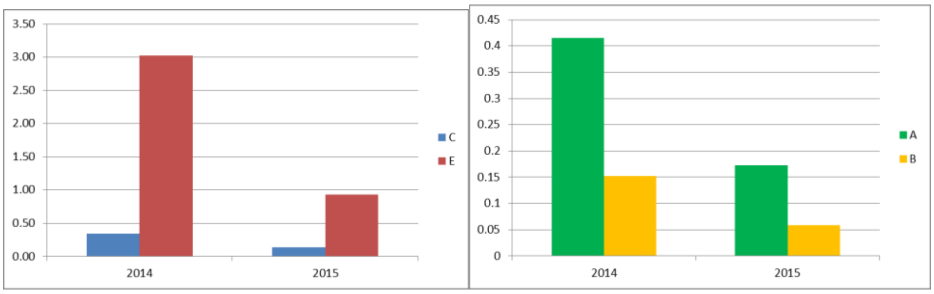

Figure 1 and 2: Average number of seeds in pear fruits.

Pollination is not directly influenced by the kind of SNH adjacent to the field

We compare the average number of seeds in treatment A (open pollination) for herbal, none and woody SNH adjacent to the orchard.

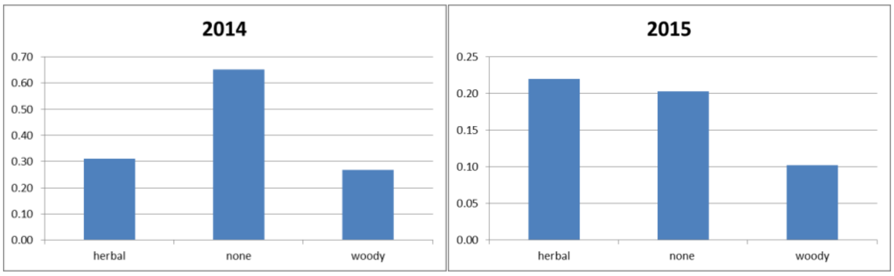

Figure 3 and 4: Average number of seeds in pear fruits depending on type of adjacent SNH. Note the difference in scale between years.

We applied a Single Factor Anova to test for differences between the type of SNH separate for both years. We do not find significant differences between the SNH types (P 0.171 for 2014 and P=0.249 for 2015). The variation within groups is far too large to confirm an effect of the treatment adjacent type SNH.

Pollination is not directly influenced by the % SNH in the surrounding landscape

Figure 5 and 6 show the correlation between the percentage of SNH in the surrounding landscape sector and the number of seeds per fruit, as a measure for pollination success.

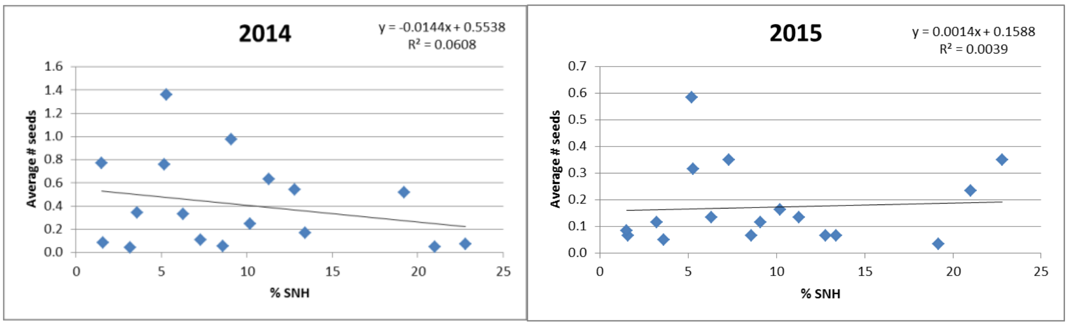

Figure 5 and 6: Correlation between % SNH around the orchard and average number of seeds

Pollinators

The most abundant pollinators in the orchard were bees, and to a lesser extend bumble bees and hoverflies

Even though weather conditions during observation were potentially good for pollinator activity, we observed only few individuals. In 2015 even fewer insects were observed as compared to 2014 (see figures below).

The abundance of pollinators is not significantly influenced by the kind of SNH adjacent to the field

High counts for the woody SNH in 2014 are based on extremely high counts in one orchard only. The difference in number of pollinators between herbal and none is close to significant (P=0.078). This finding from 2014 was not confirmed by data from 2015.

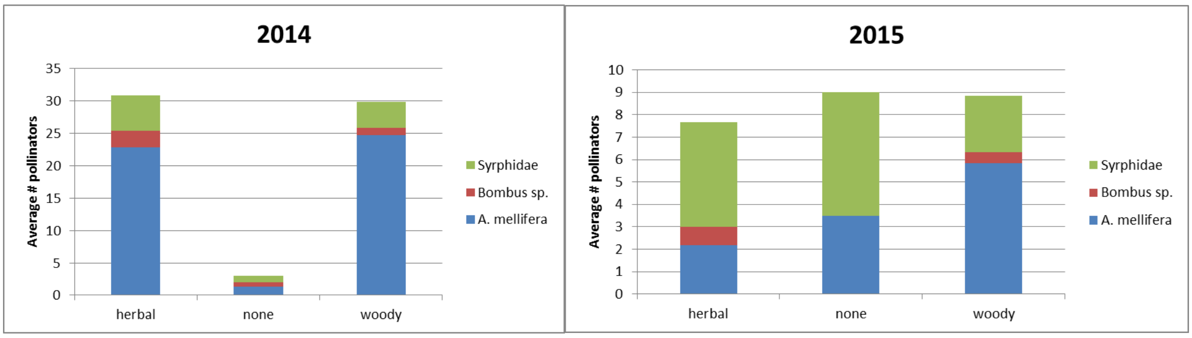

Figure 7 and 8: Average number of pollinators observed in orchards adjacent to different type of SNH

The abundance of pollinators is not significantly influenced by the distance from the adjacent SNH

No significant differences were found based on distance from herbal SNH (Two Factor Anova P 0.38 for 2014 and P=0.21 for 2015). At one orchard with adjacent herbal SNH an exceptionally high number of bees was observed at distance 1 due to bee hives close by.

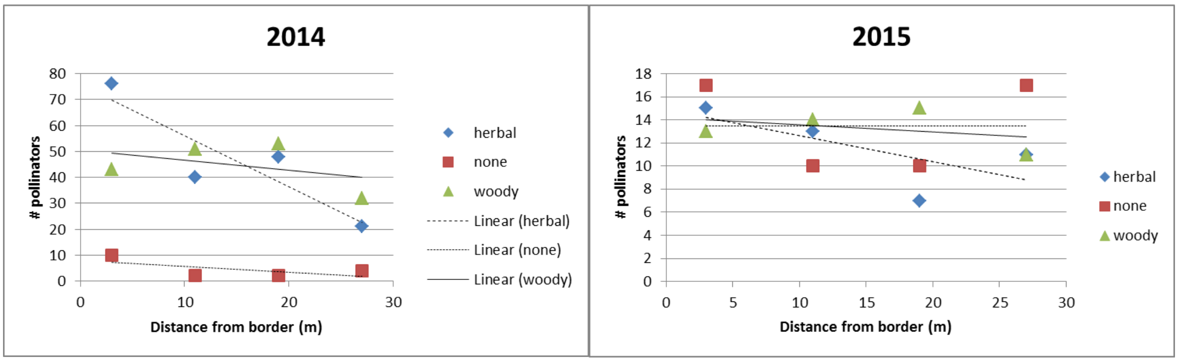

Figure 9 and 10: Number of pollinators observed depending on distance from SNH. Each point represents the sum of insects from 6 orchards observed at this specific distance.

The abundance of pollinators is not significantly influenced by % SNH in the surrounding landscape

The abundance of pollinators was not clearly related to the % SNH in the surrounding of the orchard. As in other case studies the herbaceous SNH seem to have a higher impact as compared to woody or other SNH types, we checked for potential correlation between % herbaceous SNH in the surrounding of the orchard and the abundance of the different pollinator groups in 2014 when insect numbers were higher. No positive effect of herbaceous SNH was found.

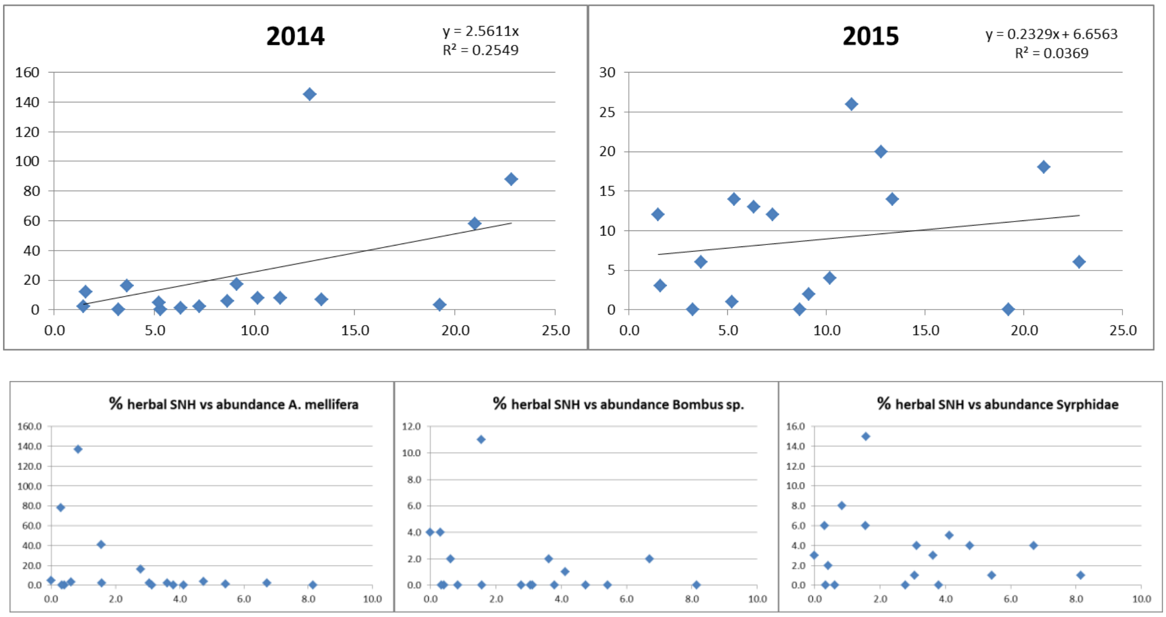

Figure 11 to 15: Correlation between (herbal) % SNH around the orchard (horizontal axis) and number of pollinators (vertical axis) observed

Preliminary conclusions

- Insects do actually contribute to the pollination of pears
- Abundance of pollinators differed considerably between years with more pollinators observed in 2014. This difference was reflected in the number of seeds in fruits
- A pollination deficit was found in both years in all orchards
- Improvement of insect pollination would lead to more seeds in fruits
- In this experiment the type of SNH adjacent to the orchard does not show a direct effect on the pollination
- In this experiment the amount of SNH in the surrounding landscape (% SNH in 1 km) did not show a direct effect on the pollination
- Further discussion is needed

2.2.6 United Kingdom

Authors: John Holland & Niamh McHugh

2.2.6.1 Introduction

Pollination of oilseed rape was investigated. This crop is self-fertile and wind pollinated, although some studies have shown that it also benefits from insect pollination which can increase seed yield and quality. Honeybees, bumblebees, solitary bees and hoverflies are known to pollinate oilseed rape, but there are differences in their efficiency depending on the number of pollen grains they can transfer, visitation rates and their abundance. Based upon these factors, honeybees were twice as efficient as Eristalis species (solitary bee) and bumblebees (Stanley et al., 2013). Some previous studies examining pollination by different taxa have used cage experiments in which pollinators have no choice about where to forage (e.g. Jauker et al., 2012) and may not reflect what occurs in the field where pollinators can choose whether to forage on the crop or in SNH. This experiment examined natural levels of foraging and the impact on pollination. The impact of three types of semi-natural habitat (SNH) were investigated: woody areal, woody linear (hedgerows) and herbaceous linear, these being the most predominant in the arable farming regions of England. The herbaceous linear was treated as the control because boundaries are almost always present around all fields, with crop to crop being rare.

2.2.6.2 Methods

The pollination deficit in oilseed rape was examined for oilseed rape. This involved comparing the difference between fully pollinated flowers (hand pollinated treatment), natural levels of wind and hand pollination (open treatment) and wind only (bagged treatment to exclude pollinating insects). However, data from the bagged treatment was discarded because the 1m2 bags were blown around by the wind which may have increased wind pollination levels. The standard QuESSA protocol for pollination studies was followed with pollination evaluated at 2, 25, 48 and 71m from the nearest SNH in winter oilseed rape. Pollinators were recorded using observations of visits to a predetermined area of oilseed rape flowers at each distance. A set of three pan traps with one of each colour (yellow, white and blue) were located at 2 and 71m and left operating for 7 days.

Analysis was conducted in R v.3.2.0. GLMMs were built using the package lme4 and the function glmer that included pollination treatment (open or hand) plus distance from adjacent SNH plus adjacent SNH type with field as a random effect. Poisson and gaussian models were built but overdispersion in poisson models was dealt with using the negative binomial. Negative binomial models were built using the package glmmADMB. Post hoc tests were used to compared between habitat differences.

2.2.6.3 Results

Neither the number of seeds per pod or the 1000 seed weight differed between the open and hand pollinated treatments. Nor was there any effect of the adjacent SNH type or distance from these.

Table. Mean number of seeds per pod and 1000 seed weight for open and hand pollination.

Pollination type	**Mean number of seeds per pod (± 1SE)**	**1000 seed weight (± 1SE)**
Hand	20.0 (0.04)	4.30 (0.08)
Open	18.9 (0.03)	4.89 (0.11)

A total of 264 visits to oilseed rape flowers were recorded of which 202 were flies (Diptera) and of these 28 were hoverflies, 21 solitary bees, 14 bumblebees and 6 others orders. In addition, there were 23 visits by honeybees. The only significant effects found were that the number of visits by wildbees ($p<0.05$), solitary bees ($p<0.001$) and total visits ($p<0.01$) declined with distance from the adjacent SNH. As solitary bees made up a large proportion of the wildbees the significance of these was probably due to the solitary bees which showed the strongest decline with distance from the SNH.

In the pan traps a total of 636 solitary bees, 83 bumblebees, 8 honeybees and 50 hoverflies were captured. The adjacent SNH type only had a significant effect ($p<0.001$) on the numbers of hoverflies where 16% more were captured next to the woody areal compared to the herbaceous linear habitat. Significantly ($p<0.001$) more (40%) bumblebees were caught at 71m compared to 2m from the SNH, whereas the opposite was found for hoverflies (P<0.001) with half as many captured at the further distance.

2.2.6.4 Conclusions

The difference between the hand and open pollination provides an indication of the pollinator deficit attributed to insect pollination alone. As no significant differences were found we conclude that for oilseed rape in this region there was no insect pollination deficit, as also found in Ireland (Stanley et al., 2013). Only low numbers of honeybees were recorded in visits and pan traps therefore this species was unlikely to have contributed much to the crops pollination. The abundance of honeybees is also largely determined by the number and location of hives rather than the influence of SNH and is not considered further here. The lack of an insect pollination deficit may be because modern oilseed rape varieties can rely on self and wind pollination alone to achieve maximum yield. Alternatively, it may be because pollinator densities were too low to have any impact. Bees are considered the most efficient pollinators of oilseed rape because of the number of pollen grains they can transfer (Stanley et al., 2013), yet bumblebees comprised only 5% of the visits to flowers. In contrast, solitary bees despite being by far the most abundant pollinator in the pan traps, formed only 8% of the visits. The majority of the solitary bees were Andrena species that nest in the ground and it is possible that they were seeking nesting sites, rather than foraging in the oilseed rape. Hoverflies can also pollinate oilseed rape (Jauker & Volters, 2008), yet they only formed 11% of the visits and only 50 were captured in the pan traps.

The type of SNH only had an effect on the numbers of hoverflies caught in pan traps, with more caught next to woody areal compared to herbaceous linear habitats, as also found in evaluations of SNH in WP2. Further analysis will be conducted to investigate whether the surrounding landscape composition was influential but given the lack of effects for local scale influences, it is unlikely that any significant effects will be found.

Some edge effects were detected with higher visitation rates by solitary bees closer to the crop edge. Solitary bees are generally regarded as being less mobile than bumblebees and hoverflies which may explain the difference, however, such edge effects were not detected for the pan traps. Too few solitary bees were observed visiting flowers to determine whether forage or nesting preferences were responsible for these effects. Fewer bumblebees were captured at the edge compared to the field centre, most likely because of the distraction of alternative foraging resources near the field edge. Much higher numbers of bumblebees were captured in the SNH for studies conducted as part of WP2.

2.2.7 Estonia

Authors: Eve Veromann, Gabriella Kovacs, Riina Kaasik

2.2.7.1 Introduction

Growing area of oilseed crops has vastly increased in prominence over the past 10 years. Oilseed rape, Brassica napus, is now the third largest source of vegetable oil in the world (http://faostat3.fao.org), which is used not only for human consumption but also as a valuable high-protein animal feed. Oilseed rape as a mass flowering crop has two controversial impacts on the pollinators – it is an important food source also for honey bees as well as wild pollinators but on the other hand it can reduce bee abundance i.e. pollination service in adjacent semi natural habitats.

Oilseed rape plants are self-fertile and partially wind pollinated but pollination has been found to increase seed yield, quality and market value.

2.2.7.2 Methods

- Measuring pollinator abundance with yellow water traps (one trap per 4 distances each 18 ff and 2 traps in the adjacent SNH (2014). Traps were kept for 3 x 4 days in the fields (1-5.05; 14-18.05; 18-22.05)
- The measurement of pollination deficit - open pollination vs hand pollination (2014)
- Measurement of pollen delivery to oilseed rape flowers in 18 fields (4 distances x 4 stigmas x 18 focal fields = in total 288 samples)(2014)

2.2.7.3 Results

Generally, the abundance of pollinators in all focal fields was low in 2014. In total, we collected 950 pollinators, from which 122 were honey bees (12.8%), 67 bumble bees (7%) and 761 solitary bees (80%). In average, significantly more pollinators were found at 2m from the edge of oilseed rape field compared to the 75 m ($\chi2=39.57$, df=3, $p<0.0001$; Figure 1). However, the distance from the edge had significant impact only on the abundance of solitary bees ($\chi2=48.81$, df=3, $p<0.0001$).

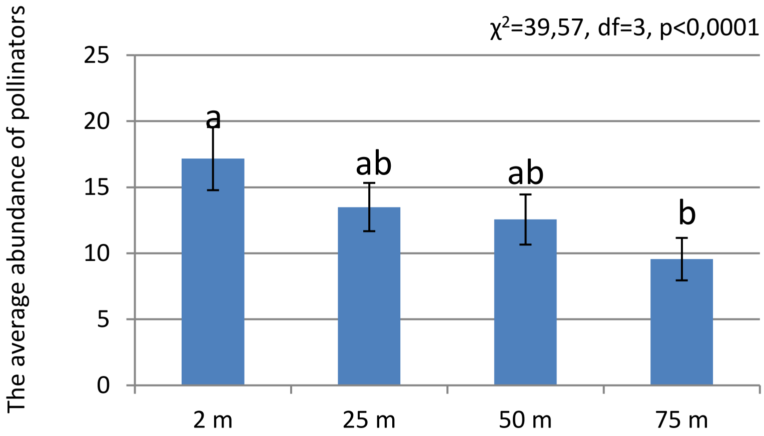

Figure 1. The average abundance of pollinators per yellow water trap in the different distances on the oilseed rape fields in Estonia, 2014.

The adjacent landscape element also influenced the number of pollinators in the yellow pan traps ($\chi2=10.89$, df=2, $p=0.0043$, Figure 2), significantly more pollinators were found in the oilseed rape fields adjacent to herbaceous linear and woody linear elements compared with the nonflowering crop field (Figure 2).

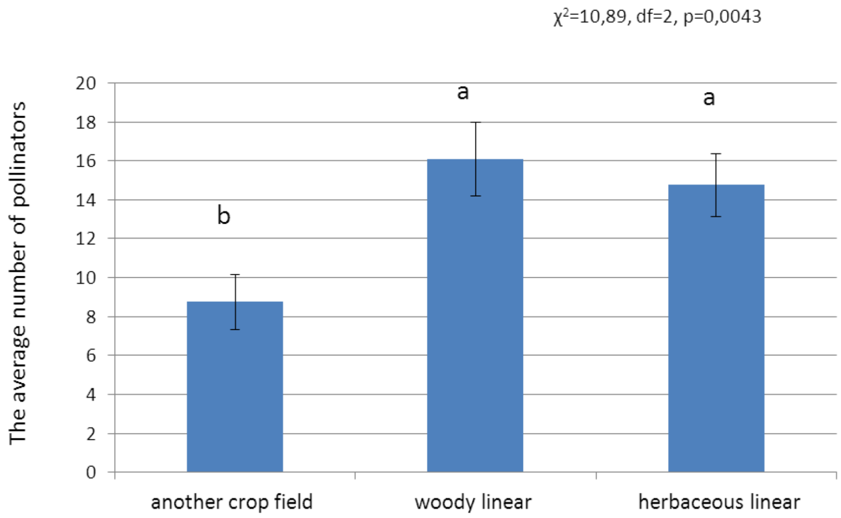

Figure 2. The average abundance of pollinators per yellow water trap on the oilseed rape fields bordered by different elements in Estonia, 2014.

The number of caught bumble bees were affected by the proportion of semi-natural habitats within 1 km radius ($\chi2= 7.30$, df=2, p=0.026) – there were significantly more bumble bees in the LS sectors with high and intermediate proportions compared to the low.

The average number of pollen grains found on the stigmas of oilseed rape flowers was 357(± 36.18 StErr) (HL=409 (± 70.43); WL=273(± 72.96); No SNH=389(± 61.83)), which generally shows that flowers were well pollinated, because for full pollination they need approximately 120 pollen grains. However, the pollen load in the stigmas varied between focal fields significantly ($\chi2=43.97$; df=17, $p<0.001$). Also, pollen delivery was significantly greater in the oilseed rape fields which were adjacent to herbaceous linear element and nonflowering crop compared to the woody linear element ($\chi2=15.23$; df=2, $p<0.001$). We did not find correlation between the number of pollen grain on the stigmas and the abundance of pollinators in the field (RS=0.06; p=0.62).

The average mass of seed per pod was 116 mg in open pollinated flowers and 129 mg in hand pollinated flowers. Therefore, the average yield deficit was 13 mg i.e. approximately 10% of the maximum (Figure 3).

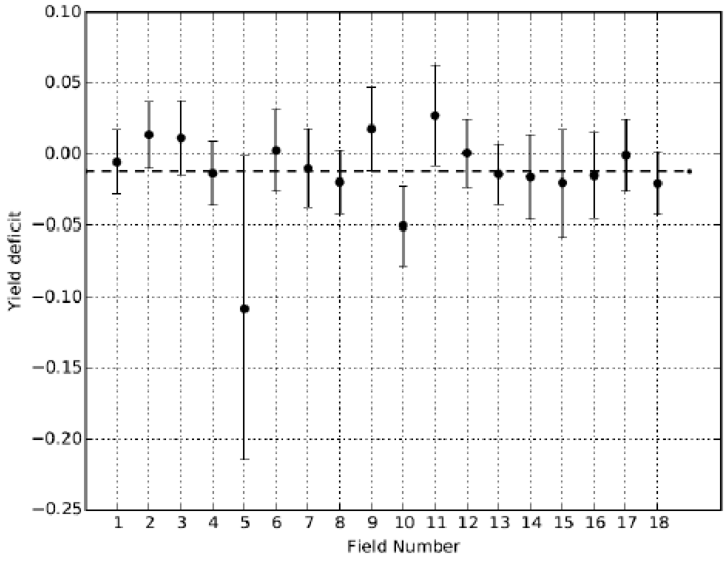

Figure 3. The average yield deficit in 18 focal fields in Estonia 2014 (figure by James Cresswell)

According to the kernel analyses conducted by James Cresswell and David Wallis, the yield deficit was influenced by herbaceous areal (decreased the deficit) and woody linear (increased the deficit) SNH-s.

2.2.7.4 Conclusion

According to collected data, wild bees and especially solitary bees can be more important pollinators in oilseed rape than it was expected before. The vast majority of pollinators caught by yellow water traps in the oilseed rape fields, belonged to the diverse group of solitary bees. Adjacent SHN-s increased the abundance of pollinators. Both, herbaceous semi-natural habitats and woody linear habitats had positive effects on the pollinator abundance. However, the yield deficit of oilseed rape plants was positively influenced by herbaceous areal habitats (deficit was smaller) and negatively influenced by woody linear habitats (deficit was greater). Therefore, farmers should provide perennial herbaceous elements with diverse vegetation, architecture and different flowering times in their farmlands to ensure the presence of nesting and overwintering sites for wild pollinators.

2.3 Synthesis pollination

The pollination of the studied focal crops showed diverging responses across the case studies. Benefits of insect pollination was increased by landscape wide available SNH measured in a 1-kilometre radius sector in the Swiss oilseed rape and German pumpkin fields. In the same case studies, bordering woody and herbaceous linear elements positively influenced the abundance of pollinators and the pollination of the crops. In two further studies investigating pollination of oilseed rape in the United Kingdom and Estonia, the abundance of pollinators was increased as well by local bordering SNH; however, this increase was not translated in an increase of the number of seed per fruit or yield. For the pollination of sunflower studied in two case studies in Italy and Hungary, neither the SNH in the surrounding landscape, nor the bordering SNH had positive effects on crop pollination. On the contrary, a small negative effect of abundantly flowering SNH in the surrounding of the fields was detected on the abundance of pollinators in the Italian case study suggesting competition between habitats for pollinators. In pear orchards in the Netherlands, pollination was proved to be largely produced by insects, although neither pollinators nor pollination were influenced by bordering SNH or SNH in the surrounding landscape. In general, pollination by insects but especially the abundance of pollinators in crop fields of mass flowering crops showed a tendency to increase with SNH either as a crop field bordering element or as an increased proportion in the surrounding landscape. This partial increase, however, did not necessarily lead into measurable effects on the produced seeds, fruits, or agronomic crop yield in all case studies.

2.4 Results from pest control case studies

2.4.1 Italy

Author: Picchi Malayka Samantha_ Scuola Superiore Sant'Anna

2.4.1.1 Introduction

Olive (Olea europaea L.) is a very important tree crop, long cultivated within the Mediterranean basin for olive oil production and in Italy, the production is mainly made up of extra-virgin oil and it is concentrated in southern regions (European Commission, 2012). In hilly areas, such as Monte Pisano area, the olive trees are grown on terraces, usually with reduced levels of chemical inputs (Duarte et al., 2008).

In the Mediterranean basin, the olive fruit fly Bactrocera oleae (Rossi) (Diptera: Tephritidae) is the key pest of olives (Boccaccio and Petacchi, 2009; Castrignanò et al., 2012) and monophagous of Olea tree species. The life cycle of the olive fruit fly is synchronized with seasonal growth of olives with 2 to 6 *annua*l generations depending on temperature (Marchi et al., 2016; Petacchi et al., 2015). In summer, the olive fly lays eggs under the surface of ripening drupes and the development of the hatched larva cause pulp consumption and premature fall of olives, lowering the yield and oil quality(Pereira et al., 2004) with severe economic consequences for producers. In olive orchards, dimethoate applications on canopies can kill larvae inside drupes, reducing the damage and the loss of oil quality. However, dimethoate has negative consequences for humans (Hohenadel et al., 2011) and for many animals (Reuber, 1984). For these reasons, there is a high request for alternative and sustainable control techniques and research directed to less problematic insecticide or to increase the conservation of the biological control mediated by natural enemies.

To date, the role of surrounding semi-natural habitats (SNH) in supporting natural enemies to crop fields was largely neglected in olive groves as scarce are studies on the role of in-field vegetation. SNH can be an important source of natural enemies or provide alternative refugees and alternative resources to beneficials. By providing these resources, non-crop habitats can support spillover of natural enemy populations to fields and help enhance their impact on pest population (Wilkinson and Landis, 2005).

The project has been defined in order to deepen the effect of SNH on natural enemies of olive fruit fly. In particular it has been explored the role of canopy spiders against the adult fly (spider case study, 2014) and the role of ground –dwelling predators ground the overwintering pupa (pupa case study, 2014 and 2015).

2.4.1.2 Methods

Figure.1 and fig.2 indicate the schematic drawing of the sampling protocol for spider case study and pupae case study (sampling protocols were adapted to specific olive case studies). Fig.3 shows the environmental variables taken into account.

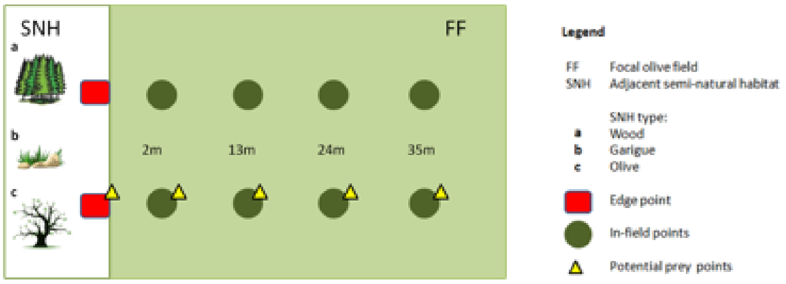

Figure 1. Sampling design of the spider case study. Spider were collected at the edge (red square) and in the olive (green round) by hand and with a beating tray.
Potential prey were sampled using sticky traps tied to one south oriented branch.

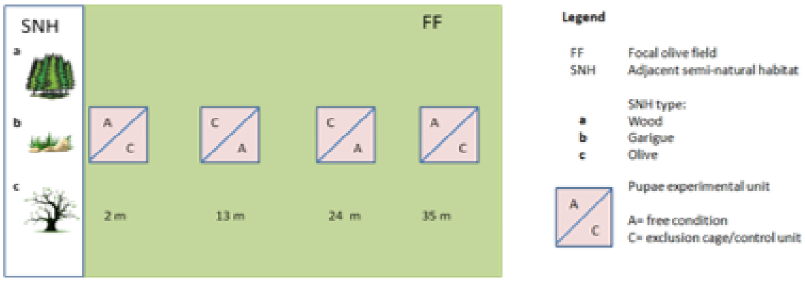

Figure 2 Sampling design of the pupae case study of 2014 and 2015. Ten pupae each treatment were left for two weeks on the ground to estimate the predatory rate (A) and the natural mortality (C).

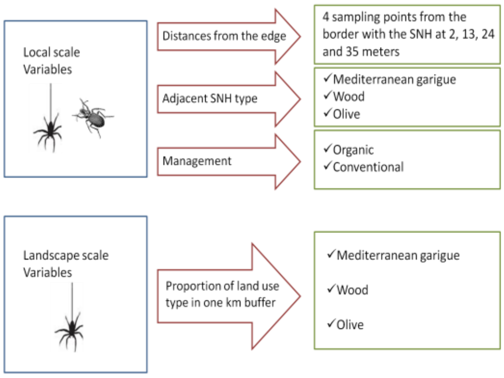

Figure 3. Schematic framework of the environmental variables considered in the PhD project. Spider case study considered both local and landscape scale variables and moreover it has been sample the edge with an additional point (data analysis and paper in preparation) while pupae case study considered only local scale variables. The 18 focal fields were chosen in order to built a crossed experimental design in order to reach n=3 fields for each SNH type and orchard management combination.

2.4.1.3 Results and Conclusion

Effect of farm management, especially pesticide application intensity

Case studies focused on conservation biological control in olive groves and on how the presence of different types of SNH at different scale may affect the pest control mediated by predators, considering inhabitant spiders of the canopies and ground dwelling predators of the soil.

The central result from both experiments showed the detrimental effect of dimethoate applications that influenced negatively in-field natural enemy guilds considered (Fig. 1) and hence they could reduce their potential effect on the density of different stages of the life cycle of the olive fruit fly: the spider case study showed that in summer, while the olive fruit fly is searching for olives to oviposit eggs and develops entirely inside drupes, the spider communities in canopies in conventional fields had reduced abundance and richness. Similar result was found for pupae case study: the conventional management of the olive orchards impacted negatively on the predation rate of pupae exposed in 2014 and 2015 experiments (Fig. 2a and 2b)

Reducing pesticide applications may contribute to the increase of the natural pest control service in olive.

In addition, a secondary effect has been detected of both adjacent SNH on pupae predation rates and of landscape composition on predatory spider guilds.

Effect of SNH

Among the SNH types the Mediterranean garigue seems to play the most important effect at local and at landscape scale. This is a dry and warm habitat (Polunin and Walters, 1985; Polunin and Walters, 1985), typical of the Mediterranean landscape that consist of a mix of silviculture (Quercus sp., Pinus sp. and Castanea sp.) and a mosaic pattern of closed and open habitats (Taboada et al., 2006; Verdú et al., 2000). In this project, the garigue had a differential effect on beneficial arthropods. Spiders in olive were reduced by the amount of Mediterranean garigue in the landscape (1 km sector buffer; Fig.3), while garigue, as adjacent SNH type to olive, seems to increase the predatory pressure mediated by ground dwelling predators, in 2014 (Fig.4).

Results from both field experiments suggested a key role of this habitat. The potential opposite and controversial role of the garigue on spiders and on ground predators should be taken into account in conservation biological control techniques and needs to be examined in depth.

These results suggested that there is a potential for integrated pest control programs in modern olive tree growing that can be based on a range of management options aimed at limiting olive fruit fly abundances, rather than depending on a single protection method. Such alternative strategies should take into account the seasonality of natural enemies and the composition of the surrounding landscape.

Interestingly, the spider case study suggested that the activity density of the olive fruit fly was negatively correlated to the abundance of various groups of spiders within olive groves. As spiders are the most relevant group of predators in olive (Cárdenas et al., 2015; Morris et al., 1999), they may be effective against the olive fruit fly and other secondary pests. It has been observed that when the pest density is low, sheet web spider family (Linyphiidae) was the guild that influenced the pest activity while at the peak of infestation, the assemblage of cursorial spiders reduced the wandering of olive fruit fly in the cover of olive trees. The effect of spiders is due to their predatory attitude and to their repellent effect on the pest and the negative relation between predators and prey depended on the specific timing of the pest infestation.

The knowledge of ecological dynamics of food chain in olive and in its surrounding will help farmers to reach a greater sustainability of the olive cultivation, inspiring new reasoning and thoughts and more sustainable approaches to olive management, consistent with the main current direction of European agricultural policy in increasing the sustainability of pesticides use (EU Directive 2009/128/EC). Increasing the efficacy of natural enemies should start from the study of the functioning of biological control in agroecosystems and it could be reached thought the identification of the key aspect of diversity to promote new sustainable strategies such as habitat manipulation (Eilenberg et al., 2001; Paredes et al., 2014).

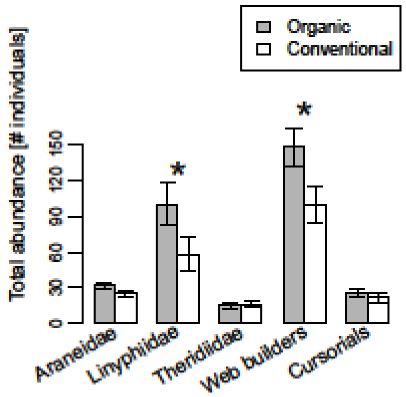

Fig 1 Effect of management on the number of individuals of the three main spider families of spiders and on the two functional guilds (web-building and cursorial spiders); the difference among organic and conventional type of management is significant for the Linyphiidae family ($F_{1,15} = 4.72$, p value = 0.045; bars represent mean value of individuals with standard error) and for web builders ($F_{1,53} = 6.05$, p value = 0.026; bars represent mean value of individuals with standard error).

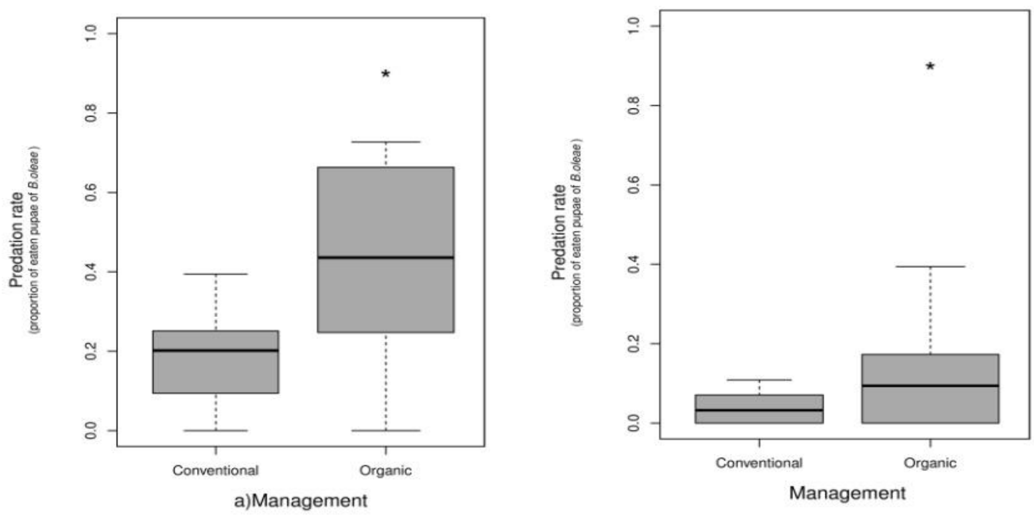

Figure 2: a) Boxplot of the predation rate of olive fruit fly pupae in 2014. a) Proportion of eaten exposed pupae as influenced by the management;
b) Predation rate of olive fruit fly pupae in 2015 as influenced by the management of olive fields. The boxplot depicts the inter-quartile range (IQR) between first and third quartiles; the line inside is the median. Significance ($p<0.05$) is represented by asterisk.

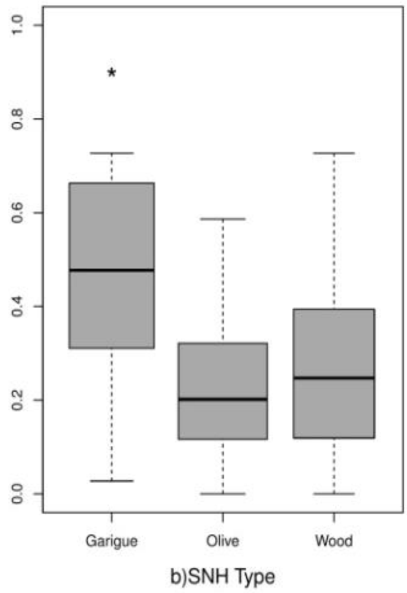

Fig. 3. Proportion of eaten exposed pupae as influenced by the adjacent SNH type of olive fields. Mediterranean garigue predatory rate differs significantly from woods and olive field. The box plot depicts the inter-quartile range (IQR) between first and third quartiles; the line inside is the median. Significance ($p<0.05$) is represented by asterisk.

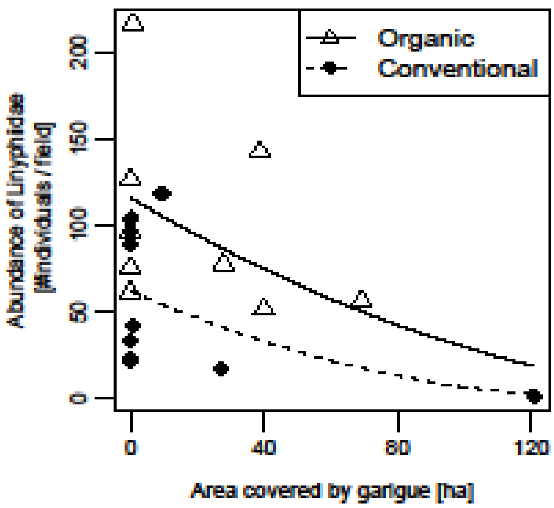

Fig 4. Effects of management ($F_{1,15} = 8.112$, p value = 0.012) and the percentage area of Mediterranean garigue ($F_{1,15} = 6.407$, p value = 0.023) in the surrounding landscape on Linyphiidae in olive groves.

Detailed information on spider case study in "Effects of local and landscape factors on spiders and olive fruit flies" Picchi M.S., Bocci G., Petacchi R., Entling M.H. 2016 Agriculture, Ecosystem and Environment,222, p.138-147

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2.4.2 Hungary

2.4.2.1 Introduction

Cereal leaf beetle group (*Oulema melanopus* and *O. lichenis* CLB) was selected as the focus pest of our study. It can be expected that numerous natural enemies can deliver ecosystem service by predating and parasitizing eggs and larvae of CLB in our case study region. This pest can cause feeding damage on the leaves of cereal crops (e.g. winter wheat) that consequently leads to yield and quality loss. Farmers often use chemical insecticides to control CLB in Hungary, although this damage is highly variable among fields and years. Clarifying the efficacy of biological control of CLB as an ecosystem service can result in reduced pesticide use in Hungarian wheat based cropping systems.

2.4.2.2 Materials and methods

In 2014 and 2015, 18 + 18 winter wheat field were assessed with variable amount of SNHs within their 1km neighbourhood (Fig. 1). In both years, six fields had woody adjacent habitat, six fields had herbaceous adjacent habitat, while six fields had no adjacent SNH.

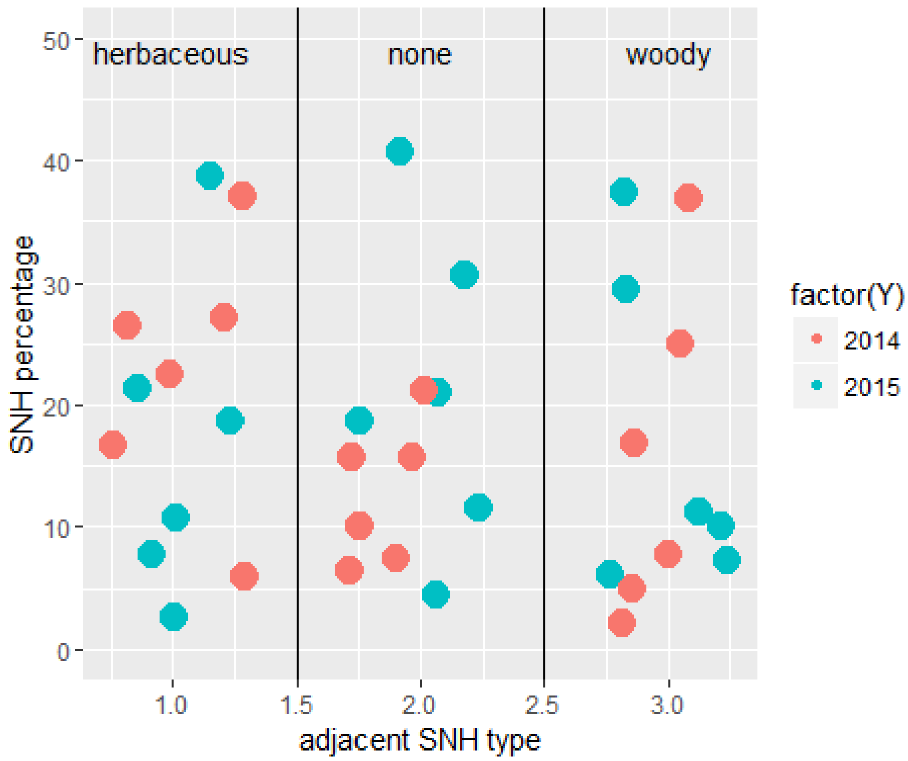

Fig. 1. Proportion of semi natural habitats within 1km neighbourhood of the investigated wheat fields, Jászság, Hungary, 2014-2015

2.4.2.3 Results crop specific pests

The investigated ecosystem service, the biological pest control of CLB, was estimated and "measured" as the larval damage on flag leaves on open plants compared to the isolated plants, i.e. damage on plants where the pests were exposed to their natural enemies vs. damage on plants where these natural enemies were excluded.

The observed flag leaf damage was lower on open plants than on the isolated plants in each wheat field (Fig. 2). That means we could identify pest control ecosystem service in all of the 36 studied fields (Fig. 3).

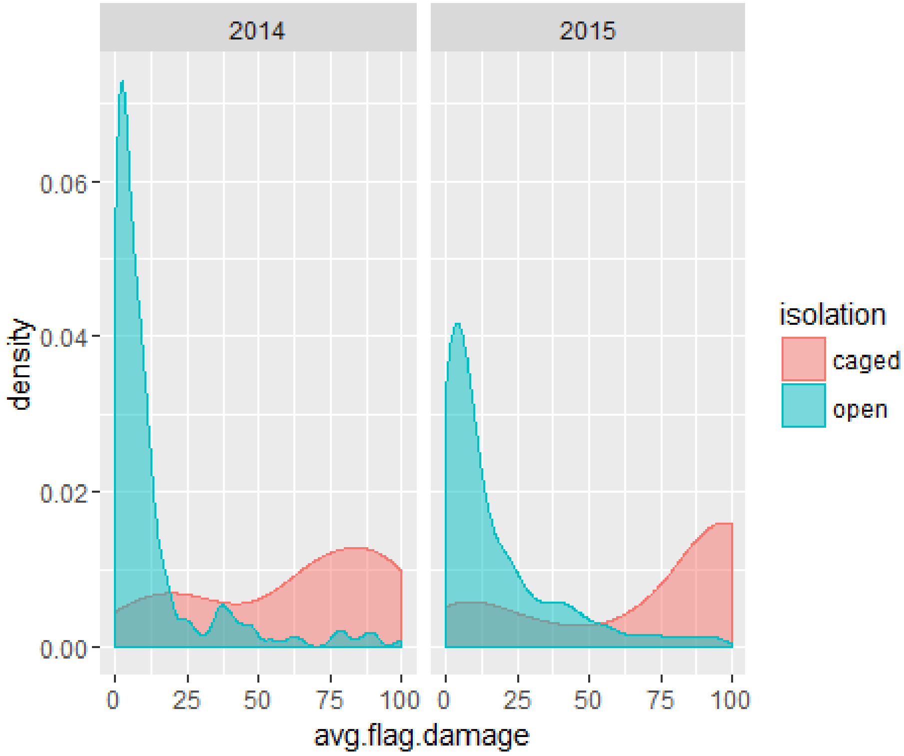

Fig 2. Distribution of average flag leaf damage caused by cereal leaf beetle on isolated and open wheat plants in the studied fields, Jászság, Hungary, 2014-2015

The saved leaf surface, the identified ecosystem service, varied between 1.2% and 91.7% (Fig. 3). However, either the type of the adjacent habitat or the proportion of the SNHs within 1 km had not affected the measured ecosystem service (p= 0.17, p=0.48, respectively, Fig. 3).

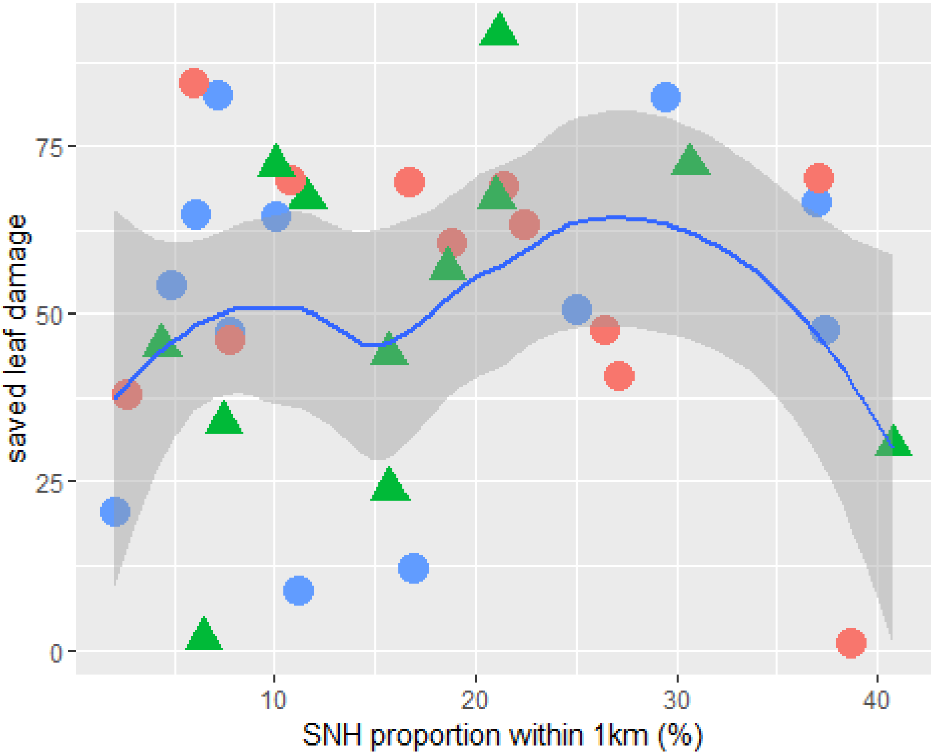

Fig. 3. Effect of proportion of semi natural habitats within 1 km on saved CLB leaf damage as the measure of biological pest control ecosystem service. Wheat fields with adjacent herbaceous SNH (red circle), woody SNH (blue circle) or without adjacent SNH in Jászság, Hungary, 2014-2015.

II. Sentinel systems

Sentinels were also used to measure predation pressure as a proxy for the biological pest control ecosystem potential. *Ephestia* eggs were placed on the wheat plans and soil surface; moreover *Calliphora* larvae were placed on the soil surface in the same winter fields as the CLB study with the same spatial arrangement.

2.4.2.4 Results sentinels

The predators consumed the different sentinels at different rate: the *Ephestia* eggs on the ground had the highest consumption level, and placed on the plants had the lowest level (Fig. 4). However, there was no effect of the adjacent habitat on the consumption of *Ephestia* eggs on plants, on the ground and *Calliphora* larvae (p=0.67, p=0.22, and p=0.91, respectively). Moreover, the proportion of SNHs did not affect the consumption of either sentinel (p=0.45, p=0.64 and p=0.55, respectively, Fig. 4).

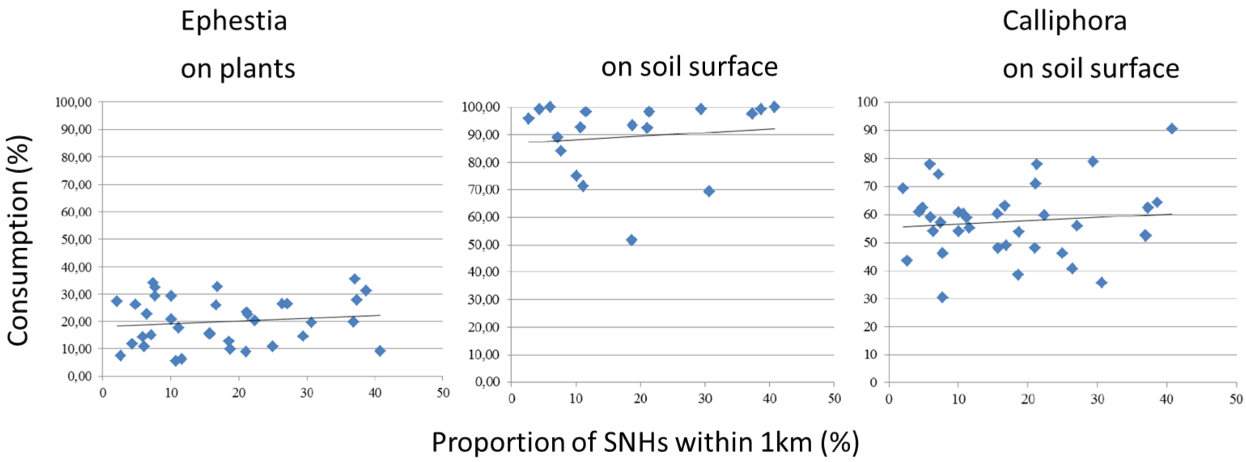

Fig. 4. Effect of proportion of SNHs within 1 km on the consumption of sentinels placed in wheat fields, Jászság, Hungary, 2014-2015

2.4.3 Germany

2.4.3.1 Introduction

Pumpkin is highly suitable to apply conservation pest control of aphids. First, pumpkin has a long residence time on the field for a vegetable culture, thus there is sufficient time to build up natural enemy populations. Second, there is a potential to reduce insecticide applications that are used by some, but not all farmers to control aphids and viruses transmitted by them. Third, the marketable pumpkin fruit is not infected with aphids or beneficials, thus the use of natural enemies for aphid suppression in pumpkin does not result in problems with consumer acceptance.

2.4.3.2 Methods

- Sentinel experiments in 18 fields per year (2014 & 2015: two rounds in June and July each)
- Aphid and beneficial activity in 18 fields per year (2014: 6 sampling rounds, 2015: 3 sampling rounds)
- Aphid pest control experiments in 18 fields with fixed infestation levels (two rounds in 2014, one round in 2015)
- Aphid-yield experiments (2014 & 2015)

2.4.3.3 Results

Sentinels

Table 1 Overview over effects of proportion of semi-natural habitats in 1 km radius (snh_1km), adjacent habitat type (SNH), distance to the field edge [m] and sampling time (June or July) on the sentinels: *Poa* seeds, *Calliphora* larvae on the ground, *Ephestia* eggs on the ground and on the plant.

sentinel	year	snh_1km		SNH		distance		sampling	
		t_{17}	p	$F_{2,15}$	p	t_{53}	p	$\chi^2_{1,17}$	p
Poa seeds	2014	0.25	0.80	0.31	0.74	-1.00	0.32	**17.5**	**<0.001**
Calliphora	2014	-0.79	0.44	0.46	0.64	0.73	0.47	1.8	0.18
	2015	t_{16}=-0.06	0.96	0.54	0.59	-0.06	0.96	-0.61	0.44
Ephestia ground	2014	0.11	0.91	0.46	0.64	**2.74**	**0.008**	**17.9**	**<0.001**
	2015	t_{16} = -0.01	0.99	0.43	0.66	**-3.3**	**0.002**	0.21	0.65
Ephestia plant	2014	-0.40	0.70	0.21	0.81	-1.00	0.33	**219.2**	**<0.001**
	2015	**t_{16} = 2.3**	**0.03**	0.65	0.54	0.16	0.88	**5.2**	**0.02**

The proportion of seminatural habitats in 1km radius increased predation on *Ephestia* eggs on the plant in 2015, but had no effect in 2014 nor on any other sentinel (Fig. 1). The adjacent habitat type had no effect on any sentinel. Distance to the field edge had contrasting effects on *Ephestia* eggs on the ground in 2014 and 2015. In 2014 predation on *Ephestia* eggs on the ground increased from field edge towards field centre, whereas in 2015 the predation decreased with increasing distance from the edge. Predation was often significantly higher in July compared to June, especially in 2014 (Table 1). Predation on seeds was only measured in 2014, because the predation was very low: Only one (of 5758) *Chenopodium album* seed was removed and only 2% (117 of 5626) of the exposed *Poa trivialis* seeds.

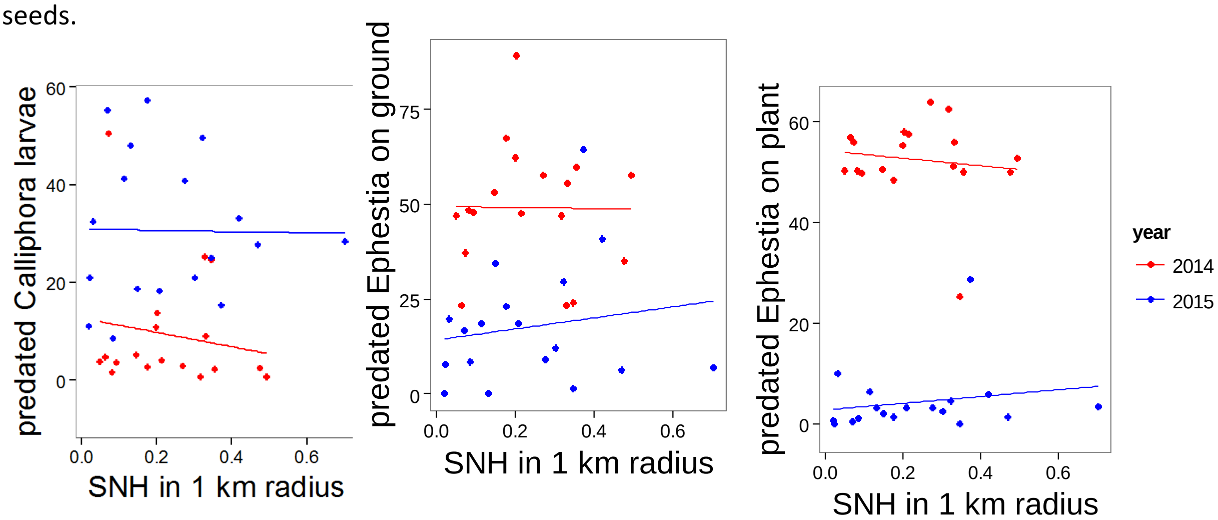

Fig. 1 A) Predation on *Calliphora* larvae was not related to proportion of semi-natural habitats in 1 km radius (2014: t17 = -0.79, p = 0.44; 2015: t16 = -0.06, p = 0.96), B) nor was predation on *Ephestia* eggs on the ground (2014: t17 = 0.11, p = 0.91; 2015: t16 = -0.01, p = 0.99), C) predation on *Ephestia* eggs on the plant increased with higher proportion of semi-natural habitats in 1 km radius in 2015 (t16 = 2.3, p = 0.03), but not in 2014 (t17 = -0.40, p = 0.70).

Crop specific pest

Effects of aphid density on yield

In 2014 and 2015 we found no effects of aphid densities on yield in our aphid-yield experiments (2014: $t_{37} = 0.7$, $p = 0.48$; 2015: $t_{38} = 0.7$, $p = 0.49$), where we created maximum densities of up to 6500 aphids per pumpkin plant ≈ 374 aphids per leaf. In 2014 and 2015 natural aphid densities [on average per field] exceeded this value only in one field (out of 36) at peak infestation, on average we found 114 ± 154 aphids per leaf at peak infestation (range 10 – 841). Virus infestation did not show a significant relationship with aphid infestation, but an unexpected trend in negative direction ($z_{16} = -1.8$, $p = 0.068$).

Effects of farming and SNH

In 2014 all aphidophaga (parasitic wasps, spiders, gall midges, lady beetles and syrphid flies), except for lacewings, were positively related to the abundance of aphids. Compared to field-field situations, fields bordering herbaceous margins tended to have higher densities of spiders ($t_{11} = 1.9$, $p = 0.076$) and had significantly higher densities of aphid gall midges (Aphidoletes) ($t_{11} = 3.0$, $p = 0.009$). Flower abundance in field margins enhanced in-field densities of lady beetles, lacewings and parasitic wasps (Fig. 1). Aphid growth rates in June were higher in organic than in conventional fields, leading to significantly higher aphid abundances by the end of July. Therefore, lady beetles ($t_{16} = 1.9$, $p = 0.076$) and lacewings (KW 30: $t_{16} = 2.6$, $p = 0.021$) tended to be favoured by organic management as well. None of the aphidophaga showed significant responses to the cover of seminatural habitats in the surrounding landscape.

In the controlled experiments aphid abundance after two weeks was not influenced by proportion of SNH in 1 km radius, by adjacent SNH or by the distance to the field edge in June 2014 and 2015. In July 2014 we found that aphid growth rates were significantly lower in fields with higher proportion of SNH in 1 km radius, but also on plants from which pest control agents had been excluded. This indicates that climatic or soil factors affected aphids more strongly than natural enemies.

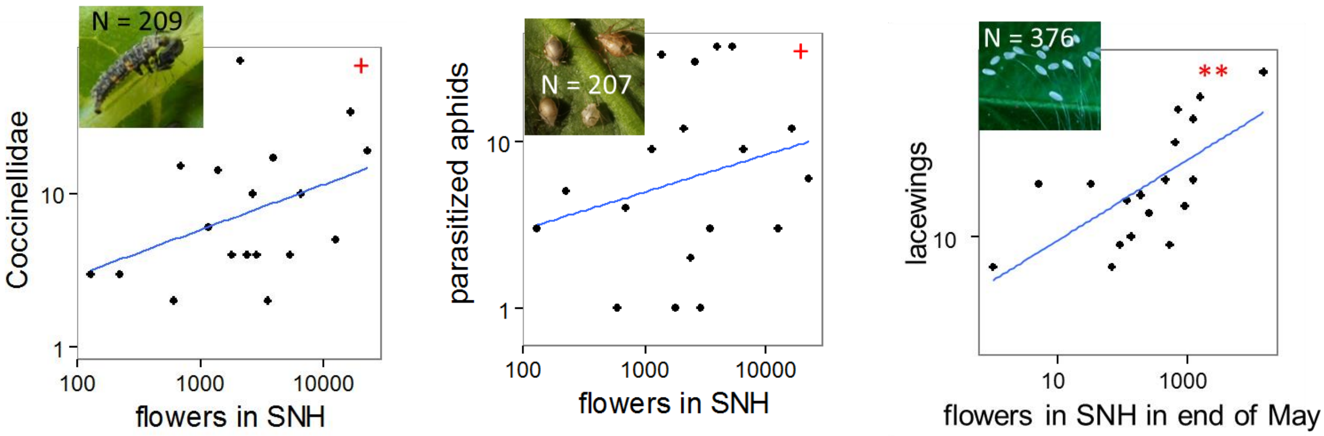

Fig. 1. Flower abundance in field margins enhanced in-field densities of lady beetles (Coccinellidae: $t_{16} = 1.8$, $p = 0.095$), parasitic wasps ($t_{16} = 1.8$, $p = 0.087$) and lacewings ($t_{16} = 3.6$, $p = 0.0026$).

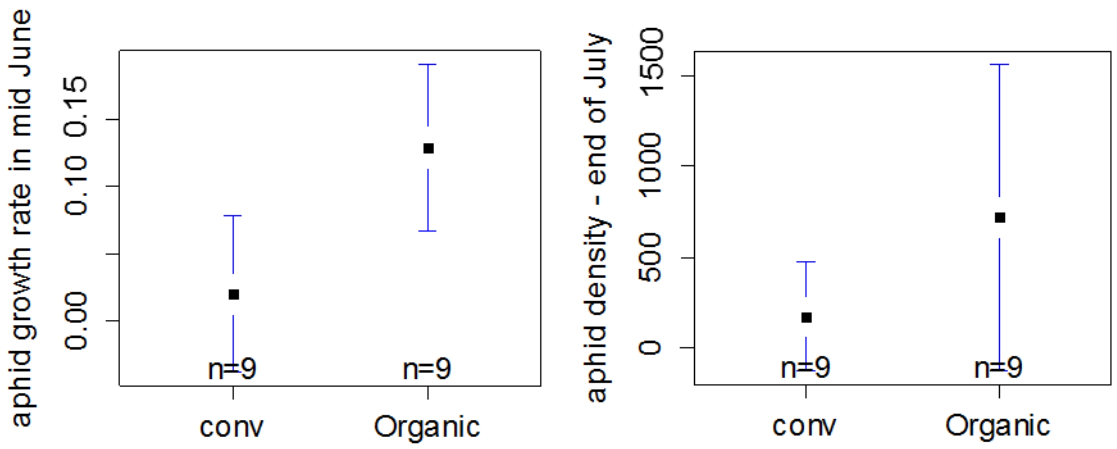

Fig. 2. Aphid growth rates in June were higher in organic than in conventional fields (KW 25: t16 = 2.9, p = 0.0099; KW 26: t15 = 2.6, p = 0.021), leading to significantly higher aphid abundances by the end of July (t16 = 2.2, p = 0.044).

2.4.3.4 Conclusion

The economic threshold for pumpkin is relatively high with above 350 aphids per leaf at peak infestation and these levels rarely occured in our study region. In addition, virus infestation did not increase with aphid infestation. Thus insecticide application is rarely necessary and conservation pest control could be applied. Further, we conclude that an interplay of field margin and management type influence aphid-enemy interactions in pumpkin fields, with surprisingly little influence of seminatural habitats in the wider landscape context. Field margins with abundant flower resources can push the abundance of lady beetles, lacewings and parasitic wasps in the field, important pest control agents of aphids.

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Pfister, Sonja C.; Schirmel, J.; Entling, M. H. (1.9.2016). Aphids and Aphidophaga in pumpkin fields react differently to management, local and landscape features. Presentation at the international Symposia “Ecology of Aphidophaga 13”.

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2.4.4 Switzerland

Authors: Louis Sutter, Matthias Albrecht, Philippe Jeanneret

2.4.4.1 Introduction

The explicit and implicit aims of creating ecological focus areas (EFAs) and implementing greening measures in European agro-ecosystems include the promotion of regulatory ecosystem services (ES) to sustain crop production in conventional cropping systems (European Union 2014; Ekroos et al. 2014). However, it remains poorly explored to what extent these goals are achieved with current policy measures. Here, we address the question of influences of SNH on ecosystem services questions focusing on natural control of pests in winter oilseed rape Brassica napus L. (hereafter OSR), which is amongst the most important food, fodder and biofuel crops worldwide. Many pest species impose usage of phytosanitary products in OSR that could potentially be replaced by natural pest control to mitigate yield loss (Alford 2003). Thus, there is high potential for ecosystem management measures to promote natural pest control services in conventional OSR production. To investigate the effect of adjacent EFAs and landscape-scale greening measures natural pest control in OSR and its influence on crop yield, we tested the four following interrelated hypotheses:

1. The local establishment of two commonly implemented types of EFAs (sown wildflower strips and hedgerows) enhances natural pest control service delivery in adjacent OSR crops.
2. The effectiveness of these adjacent EFAs in promoting natural pest control is reinforced by increasing the share of greening measures implemented at the landscape scale.
3. Natural pest control can increase final crop yield beyond agricultural management practices in conventional OSR production.

2.4.4.2 Results

Adjacent EFAs and landscape-scale greening measures driving ES providers and ES

Predatory ground beetle abundance increased from 61 to 100 individuals along the gradient in landscape-scale greening measures but did not significantly differ among adjacent EFA types or control habitats (Fig. 1c). However, pollen beetle predation increased significantly with landscape-scale greening measures from 10% at 6% to 23% at 26% landscape-scale greening measures (Fig. 1d), but no significant effect of the adjacent EFA could be detected either. Parasitism of pollen beetle larvae (8% on average) was independent from adjacent EFA and did not change with increasing landscape-scale greening measures (Fig. 1d; Table 1).

Effects of ES on OSR yield

Pollen beetle predation significantly contributed to crop yield after accounting for crop management with a predicted increase in OSR yield by 0.4 t/ha (9%) when predation increased from 0 to 50% (Fig. 2). Insect pollination and parasitism did not significantly contribute to OSR yield after accounting for management intensity, and there were no significant interactive effects among the measured ES on OSR yield (Fig. 2). Furthermore, neither adjacent EFA nor landscape-scale greening measures or their interaction had significant direct effects on OSR yield.

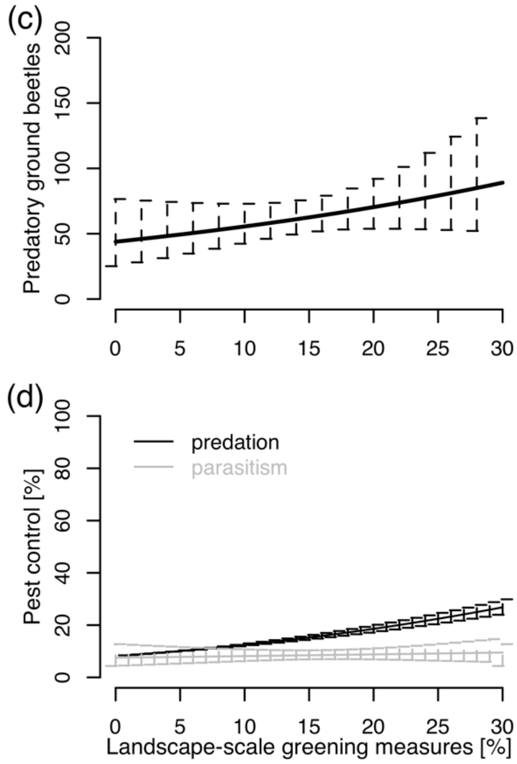

Figure 1 Effects of landscape-scale greening measures and adjacent EFA (wildflower strip (red), hedgerow (green), and no EFA (black)) on (c) number of predatory ground beetles, (d) predation on pollen beetle (black) and pollen beetle parasitism (grey). Predicted values 95% confidence interval for the investigated gradient (6–26%) of landscape-scale greening measures (n = 18 fields). Where no differences between adjacent habitat types occurred, only the average values for all three habitat types is shown.

2.4.4.3 Conclusion

Agriculture has to meet the growing demand for food while minimizing negative impacts on biodiversity and ecosystem functioning. It is hoped that the implementation of greening measures helps to achieve this goal by promoting farmland biodiversity and ES that sustain high and stable crop yields. Our results suggest, however, that beneficial effects of greening measures on the regulatory ES pest control in conventional OSR production become relevant only at increases in proportions of greening measures–much higher than the currently required 5% greening measures in the EU. However, the agricultural landscapes studied here did not comprise highly simplified and cleared landscapes largely lacking any greening elements or other semi-natural habitats. Regulatory ES may be restored and considerably enhanced already at lower increases in greening measures implemented in such landscapes. Furthermore, it is important to note that we investigated effects of greening measures in intensive, conventional OSR production systems. Through reduced negative effects of pesticides in organic crop production, the effect of multiple ES for crop yield are expected to be more robust compared to conventional production systems that still mainly rely on anthropogenic inputs. However, organic agriculture usually needs more land to produce the same quantity of food compared with conventional production. Whereas the conventional production system studied here represents the prevailing form of agriculture in Europe, highlighting the importance of evaluating the consequences of EFAs and greening measures for the provisions of regulatory ecosystem services in these systems. Although final crop yield was mainly driven by management practices rather than greening measures, our study shows that both the local creation of EFAs, such as species-rich, perennial wildflower strips and hedgerows, nearby OSR crops and a considerable landscape-scale augmentation of greening measures can promote multiple regulatory ES to sustain crop yield even in conventional production systems. Our findings of beneficial effects of local and landscape-scale implementation of EFAs and other greening measures on important regulating ES may help to encourage farmers to implement them. Further research is needed to investigate how EFAs and other greening measures can be improved to make them more effective in achieving their multiple goals. Future studies should especially consider trade-offs and synergies at large scale between ES provision, food production and biodiversity conservation needs.

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2.4.5 Netherlands

Quessa pear case study, pest control
Author: Herman Helsen

2.4.5.1 Introduction

Crop: pear cv Conference
The main pear cultivar in NL is Conference (>75% of the area). It is a high input crop, with numerous pesticide applications. Insecticides are applied yearly against several insect pests. In QUESSA we considered two crop specific pests.

Pear psylla (mainly *Cacopsylla pyri*) is the main arthropod pest in Dutch pear orchards. This phloem feeder has multiple generations per year, a large reproductive capacity, and it readily develops resistance to pesticides. Damage is mainly done by the larvae that feed on buds, shoots, flowers and young fruits. Pear psylla usually requires more than one insecticide application per year.

Several leafroller species (Tortricidae) may reach pest status in pear orchards because they damage the fruits by feeding on the fruit skin. The summer fruit tortrix *Adoxophyes orana* is one of the common species in Dutch orchards. It has 2-3 generations per year. Control of leafrollers takes place by insecticide sprays or pheromone mating disruption techniques.

Integrated control strategies aim at keeping the psylla and tortrix populations at an acceptable low level throughout the year. Many factors may regulate the pests to some extent. In the case of pear psylla, sufficient control is achieved only with the presence of a range of natural enemies, combined with cultural control measures and an intelligent use of selective pesticides. For summer fruit tortrix, it has been shown that natural enemies may play an important role in keeping populations at a low level.

2.4.5.2 Material and methods

All observations were done in 18 pear orchards (main cultivar: Conference) in the Netherlands. The orchards were under conventional/IPM crop protection management. In 2014 and 2015 sentinels were placed in all orchards, following the general QUESSA protocol.

Table 1. Sentinels used and dates on which exposed in focal field pear orchards.

			exposure dates (start, with duration of 24 hrs)			
	stage	position	2014-1	2014-2	2015-1	2015-2
Ephestia	eggs	ground	15 May	1 July	20 May	2 July
Ephestia	eggs	tree	15 May	1 July	20 May	2 July
Calliphora	larvae	ground	15 May	1 July		
Poa annua	seeds	ground	15 May	1 July		
Chenopodium album	seeds	ground	15 May	1 July		
Psylla pyri	eggs	tree		1 July*		
Adoxophyes orana	eggs	tree			24-aug	

**) Psylla sentinels could not be evaluated because of strong decay during 24 hrs exposure.*

Table 2. Observations on populations of pest (Psylla pyri) and predators (common earwig, F. auricularia) in focal field pear orchards.

			observation dates			
	stage sampled	position	2014-1	2014-2	2015-1	2015-2
Psylla pyri	larvae	leaves	20 Oct*	21 Oct**	2 July	12 Oct
Forficula auricularia	adults	tree	15 July		20 July	24-sep

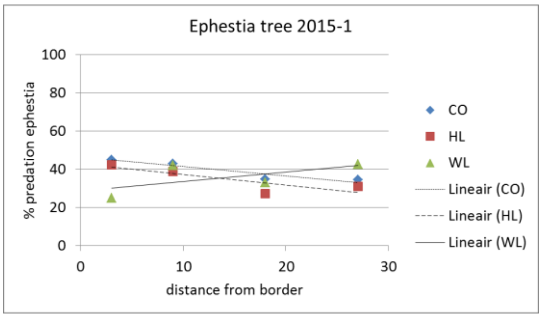
**) visual assessment; **) extraction of larvae by Berlese technique.*

Six focal fields bordered a woody linear (WL) semi-natural habitat (SNH), six bordered an herbaceous linear (HL) SNH and another six bordered no SNH and a crop instead (CO). Generally, sentinels were placed in 2 transects per focal field. Transects started at the border of the field, and measurement points were at 3, 9, 18 and 27 meters from the border.

2.4.5.3 Results

1. *Does the SNH bordering the focal field affect the predation of sentinels or the natural densities of earwigs or the (crop specific) pear psylla?*

- *Calliphora* larvae and seeds of *P. annua* and *C. album* were hardly preyed upon in pear orchards. Less than 20% of the *Calliphora* larvae had signs of predation after a 24 hr exposure period. For the seeds, predation levels were even lower. There was no effect of the bordering SNH on the predation. Because of the low level of predation, the 2014 sentinel experiments for these species were not repeated in 2015.
- Predation on eggs of *Ephestia* exposed on the orchard floor strongly varied between orchards and was high in most cases. There was no effect of the bordering SNH on the predation.
- Predation on eggs of *Ephestia* on the trees was between 0 and 100% when exposed in May (2014 and 2015), but the average predation was much higher in July in both years, indicating an increase of predator density in the orchard during summer. There was no effect of the bordering SNH on the predation (example fig 2015-1 and 2015-2).



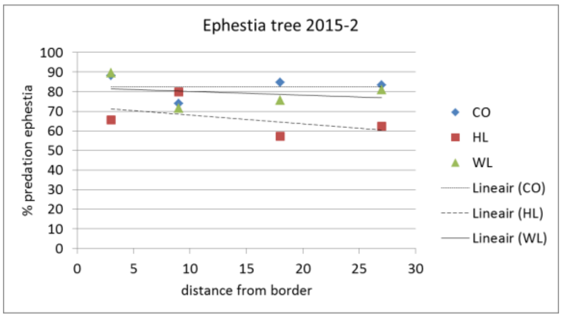


Figure 1. Average % predation of *Ephestia* eggs at four distances from bordering WL SNH, HL SNH and no SNH 2015-1 and 2015-2.

- Predation of A. orana eggs on the trees was between 65 and 96% on average per orchard after a 24 hr exposure period. There was no effect of the bordering SNH on the predation
- Earwig density strongly varied between orchards, with several orchards that had no earwigs at all. In case earwigs were present, there was no effect of the bordering SNH on the density.
- The density of pear psylla in October 2014 is shown in table 3. There was no significant effect of the (distance to the) SNH, but this might be due to the absence of psylla in several orchards at the time of sampling. In three orchards near woody linear elements where psyllids were present, infestation was lower near the SNH.

Table 3. Density of pear psylla in October 2014 in 18 focal fields, bordering no SNH, herbaceous linear SNH or woody linear SNH.

		distance from border			
border	orchard	3	9	18	27
CO	L	4	6	4	4
	M	6	8	7	0
	Q	2	0	0	0
	U	0	2	0	0
	V	0	0	0	0
	Z	0	0	4	0
HL	J	17	19	29	16
	K	0	2	0	0
	N	9	2	8	10
	T	0	0	0	2
	W	8	29	21	77
	Y	0	6	8	7
WL	G	0	0	0	0
	H	0	0	0	8
	P	10	8	8	8
	R	2	4	21	18
	S	0	8	32	25
	X	7	16	41	84

2. *Interaction between earwigs and sentinels/natural infestation of psylla*

- There is a significant effect of earwig density on the predation of sentinels of *Ephestia* in July. Early in the season, in May, this effect is not to be expected as earwigs are present in the trees from June onwards only. Earwigs also had a significant effect on the crop specific sentinels of A. orana eggs.

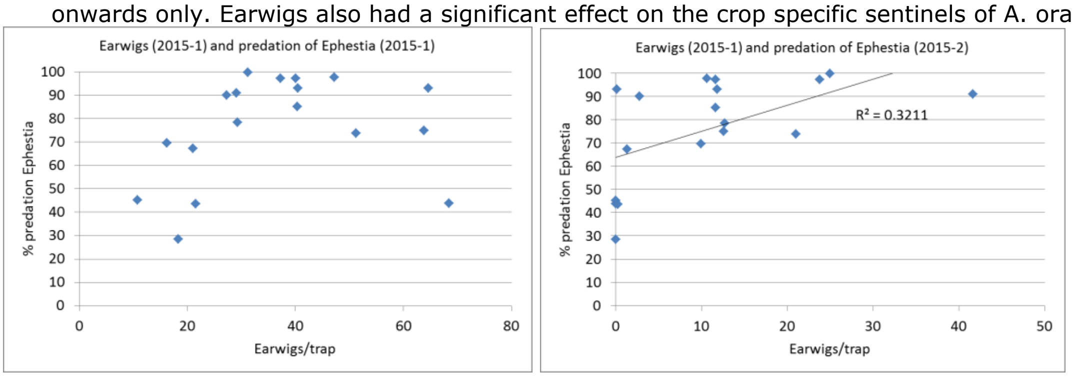


Figure 2. Earwig density in July and predation level of *Ephestia* in May (left) and July (right) 2015.

- We see a strong, significant effect of earwigs on the natural autumn populations of pear psylla, both at measurement point level and at a field level. At measurement point level, most data points are on or near the axes (see figure 3): if there are earwigs present, there are few psyllids or vice versa.

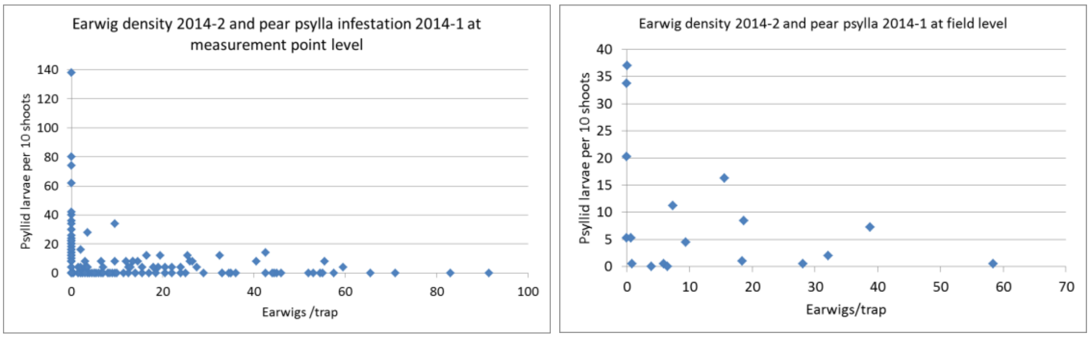
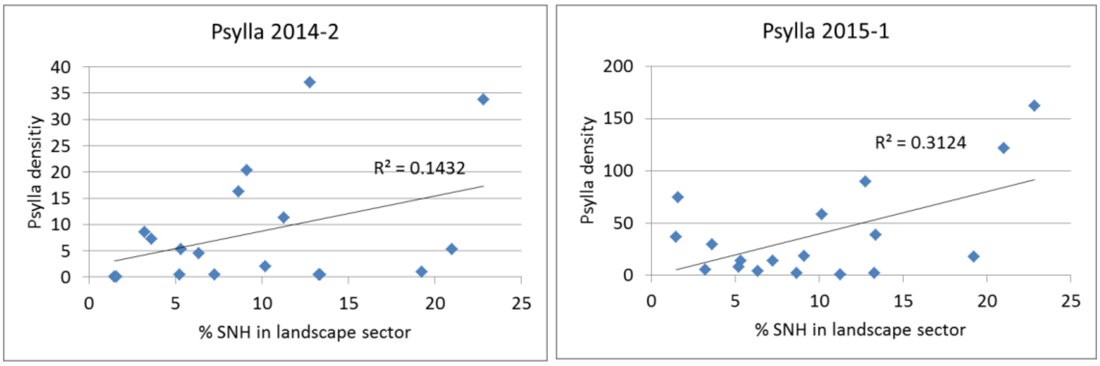


Figure 3. Earwig density and autumn population of pear psylla.

3. Landscape sector effects on pests

- There was no effect of the amount of SNH in the total 1 km landscape sector on the predation level of sentinels. Figure 4 shows a (non-significant) effect of the landscape on the pear psylla density. A higher % of SNH coincides with a higher psylla density. Only the effect of the total % SNH was analysed here.



2.4.5.4 Discussion

- We saw no effect of the SNH nearby the focal field on the level of predation of sentinels. The strong effect of earwigs on several of the sentinels and on the psyllid population may have camouflaged any landscape effects.
- Due to low density of the sentinels, we only measured the effect of generalist predators already present in the orchard. In the case of high pest densities, other mechanisms may play a role, such as attraction of specialist predators from the surrounding landscape to the infested crop. Such effects have been shown for pear psylla. So different pest densities may lead to different landscape effects.

- Management intensity in pear orchards is high, and the focal fields received numerous pesticide applications per year. Analysis of the insecticides applied, and their potential effect on pests and predators, still has to take place.
- Several orchards in the experiment had no or very few earwigs. Given the strong effect of earwigs on pear psylla density shown in this work, the main ecosystem service to stimulate is the presence of earwigs.

2.4.6 United Kingdom

Authors: John Holland & Niamh McHugh

2.4.6.1 Introduction

Levels of pest control were evaluated in fields adjacent to three types of semi-natural habitat (SNH): woody areal, woody linear (hedgerows) and herbaceous linear, these being the most predominant in the arable farming regions of England. The herbaceous linear was treated as the control because boundaries are almost always present around all fields, with crop to crop being rare.

2.4.6.2 Methods

The standard QuESSA protocol was followed with sentinels placed at 2, 25, 48 and 71m from the nearest SNH in winter wheat. The project wide sentinels were deployed in 2014 and 2015 consisting of *Calliphora* vomitoria larvae, *Ephestia kuehniella* eggs, *Poa annua* and *Chenopdium album* seeds on the ground, and *Ephestia* eggs on the crop. The same experimental design was repeated in in each year, although the fields were different because of the crop rotation. In addition, sentinels of Drosophila melanogaster pupae and on the ground were used in 2014 which represented dipteran pests such as *Sitodiplosis mosellana* and in 2015 *Lucilia sericata* (Green blue bottle fly) larvae which are smaller than *Calliphora* and consequently vulnerable to a wider range of predators. The cereal aphid *Sitobion avenae* attached to the crop was also tested in both years. These sentinels were attached to dry stick card that was then coated with fine sand to allow predatory insects to walk across the surface. All sentinels placed on the ground were covered with a metal cage (1cm mesh) to prevent access by birds and rodents. The abundance of naturally occurring cereal aphids was also monitored in both years by counting the numbers on 25 tillers at the same time and location as the sentinels. In 2015 fields were selected that were as close to the ones used in 2014. All types of SNH of >2m width within a 1km radius were mapped and entered into a GIS.

Analysis was conducted in R v.3.2.0. Variables relating to habitat (HL, HA, WA, WL) area measurements were rescaled using the centring function in the arm package. This function standardises a variable by centring them to fluctuations around zero and dividing by 2 sd's, leaving only relevant variation for analysis. Data was analysed using the glmer function from the package lme4. Landscape sector was included as a random factor in all models to account for potential variation associated with farm scale factors. Round and year were included as fixed effects, both of these variables only have two levels. They therefore cannot be included as a random term because of the need to 5 levels to calculate the associated variance correctly. Family type varied depending on the type of response variable. For count data, models were either poisson (count of number of a predation event happened) or binomial (if we knew the number of times a predation event happened and the number of times it didn't happen). For continuous data the response variable was checked to ensure distribution and analyses used the lmer function in lme4. For all models we used pearson residual plots with 95% pointwise confidence intervals to highlight potential outliers and non-linear relationship in habitat area data. Non-linear relationships were also tested with a

Generalised Mixed Model (GAM). If the GAM showed a relationship was significantly non-linear the model was rerun as a Generalised Mixed Effects Model (GAMM) with a smoother term added to the variable in question. We also tested for overdispersion in models, if a model was overdispersed a random level intercept was added to the equation. The analysis was repeated using the total SNH within the LS rather than individual types.

2.4.6.3 Results

The level of predation and distribution of the data varied considerably between the different sentinel systems with higher mean levels of predation for *Calliphora* larvae (53%), Lucilia larvae (57%), *Ephestia* eggs (63%) and Drosophila pupae (37%) on the ground, but low levels for Sitobion (12%) and *Ephestia* eggs (22%) on the crop, with even lower levels for the seeds, *Chenopodium* (8%) and *Poa* (4%) on the ground. For all sentinels 100% predation sometimes occurred (Figure 1).

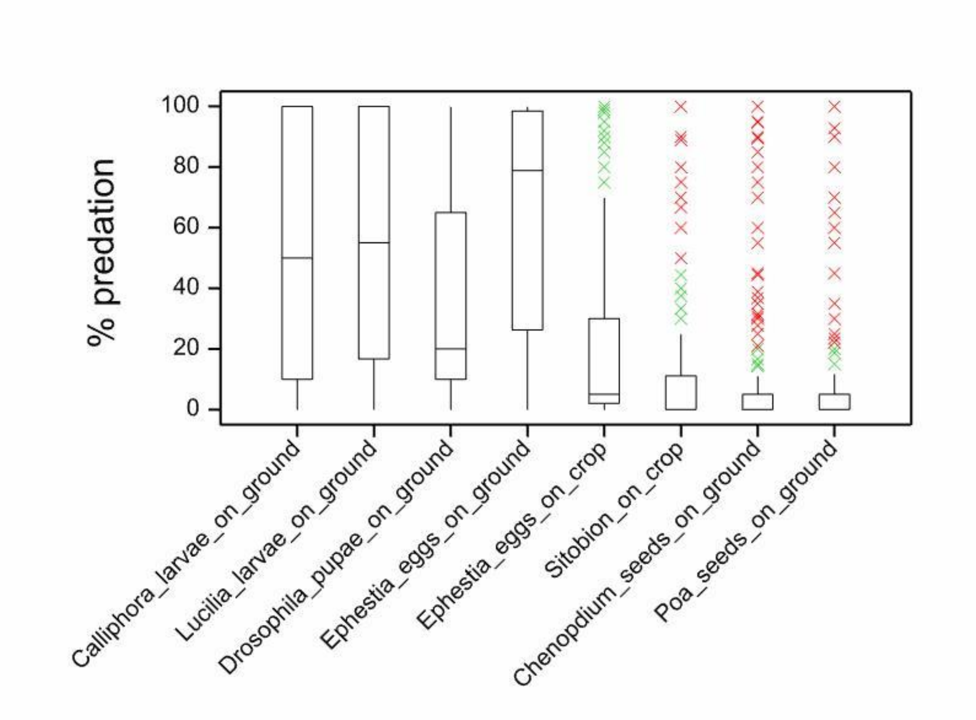


Figure 1. Sentinel percentage predation showing median (horizontal line), interquartile range (box), solid whisker extending to the upper quartile plus 1.5 times the interquartile range or maximum value if smaller.

The data for *Calliphora* was abnormally distributed and the model would only run if year and sampling occasion were excluded. The data for aphid numbers on the crop included many zeros in 2014 and the model could only be run by excluding year as a fixed effect and only including the total SNH in the LS rather than individual types. For the other sentinels no other significant effects were found using the total SNH in the LS.

Effect of proportion of SNH in the LS.

The proportion of HA habitat had a positive effect on the level of *Calliphora* larvae, Drosophila pupae and *Chenopodium* predation (Table 1). On the other hand, the proportion of woody linear had a negative effect on *Chenopodium* and Sitobion sentinel predation. Similarly, woody areal habitats had a negative effect on Drosophila pupae predation. The total area of SNH in the LS had a negative effect on naturally occurring aphids on the crop, in other words LS with more SNH led to fewer aphid pests.

Effect of adjacent SNH type

Few effects were found except that predation of Drosophila pupae, *Calliphora* and Lucilia larvae were lower in fields bordered by WL than HL habitats.

Effect of distance from adjacent SNH

Predation of *Calliphora* and Lucilia larvae, and seed predation for both species increased with distance from the SNH. In contrast, aphid predation of the sentinels decreased with distance from SNH.

Effect of sampling occasion

Predation of *Ephestia* eggs and *Chenopodium* seeds was higher on the first sampling occasion, but was higher on the second occasion for aphid sentinels.

Effect of year

Predation levels for four sentinels were higher in 2015 than 2014.

Table 1. Summary of effects for predation of sentinels and in winter wheat.

where effects indicated. ↑ = increase, ↓ = decrease in relation to variable and significance of effect indicated by +p<0.1, *=p<0.05, **=p<0.01, ***=p<0.001)

Method	**SNH types in landscape**	**SNH type in adjacent boundary**	**Distance from SNH**	**Sampling occasion**	**Year**
Calliphora on ground	HA↑** WL↓** WA↓*	WL↓*	↑ *	Not tested	Not tested
Lucilia on ground		WL↓+	↑ *		
Drosophila pupae on ground	HA↑+, WA↓+	WL<HL+			
Ephestia on ground	HA non-linear effect			1 > 2**	2015>2014***
Ephestia on crop					
Sitobion on crop	WL↓*		↓ *	2 > 1**	2015>2014***
Poa on ground			↑ **		2015>2014***
Chenopodium on ground	HA↑*, WL↓*		↑ **	1 > 2*	2015>2014***
Natural cereal aphid infestation	↓*** with total SNH			Not tested	Not tested

2.4.6.4 Conclusions

Predation levels of the sentinels were in some situations very high, but on the other hand were low on the crop for the animal prey items. We can conclude that biological control was occurring and there is considerable potential to improve this because in some cases predation levels were 100%. There was considerable variability in the data, but the underlying causes were not always identified. The only consistent effect of SNH at the landscape scale (although effects were sometimes weak) was that herbaceous areal habitats increased predation of four ground based sentinels. At the field scale there was some indication that the proportion of woody areal habitats had a non-linear influence on two of the sentinels that requires further investigation. This suggests that what was measured were background levels of control by predators that reside within fields, rather than by those relying on resources provided by SNH, such as floral or alternative prey. The variation between sites may therefore reflect more the within-field management (e.g. tillage, insecticide usage) and requires further investigation. The overall level of aphid pests was, however, lower as the proportion of SNH increased in the landscape.

Predation of *Calliphora, Lucilia* larvae and seeds increased with distance from the SNH. For seeds this may be because alternative foraging resources were not available. Weed levels and therefore weed seeds are usually higher in field headlands and decrease with distance into the field. Likewise, if the predators were omnivorous, insect prey are also more abundant nearer to field edges. Aphid predation decreased with distance for SNH and collaborates with previous research (Holland et al., 2009) showing that pest natural enemies are higher around the edges of fields. Predation of the fly larvae which represent quite large prey items was probably higher further from the field edges because the larger carabid beetles overwinter within fields and densities are higher in field centres than the edge (Holland et al., 2005; 2009).

For four of the sentinels there were between year differences and for three differences between sampling occasions indicating that predation levels are inconsistent. Measures to increase the abundance and functional diversity of predators could help provide more consistency in predation levels. Evaluations of the factors driving predator abundance would help in providing better recommendations for farmers.

Where predators were observed on the animal prey these were predominantly beetles (Carabidae or Staphylinidae). No predators were observed on the seed cards.

The analyses presented here are preliminary and do not include other explanatory variables such as the abundance of service providers (pest natural enemies) and management inputs that may further explain the findings.

2.4.7 Estonia

Authors: Eve Veromann, Gabriella Kovacs, Riina Kaasik

2.4.7.1 Introduction

Oilseed rape is attacked by several insect pests but pollen beetles (*Brassicogethes aeneus* syn. *Meligethes aeneus*) are considered to be one of the most important and yield limiting pest throughout Europe. Pollen beetles are univoltine, they emerge from overwintering sites in spring when air temperature exceeds 10 degrees C and feed on pollen from plants of different families.

When temperature exceeds 12 degrees C, they start to seek cruciferous plants for mating and oviposition. They lay eggs in the oilseed rape buds. First instar larvae feed pollen within the bud and second instar on open flowers. Mature larvae drop from the flowering canopy to the soil and pupate below soil surface. The major damage for oilseed rape plants are caused by the feeding adults during the bud stage of plants. However, larval feeding inside the buds also causes damage.

The population size of pollen beetles can be controlled by naturally occurring enemies – hymenopteran parasitoids and predatory arthropods. The eggs and larvae of pollen beetles are attacked by at least nine species of hymenopteran endoparasitoids but four of them are widely distributed and common throughout Europe. In addition, pollen beetle larvae are vulnerable to ground dwelling predatory arthropods during the time when they are dropping to soil to pupate.

2.4.7.2 *Methods*

- Sentinel experiments in 18 fields per year (2014 & 2015: two rounds during the time when larvae drop to the soil)
- Pollen beetle and beneficial arthropod activity in 18 fields (2014 & 2015)
- Pollen beetle pest control experiments in 18 fields (2014 & 2015)

2.4.7.3 *Results*

Sentinels

The predation rate of *Calliphora* larvae was statistically significantly correlated with the abundance of Carabidae and Staphylinidae in the fields (r2= 0.09; p<0.01), Figure 1 and 2.

A B

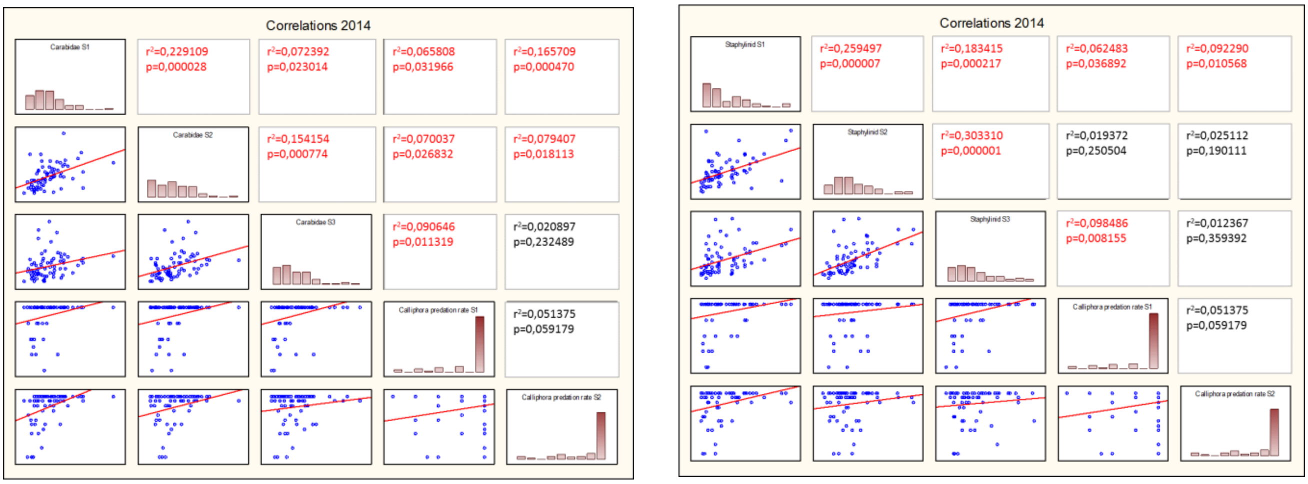


Figure 1. Correlations between predation rate of *Calliphora* larvae with carabids (A) and staphylinids (B), 2014, Estonia.

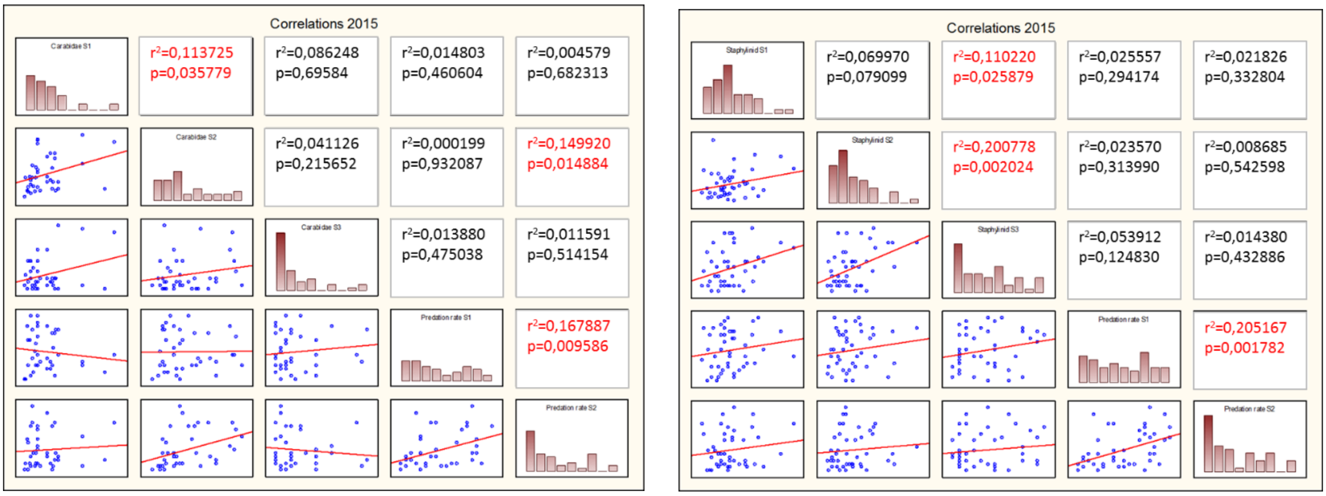


Figure 2. Correlations between predation rate of *Calliphora* larvae with carabids (A) and staphylinids (B), 2015, Estonia.

The proportion of semi-natural habitats within the 1km radius had no effect on the predation rate of *Calliphora* larvae in 2014 nor in 2015. And also the adjacent habitat type had no effect on this sentinel.

Sampling date had significant and controversial impact on the predated seeds (F(2,285)=22.8; p<0.0001): number of predated *Poa* seeds was grater on the first sampling date (01.06.2014) but number of predated *Chenopodium* seeds was greater on the second sampling date (15.06.2014; Figure 3.)

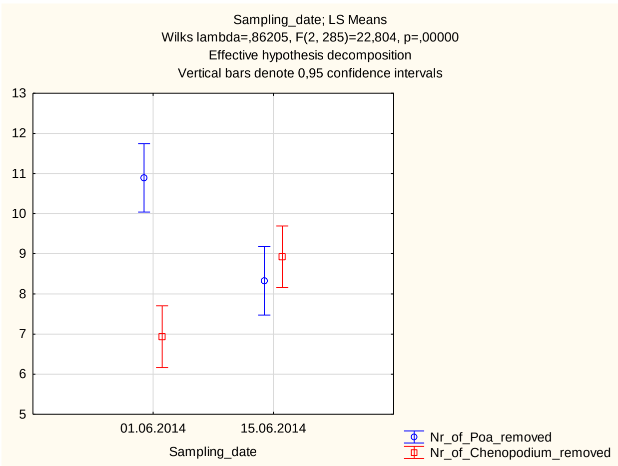


Figure 3. Mean number of predated seeds in the oilseed rape fields in Estonia.

The adjacent semi-natural habitat affected the predation rate of *Poa* seeds (P<0,05) in the second sampling date – significantly greater number of seeds were predated in the oilseed rape fields with adjacent semi-natural habitats than fields that were bordered by another crop field (Figure 4).

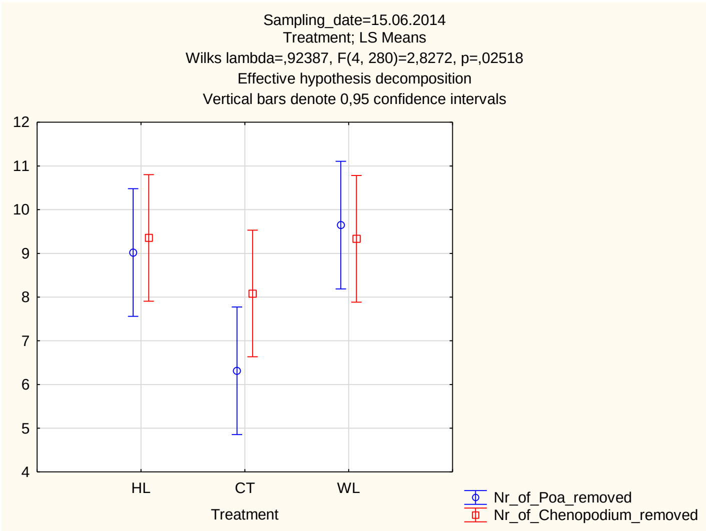


Figure 4. Mean number of predated seeds in oilseed rape fields bordered by herbaceous linear (HL) and woody linear (WL) habitats and by another crop field (CT), 15.06.2014, Estonia.

Crop specific pest

The number of *Meligethes aeneus* per oilseed rape plant was influenced by the distance from the field edge and the bordering landscape element type. Herbaceous linear SNH did not support the abundance of the main pest in oilseed rape crops (Figure 5). The number of pests in oilseed rape crops depended on the distance from the margins; there were significantly more insects in the crop edges than in the centre of crops (Fig. 6). In addition, in the sampling points near to the field edge (2m - D1 and 25m – D2), more beetles were found in the fields that were bordered by woody linear habitats (p<0.003), herbaceous linear elements and another crop field did not support the abundance of this pest in the field. The number of beetles further from the field edges (50m – D3 and 75m – D4) was influenced by the proportion of agricultural land within the 1km radius: if proportion of agricultural fields was <32.7% then the number of beetles was smaller than in the landscapes where the proportion of agricultural fields was >32.7% (p<0.001).

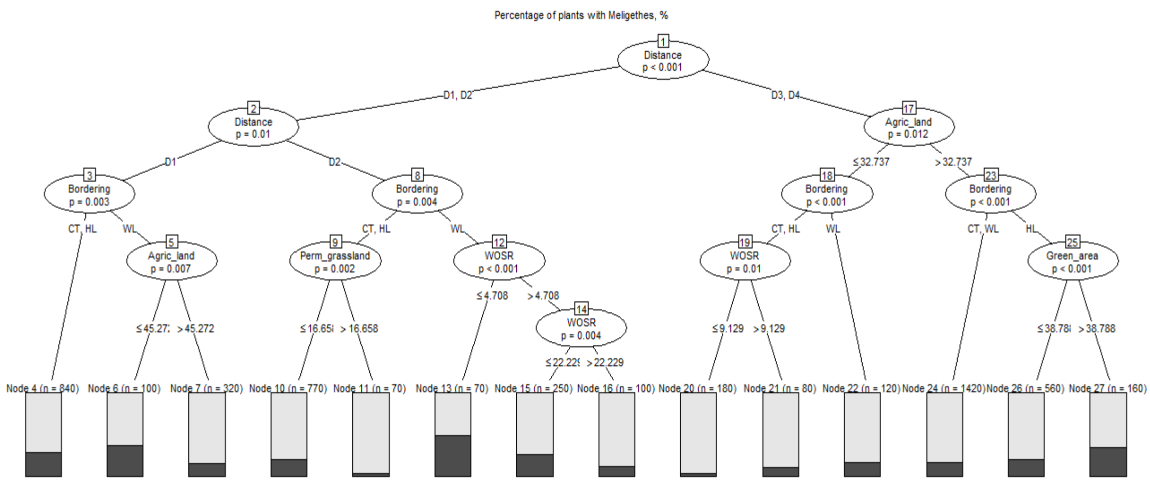


Figure 5. Classification tree of landscape parameters (percentage of permanent grassland, green area and agricultural land, WOSR, bordering type and distance from border) to predict the percentage of

plants with adult *Meligethes* (2014, 2015). The minimum splitting criteria was set as univariate p<0.05. For each final node the distribution of plants with (black bar) and without (grey bar) adult *Meligethes* is presented.

Pest control of crop specific pest

Herbaceous linear elements had a positive effect on the parasitism rates of Meligethes aeneus larvae (pollen beetle) ($R2= 0.61$; $F1, 16= 27.56$, $p<0.0001$; Figure 9). Parasitism rate increased significantly with increasing proportion of herbaceous linear habitats within the 1km radius landscape sectors.

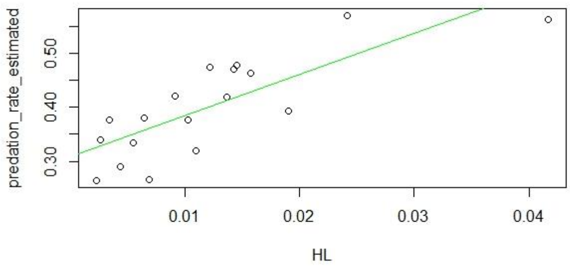


Figure 6. Parasitism rate of Meligethes aeneus in relation with the proportion of herbaceous linear elements in the landscape sectors, Tartu County, Estonia, 2014.

Also, the proportion of green areas (i.e. woody areal and linear, herbaceous areal habitats and permanent grasslands all together) influenced the parasitism rate of pollen beetles (p<0.009). If the proportion of green areas was greater than 45.6% then the parasitism rate was also greater (Figure 7).

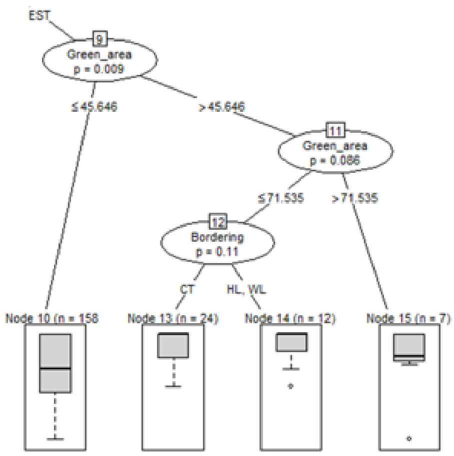


Figure 7. Classification tree of landscape parameters (percentage of permanent grassland, green area and agricultural land, WOSR, bordering type and distance from border) to predict the parasitism rate of *Meligethes aeneus* larvae caught with funnels (pooled data of 2014, 2015). The minimum

splitting criteria was set as univariate p<0.3. For each final node the box plot of parasitism rate is presented.

The number of predatory arthropods caught by pitfall traps was influenced by the landscape element adjacent to oilseed rape field (p<0.001; Figure 8). The woody linear habitat did not enhance the presence of predatory arthropods in the oilseed rape field.

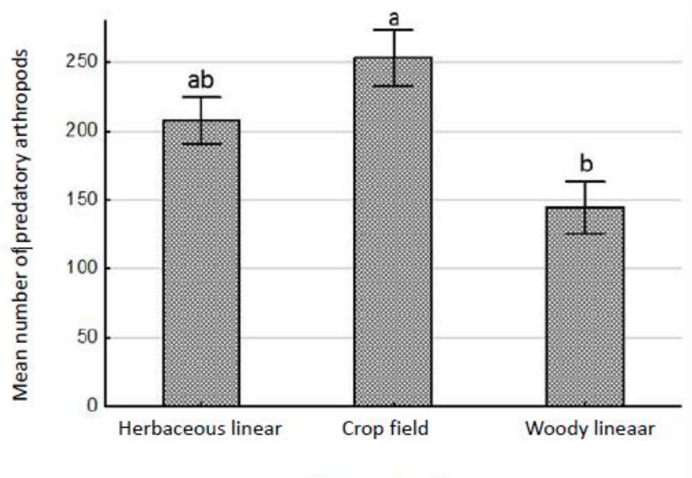


Figure 8. The mean number of predatory arthropods per pitfall trap over all sampling times in oilseed rape fields with different adjacent elements, 2014, Estonia.

However, overwintered predatory arthropods (including carabids) were the most abundant in herbaceous linear and woody linear elements (Figure 9, 10) thus, woody linear habitats are important habitats during overwintering time for predators.

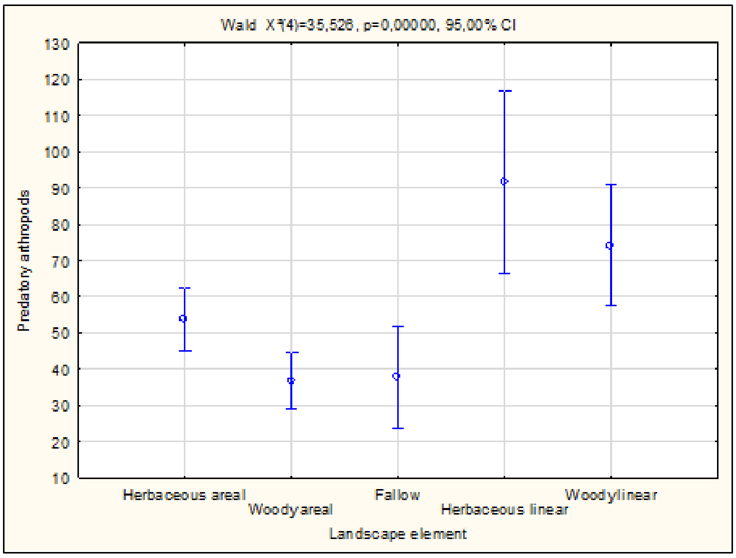


Figure 9. The mean abundance of overwintered predatory arthropods per pitfall trap (N=100) in different SNH-s in Tartu County, Estonia, 2014.

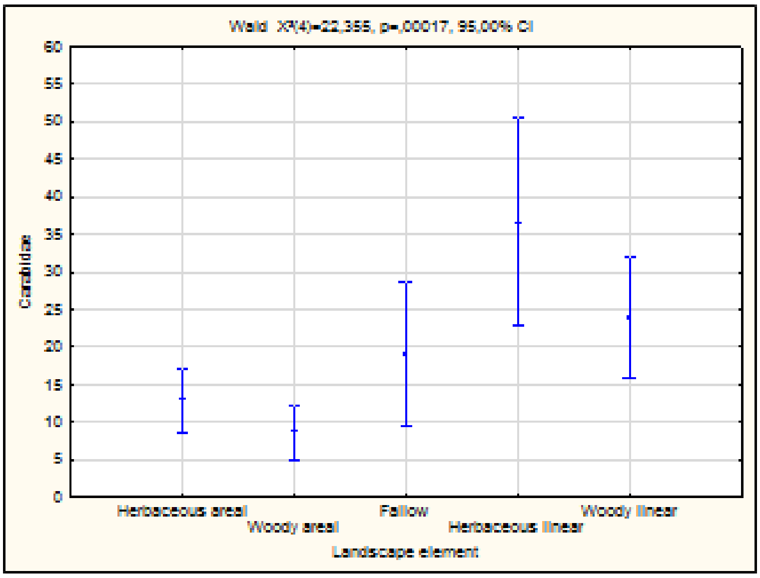


Figure 10. The mean abundance of overwintered carabids per pitfall trap (N=100) in different SNH-s in Tartu County, Estonia, 2014.

2.4.7.4 Conclusion

We can conclude that herbaceous linear habitats, even if their relative proportion in landscape is small, have an important role in promoting pest control agents, both parasitiods as well as predatory arthropods. In addition, greater proportion (>45.06%) of semi-natural habitats within the 1km landscape sector enhanced the parasitism rate of pollen beetles. Field margins with tussocky grasses and diverse permanent vegetation offers shelter and overwintering sites for ground dwelling arthropods and provides alternative food and host resources for parasitoids.

2.4.8 France

Author: Brice Giffard

2.4.8.1 Introduction

Effects of SNH cover and presence on ecosystem services in vineyards (France - 2 CS)

Agricultural intensification at different scales is a major driver of losses of biodiversity in human modified landscapes. The landscape-scale reduction in habitat heterogeneity is known to strongly affect biodiversity and associated ecosystem services. Among the different service-providing communities, generalist predators such as carabid beetles contribute to important ecosystem services such as the biological control of insect crop pests. Perennial crops such as vineyards studied in French CS, differ greatly from *annua*l cropping systems in terms of disturbance for natural enemy communities: high amounts of agrochemicals are sprayed but they are also more stable habitats in space and time (no crop rotation and lower levels of soil disturbance). These agrosystems are then particularly interesting to assess the effects of landscape and local complexity on biodiversity (measured both on pests and on natural enemies) and their associate ecosystem services (measured on sentinel systems). Other services of semi-natural habitats can also be identified such as soil erosion or carbon storage (ongoing analyses). Pests observed will be *Lobesia botrana* (Torticidae) and

Empoasca vitis (Cicadellidae) and the results are shown for the adult abundance and/or the larvae abundance, responsible for damage on vine grapes and leaves.

2.4.8.2 Results:

SNH effect on pests: local and landscape effects

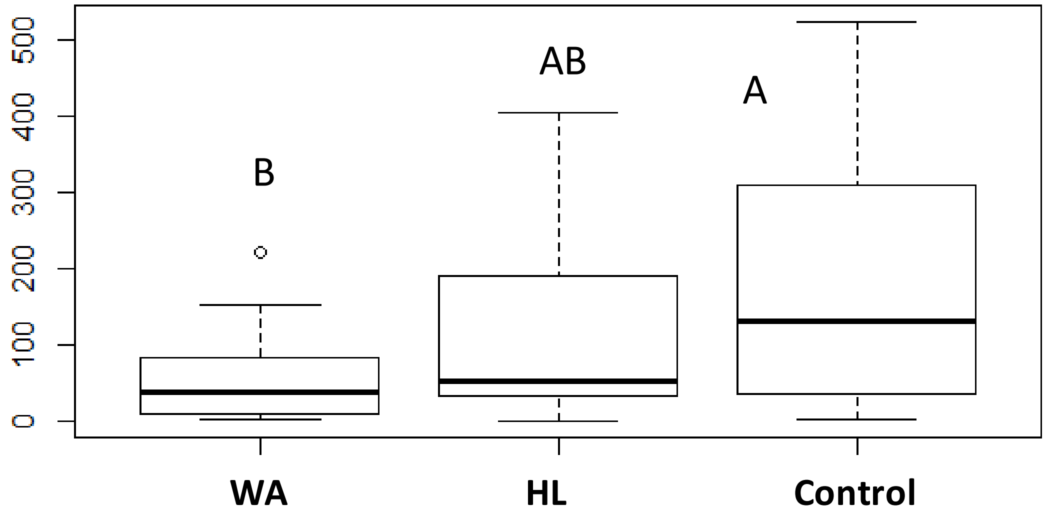


Figure 1: Abundance of *Lobesia botrana* moths in 2014 in both CS (36 vineyards) function of the presence adjacent SNH (WA woody area) or HL (herbaceous linear) or without adjacent SNH (Control). Different letters indicate significant differences between modalities ($p<0.05$).

Interestingly, the two pest species associated to vineyards showed a different response to the presence or the cover of semi-natural habitats at the local or landscape levels. The abundance of moth species *Lobesia botrana* is significantly and negatively influenced by the presence of woody habitats at the local level (Figure 1) and of SNH cover at the landscape level (Figure 2). Conversely, the leafhopper species seems to be not affected (Figure 3).

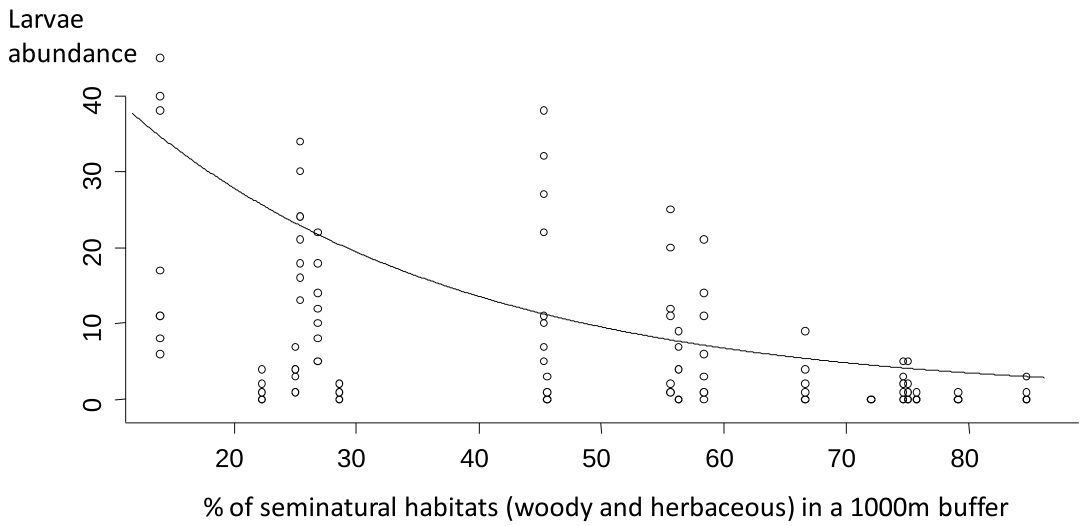


Figure 2: Abundance of *Lobesia botrana* larvae on grapes in 2014 in both CS (36 vineyards) function of the cover percentage of semi-natural habitats (woody and herbaceous together). A significant Poisson and negative relationship was found for both sites and during the whole season.

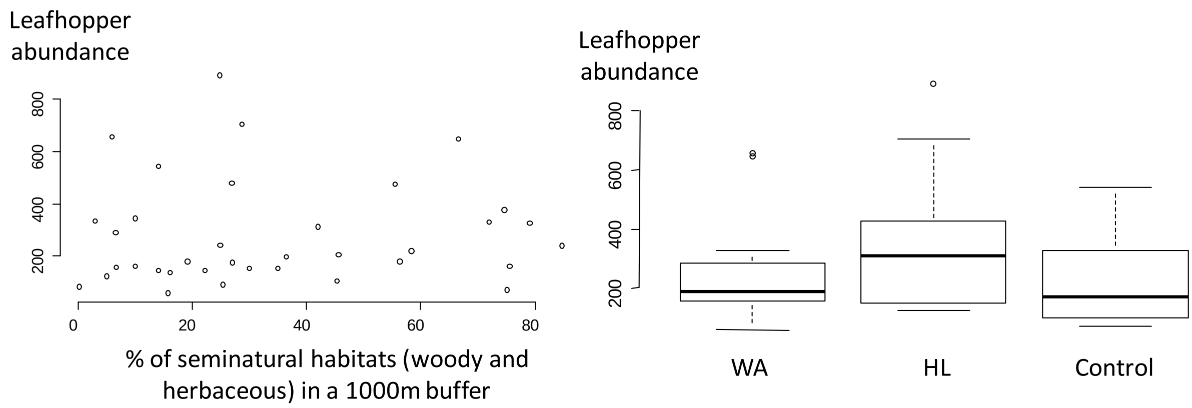


Figure 3: Abundance of *Empoasca vitis* larvae on leaves in 2014 in both CS (36 vineyards) function of the presence or absence of SNH (left figure) or the cover percentage of semi-natural habitats (woody and herbaceous together - right figure). Any significant effect was found for this pest species.

SNH effect on natural enemies (carabids - staphylinids - spiders - opiliones): local and landscape effects on their abundance

Further analyses of landscape composition are necessary for the Mediterranean site but we can already show that the abundance of all of these groups are very low and it will be more complicated to highlight effects of landscape elements.

Very little effects (see Table 1) were found on the effects of SNH cover on abundances of insectivorous predators in our vineyards. However, we found that carabids, staphylinids and opiliones are negatively influenced by vine monoculture, i.e., an increase of vine cover at the landscape scale (1000m buffer). We also found several negative effects of an increase SNH cover in the abundance of different groups and at different scales, indicating that SNH elements can negatively influenced some of these service provider species (but maybe not their diversities), even if the effects seem to be not in the 2 consecutive years of survey.

Natural enemies' abundance	**Woody elements in 100m buffer**	**Herbaceous elements in 100m buffer**	**Vine cover in 100m buffer**	**Woody elements in 1000m buffer**	**Herbaceous elements in 1000m buffer**	**Vine cover in 1000m buffer**
Carabids	**-1.915 *** 0.881	-0.449 0.468	-0.308 0.580	-0.327 -1.709	-0.711 0.126	**-2.141 *** **-1.96 ***
Staphylinids	0.713 -0.702	0.690 -1.803	0.705 1.543	-0.911 **-1.89 ***	-1.197 0.103	**-2.821 *** **-2.853 ****
Spiders	-0.392 -0.336	-0.473 -1.269	-0.520 -0.974	0.584 -0.299	0.183 -0.540	1.094 -1.062
Opiliones	0.062 1.015	**-2.518 *** **2.021 ***	1.449 **3.203 ****	-0.228 0.451	**-2.893 **** -1.663	**-2.301 **** 1.378

Table 1: Summary of GLMM (Generalized Linear Mixed Models) assessing for the effects of the covers of vine fields, woody and herbaceous elements at 2 scales around plots (100m and 1000m). Results are shown for the 2 consecutive years of survey (2014 in the first line and 2015 in the 2nd) and only for the oceanic site (VIN_PC1 - Libournais). Statistics shown are t-values associated with asterisks and written in bold when significant (* if p-value < 0.05,). Negative t-values indicated negative relationships.

Local and landscape SNH effect on predation (sentinel systems and bird predation)

Some of the sentinel systems used to assess for arthropod predation showed any significant effect of SNH local presence or cover at the landscape scale (*Ephestia* eggs on the plant or on the ground, aphid cards) in both sites and for both years of measures. However, very important differences of responses were noted between sites (seen also for the abundance of service providers) and further analyses will be conducted to see if we can link abundance of natural enemies and predation on sentinel systems.

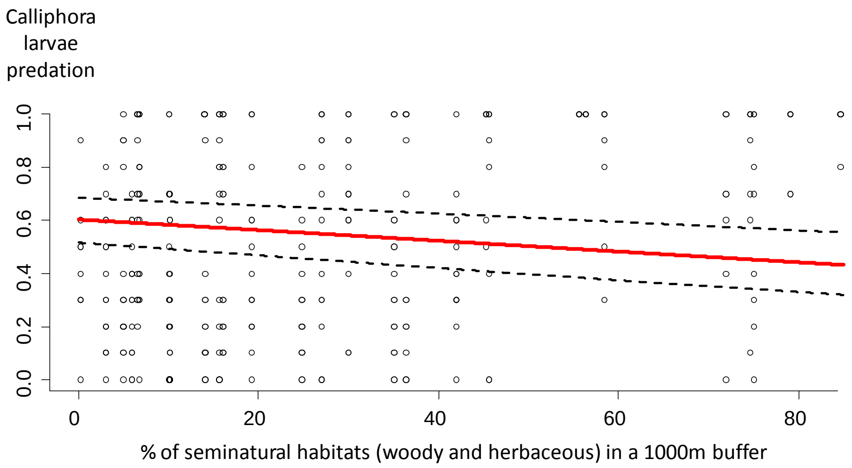


Figure 4: *Calliphora* larvae predation (percentage between 0 and 1) function of the cover percentage of semi-natural habitats (woody and herbaceous together). A significant negative relationship was found for both sites and during the whole season 2014 (also found in 2015).

2.4.8.3 Conclusion

SNH cover and presence around vineyards at local level have been found to strongly negatively influence the pest abundance (for one of the two pest species), which is, for the moment, not consistent with results found for predation measured in sentinel systems (no effect or negative effects on predation rates) or on biodiversity (abundance natural enemies rather negatively linked with SNH cover)

2.5 Synthesis pest control

The natural pest control in the investigated cropping systems was generally more influenced by available SNH at landscape level (i.e. landscape complexity), than locally bordering SNH. However, three out of eight case studies demonstrated an increase in predation of crop specific pests through bordering SNH. In the Italian case study, the availability of Mediterranean garrigue increased the parasitism of the olive fly in orchards, and bordering herbaceous linear elements increased the parasitism of pollen beetle in Estonia and ground predation in wheat fields in southern England. In four case studies, where no direct effect of locally bordering SNH were detected, the total amount of SNH measured in a 1-kilometre radius sector around the studied focal crop fields positively influenced the natural predation of damage-causing pest species. The proportion of SNH increased the predation on pollen beetles in Swiss and Estonian oilseed rape fields. In the United Kingdom the proportion of grassland in the surrounding landscape increased predation rate in wheat fields, whereas woody habitats rather negatively influenced predation. In Germany, the abundance of predators was positively influenced by the proportion of SNH at landscape level, but a direct reduction of aphid number, the principal pest in pumpkin production, was not recorded. In the Netherlands, no effect of SNH could be demonstrated on sentinels. Results suggest that pest control agents rather react to the amount of SNH at landscape level (i.e. landscape complexity/diversity) than to local implementation of current SNH, which role of attracting predators into fields for successful natural pest control seems less important than expected.

2.6 Synthesis pollination and pest control

Based on 7 case studies of crop pollination and 8 case studies of pest control across Europe, the role of semi-natural habitats is summarized as follows: semi-natural habitats bordering crop fields showed tendency to efficiently attract pollinators and increase pollination of the crop whereas the proportion of SNH in the surrounding landscape had more impact on natural enemies and pest control.

3 Report on other ecosystem services

3.1 Introduction

Assessment of other key ecosystem services identified in conjunction with the local stakeholders and SAB has been performed in case studies according to the pre-selected cropping systems. The other investigated ecosystem services varied between case studies and included landscape aesthetic (8 case studies), soil erosion (1 case study), soil fertility (4 case studies) and organic matter storage (2 case studies). In addition, the impact of semi-natural habitats on so called disservices was recorded, namely weed invasion (3 case studies) and bird damage (1 case study).

3.2 Landscape aesthetic

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3.2.1.1 Introduction

Literature concentrating on ecosystem services provided for landscape aesthetics are rather seldom. Nevertheless, Wratten et al. (2012) evaluate the benefits of habitat enhancement for pollinators for other ecosystem services. They conclude, that semi-natural habitats consisting of temporary flowering cover crops or perennial or *annua*l flowering species, hedgerows and grass buffer strips can enhance rural aesthetics (Wratten et al., 2012). Even though, one reason for the rare evaluation of ecosystem services provided for the attractiveness of the landscape, may be the fact, that ecosystem services as a part of landscape ecology is not yet connected to the social system (Termorshuizen and Opdam, 2009). As a consequence, Termorshuizen and Opdam (2009) claim for including values in ecological science. Hermann et al. (2014) adopt this idea and use the concept of landscape services as proposed by Termorshuizen and Opdam (2009) to evaluate landscape services in European cultural landscapes. They define landscape services as “all goods and services that landscapes provide for well-being” (Hermann et al., 2014). With this definition in mind this report analyses the effect of grassy and woody semi-natural habitats on landscape aesthetics in six European countries.

Grassy and woody elements in landscape aesthetics

The role of grassland and woody elements in landscape preference is evaluated in different studies and in different settings.

In the United States the approval for different types of buffer in the urban fringe of east-central Illinois was evaluated (Sullivan et al., 2004). Pictures with no buffer strip, a basic buffer strip and an extensive buffer strip were shown to farmers, academics of the University of Illinois and to residents of the region. Furthermore, participants were provided with information about the three different types of buffers. The buffers consisted of different grassland types or of trees. In the crop landscape (corn and soybeans) the three groups of participants preferred a situation with a buffer strip to a situation without a buffer strip. Nevertheless, the academic and the residential group preferred an extensive buffer strip to a basic buffer strip, while farmers preferred the extensive buffer strip to no buffer strip, but they most approved a basic buffer strip.

A more recent paper deals with the ecologic and aesthetic function of different landscape scenarios in Washington State (US). Starting on a base scenario with a few woody conservation buffer strips, woody buffer strips were added on three steps (Klein et al., 2015). Based on GIS modelling and Photoshop® simulations, the study comes to a similar result as Sullivan et al. (2004): as more woody buffer strips are added, as more the landscapes are preferred. Nevertheless, there is no significant difference between the preference for the second and the third level of woody buffer strips.

In a European context Strumse (1994) evaluated the visual preference for agrarian landscapes in Western Norway. Generally, traditional landscapes are preferred to modern agrarian landscapes. From the 60 presented colour slides the seven most preferred are slides with traditional buildings containing stone walls and trees, but also a species rich hay meadow and a meadow flowering with dandelion. Meadows seem to be preferred as traditional and species rich flowering element.

The relation between biodiversity and preference was analysed in different experimental studies by Lindemann-Matthies and Bose (2007) and Lindemann-Matthies et al. (2010b). In the first study (Lindemann-Matthies and Bose, 2007) participants had to design their own favoured meadow. From 54 pots consisting of one wild plat species they hat to select 25 pots to design their favourite meadow. In the second part of the experiment, participants had to imagine and describe their meadow of their dreams. In both cases the experimentally designed meadows were rich in species and structures (Lindemann-Matthies and Bose, 2007). The meadows arranged by participants consisted of a green structured matrix with different colourful flowers. In the second study (Lindemann-Matthies et al., 2010b) several meadow-like arrays of different species richness and evenness as well as two larger scale natural meadows were presented to lay people. Participants were asked to estimate species richness and to rank the presented arrays according to their preference. In both cases participants were able to estimate species richness more or less correctly. Furthermore, in both cases, participant's aesthetic appreciation increased with species richness (Lindemann-Matthies et al., 2010b). This preference for colourful flowering meadows could be corroborated with three studies basing on photographs. In the first study participants had to rate four photographs out of 244 photographs depicting agricultural crops, meadows, hedgerows and high-stem orchards in different seasonal stages. Photographs depicting landscape elements consisting of trees and or characterized by colourful flowering were higher rated than flat green or brownish elements (Junge et al., 2015). On the landscape level landscapes consisting of a higher proportion of species rich meadows and trees were higher rated than landscapes dominated by crop fields or intensively used meadows. This was true for a landscape in the Swiss Lowland (Junge et al., 2011) as well as for a mountainous landscape (Lindemann-Matthies et al., 2010a).

How to measure the influence of SNH on landscape aesthetics?

The studies presented above suggest that SNH have a positive influence on the attractiveness of the landscape. Overall it can be concluded, that laypersons are able to perceive species richness and they prefer species rich and colourful vegetation. As SNH are in most cases established to enhance biodiversity, they have in most cases a more diverse vegetation structure and more colourful wild flowers. Nevertheless, the conclusion is not as simple, as there are several constraints:

SNH, in Switzerland named as 'areas to promote biodiversity' (APB), are not of a homogeneous botanical quality. Vegetation relevés in Switzerland show that APB must not be species rich in any case (Herzog et al., 2005). Considering SNH from different countries in Europe, as realized in QuESSA, may distinctly increase this variation in botanical quality (species richness). This fact arises the question, if SNH, particularly SNH grassy are still preferred as being managed at low intensity and probably containing a more complex vegetation structure.

Another solution could be to try to upscale landscape preferences. This issuce is discussed by van Zanten et al. (2014). This fact implies, that it would earn more reliable answers if additional surveys for each country adapted to the project will be done. Nevertheless, it is aimed at making all questionnaires similar, so as the data easily can be compared and analysed together.

Traditionally landscape pictures are rated or ranked in order to evaluate their preference (Steinitz, 1990; Dramstad et al., 2006; Lindemann-Matthies et al., 2010a; Junge et al., 2011; Frank et al., 2013; Schirpke et al., 2013; Junge et al., 2015). Besides rating or ranking, in these studies, landscape quality is explained either by landscape metrics (Dramstad et al., 2006; Frank et al., 2013; Schirpke et al., 2013) or by Likert-scale based on attributes such as species rich, boring, nice, etc., describing the landscape (Lindemann-Matthies et al., 2010a; Junge et al., 2011; Junge et al., 2015). Both methods give an abstract description of the evaluated landscape or landscape element. Nevertheless, it is difficult to disentangle, to which extend flowers of different colours account for the height of the ranking or the rating. An additional problem of ratings is their tendency to be clustered around the mean of the ranking scale.

Discrete-choice experiments are traditionally used in marketing to evaluate the selling potential of new products. Discrete-choice experiments are based on different attributes expressed on different levels, which characterise the product. Sets consisting of a manageable number of products differing in their attributes and levels are presented to participants. Discrete Models enable to specify, which characteristic of each attribute provides how much utility to the participant. The best product will therefore be this one, which provides the most utility for the participant. Transmitted to our problem, a suitable discrete-choice model should tell us, which characteristics of the different combinations of crop and SNH most add to landscape attractiveness. Literature considered above, evaluating the relationship between biodiversity and landscape preference e.g. (Lindemann-Matthies and Bose, 2007; Lindemann-Matthies et al., 2010b) suggest, that flowering, colours and vegetation structure may influence landscape preference. In order to apply a discrete choice model, participants have to make a decision: Either by selecting the photo of the most preferred combination or by ranking the photos of the different combinations. With respect to apply discrete choice models we decided to rank the photographs. For this report only basic analysis to understand the data were performed. After we aim at establishing and testing a choice model including the characteristics of the depicted crop – SNH combination such as flowering, colour and vegetation structure based on the data of Switzerland. After it will be tested, if this model can be applied for the other countries.

3.2.1.2 Material and Methods

Photo Material

Adopting the experimental design of QuESSA, each partner involved in landscape aesthetics (F, D, HU, I, CH and UK) took photographs of all combinations used to analyse pollination and predation. Photographs were taken following several rules: In order to depict the different aspects of the vegetation (e.g. flowering), pictures were taken at three or four different stages (see table 1). The pictures had to depict always the same section of the landscape, always with the same focal length and always from the same place. The pictures should be taken always in an angle of about 35 degree from a perpendicular baseline of the fields. This enables to depict the combination and to give at the same time a better aspect of landscape than when the picture would be taken perpendicular to the combination of fields. Furthermore, the field adjacent to the focal crop had to be always on the same side, while hedgerows or other woody SNH had always to be in the background so as they do not hide the focal crop field.

Table 1:Dates for S1 – S4 for taking photographs in each country

Phenological zone / country	S1 Start vegetation period	S2 2. sampling	S3 3. sampling	S4 4. sampling six weeks before the end of the vege-tation period (4. 11.)
Italy	31.3.	12.5.	23.6.	23.9.
France	31.3.	12.5.	23.6.	23.9.
Hungary	10.4.	22.5.	3.7.	23.9.
Germany	10.4.	22.5	3.7.	23.9.
UK	15.4.	27.5.	8.7.	23.9.
Switzerland	15.4.	27.5.	8.7.	23.9.

From these 18 pictures for each combination in each country two combinations of core crop with crop and SNH were selected which are most representative for the respective combination and / or represented the most homogeneous series over time. Table 2 shows for each involved country the core crop and the two adjacent crops considered for the study. The type of adjacent crop was selected in order to have a comparison between core crop and adjacent crops across the countries or to have a comparison to the SNH grassy (intensively used grassland). Intensively used grassland is furthermore an important element in crop rotation in Switzerland. Another criteria for selecting an adjacent crop was flowering. As we suppose that SNH grassy are flowering the comparison to a flowering crop was important. Therefore rape-seed was chosen.

It would have been important to show pictures of the landscape level as well. For the involved landscape types it turned out to be difficult to add SNH without completely altering landscape diversity. Furthermore, in the cases of France and Italy with three dimensional corps (vineyards and olive groves) it would have been difficult to add SNH so as they can be seen but they are not adjacent to the crop as in the combination. Only the UK pictures offered a landscape constellation which was easy to edit and to add SNH.

Table 2:Core crops and adjacent crops in the different countries

Country	Core crop	Adjacent crop
France	Vineyard	Vineyard
Germany	Pumpkin	Rape seed / wheat
Hungary	Sun flower	Rape seed / cereal
Italy	Olive grove	Olive grove
Switzerland	Rape seed	Wheat / intensively used grassland
United Kingdom	Wheat	Cereal *

*In UK pictures on the landscape level were shown.

As the presented pictures should be shown in a questionnaire (see section below) they should differ in anything else but the adjacent field, i.e. the crop or SNH. Despite all rules, they had to be homogenised by photo editing. For each country the background had to be homogenised by transferring to all pictures the same neutral but realistic background fitting the depicted stage. Furthermore, the focal crop had to be similar regarding weeds, colour quality etc. for all pictures of one country. Therefore, one focal crop field was used for all shown pictures in one country. Consequently they were replaced by photo editing. Finally for each country and each stage a fourth combination was created by photo editing: the combination crop – SNH grassy – SNH woody. For this combination one of the hedgerows was copied in the background of each of the crop – SNH grassy combinations.

Questionnaire

The base to evaluate the effect of SNH on landscape aesthetics was an online questionnaire for each involved country. It was compiled in UniPark. The core of each questionnaire were sets of four photographs depicting the four combinations: crop – crop (cc), crop – SNH grassy (cg) crop – SNH woody (cw) and crop – SNH grassy – SNH woody (cgw). Depending on the country and its core crop the combinations were depicted in three or four seasons (see table 1). The dates for taking the photographs were defined by the phenological evolution of the plants and were also used for vegetation sampling.

In Hungary and UK pictures were taken for all phenological periods. In France and Italy only the first, the second and the fourth period were considered as the differences between the second and the third were difficult to detect. In order to avoid disturbing participants with too many similar pictures, the pictures of the third period were not shown. In Germany pumpkin did not yet exist in the first period while in Switzerland rapeseed was still harvested in the fourth period.

As two different adjacent crops and also two different SNH grassy as well as woody were shown, the questionnaire consisted of two series of three or four sets of four pictures.

In a first step participants had to rank the four pictures of each set in the two series. The photographs had to be raked from 1 (the picture they liked best) to 4 (the picture they liked least). After ranking the two series, participants were shown the pictures assigned with rank 1 of one of the two series. Participants had to rank again the pictures of each season they liked best. The same was done for the pictures with rank 4. As a result, we know for each participant his / her most and least favoured combination. Both pictures they had to characterise by means of a Likert scale and a set of adjectives. The provided adjectives were derived from (Junge et al., 2015). Furthermore they were asked, how the most and the least preferred combination could be made nicer. Different options were offered as a semantic differential.

For each country a sample was provided by a panel of respondi ® (www.respondi.com). This samples are representative for the population of each country with regard to sex, age and education. For Switzerland it was furthermore representative for the French – German ratio. After data validation for each country the answers of a sample of 352 participants were available. The sample of participants was representative for the respective country. The surveys for Germany Hungary and Switzerland were conducted between June and August 2015, the surveys for France Italy and UK were conducted between March and April 2016.

The base for all questionnaires was an English version. It was written in a rather technical language and was used as a prototype. It was thereafter translated by the different partners to German for Germany, to German and French for Switzerland, to Hungarian, to French for France and to Italian. For UK the English was adapted in some cases by the British partners. When translating or adapting the English prototype it was the aim to preserve the meaning of the questions but to provide a language which is intelligible for the participating lay persons.

Statistical methods

For a first step the data were analysed with descriptive statistics as mean, boxplots and summing up the number of best and least per combination. Furthermore, for each country a model with fixed and random factors was applied in order to find significant differences between combinations. In a second step discrete choice model will be applied in order to better define the characteristics of the most and the least preferred combinations.

3.2.1.3 Results

Mean Rank of the combinations

Overall in the six countries 40 sets with 4 photographs were showed. Each set contains the four combinations crop – crop (cc), crop – grassy (cg), crop – woody (cw) and crop – grassy – woody (cgw) which the participants ranked. Table 3 shows the means for each photograph in its series and season. Rank 1 means participants liked this combination best, rank 4 means participants liked this combination least. In 24 cases the cw combination has the lowest mean rank, what means it was liked best. This applies in 11 cases for the combination cgw, in 5 cases for the cc combination and never for the cg combination. In 23 cases the cg combination has the highest mean rank, what means it was liked least. This applies in 13 cases for the cc combination and in 2 cases for the cw and the cgw combination respectively.

Table 3:Mean rank of each photograph shown in the surveys. Best mean rank are in red, least mean rank are in blue.

Country	Set	Sesaon	cc	cg	cgw	cw
France	Series 1	S1	2.73	*3.17*	2.42	**1.68**
France	Series 1	S2	2.00	*3.21*	2.82	**1.97**
France	Series 1	S4	2.31	*2.97*	2.66	**2.06**
France	Series 2	S1	*3.14*	2.81	2.22	**1.83**
France	Series 2	S2	2.19	*3.05*	2.66	**2.10**
France	Series 2	S4	2.08	*3.12*	2.80	**2.01**
Germany	Series 1	S2	2.55	*3.13*	2.25	**2.07**
Germany	Series 1	S3	2.67	*3.31*	2.72	**1.30**
Germany	Series 1	S4	*3.17*	2.81	2.35	**1.66**
Germany	Series 2	S2	**1.47**	*3.29*	2.41	2.83
Germany	Series 2	S3	2.82	*2.89*	2.19	**2.09**
Germany	Series 2	S4	*3.46*	2.57	2.11	**1.86**
Hungary	Series 1	S1	2.05	*3.58*	2.90	**1.47**

Hungary	Series 1	S2	2.11	*3.46*	2.87	**1.56**
Hungary	Series 1	S3	*3.01*	2.81	2.61	**1.57**
Hungary	Series 1	S4	*3.22*	2.82	2.38	**1.59**
Hungary	Series 2	S1	**1.51**	2.91	2.36	*3.22*
Hungary	Series 2	S2	*3.30*	2.31	**2.12**	2.27
Hungary	Series 2	S3	*3.48*	2.23	**2.13**	2.15
Hungary	Series 2	S4	*2.81*	2.49	**1.95**	2.74
Italy	Series 1	S1	2.61	*2.65*	**2.17**	2.56
Italy	Series 1	S2	2.59	*2.72*	**2.16**	2.53
Italy	Series 1	S4	2.30	*2.92*	**2.24**	2.54
Italy	Series 2	S1	**1.87**	2.42	2.78	*2.93*
Italy	Series 2	S2	**2.18**	2.35	*2.74*	2.72
Italy	Series 2	S4	**2.03**	*2.92*	2.67	2.38
Switzerland	Series 1	S1	2.32	*3.42*	2.92	**1.32**
Switzerland	Series 1	S2	2.33	*2.82*	**2.27**	2.56
Switzerland	Series 1	S3	*3.10*	2.87	2.02	**2.00**
Switzerland	Series 2	S1	2.42	*3.45*	2.55	**1.55**
Switzerland	Series 2	S2	*3.49*	2.29	**1.60**	2.60
Switzerland	Series 2	S3	2.96	2.36	**1.52**	*3.14*
UK	Series 1	S1	2.79	*2.97*	2.50	**1.74**
UK	Series 1	S2	2.65	2.65	*2.78*	**1.92**
UK	Series 1	S3	*2.96*	2.63	2.63	**1.78**
UK	Series 1	S4	2.81	*3.06*	2.11	**2.02**
UK	Series 2, landscape	S1	2.74	*2.99*	2.38	**1.89**
UK	Series 2, landscape	S2	*3.16*	2.59	2.07	**2.18**
UK	Series 2, landscape	S3	*2.89*	2.40	**2.02**	2.69
UK	Series 2, landscape	S4	*3.17*	2.23	**1.89**	2.70

Number of liked best / least per combination and season

After ranking the two series of three or four sets, participants had to rank the photographs of the combination they likded best in each season of one of the two series. Figure 1 shows how often each combination was assigned to rank 1 broken down by series and season.

Regarding the combination, rank 1 was often assigned to cw. This is very clear for series 1 in Germany, Hungary, Switzerland and UK. In series 2 of Germany the cc combination was most often named as most preferred. A similar case can be found in Hungary series 2, but less clear. In both series of France as well as series 2 of Switzerland the cc combination is also often named as most preferred, however, the number of the cw combination is higher.In Italy and in the landscape series of UK the distribution among the combinations is much more even. Howerer, the cgw combination plays an important role in Italy (series 1) and in the landscape series of UK. In series 2 of Italy the cc combination comprises the bigest proportion of rank 1.

Regarding the seasons, in Switzerland and UK photographs of season 1 are most often named as most preferred. For Germany, as season 1 is not available, it is season 2 and season 3 depending on the series. In the other countries there is not such a clear preference for one season. Series 1 in Hungary shows a high number of season 3, but its dominance is less clear than the dominace of season 1 in Switzerland and UK.

Figure 2 shows how often each combination was assigned to rank 4 broken down by series and season. In all countries and all series the combination cc and cg share the higest number of rank 4. In all countries but France, season 3 and / or season 4 shares the highest number of rank 4. In France season 1 shares the highest number of rank 4.

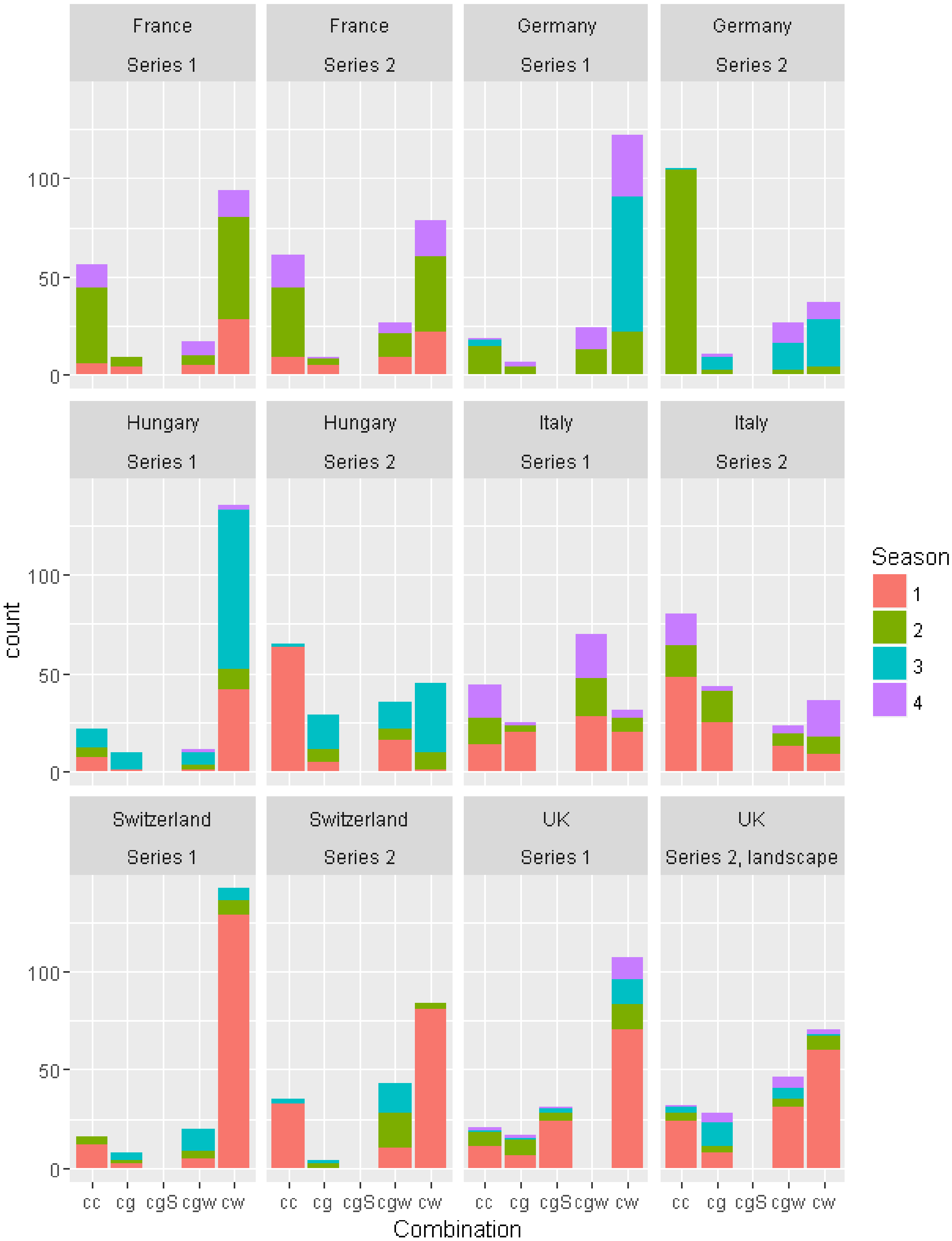

Figure 1: Number of rank 1 for each combination in each country, series and season.

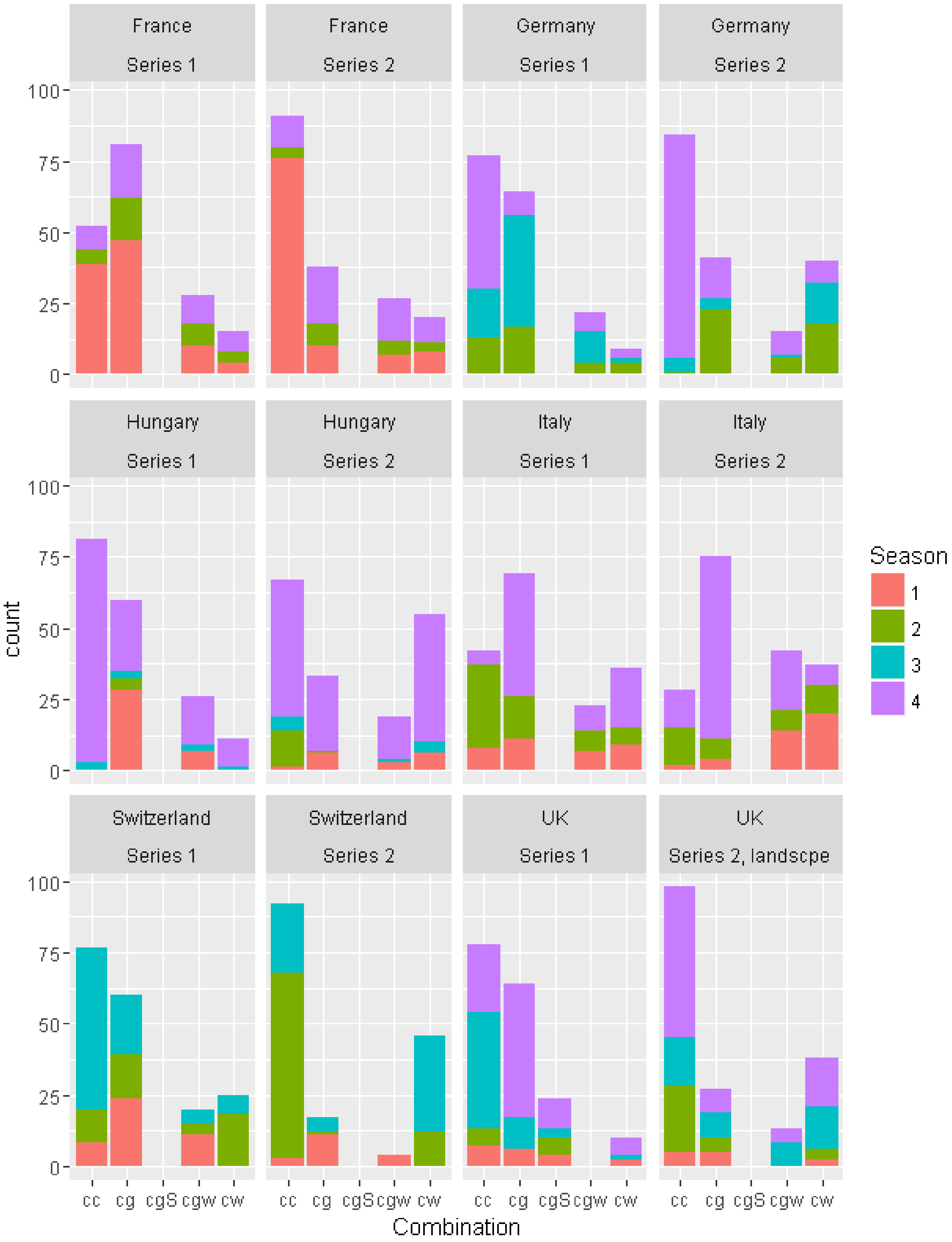

Figure 2: Number of rank 4 for each combination in each country, series and season.

Table 4:Significant differences between crop – crop combination and the other combinations. A more preferred cc combination has a lower rank than the compared combination, a less preferred cc combination has a higher rank than the compared combination.

Combination 1	Combination 2	Country	Season series 1	Season series 2
cc is significantly more preferred than	cg	France	S1, S2, S4	S2, S4
		Germany	S2, S3	S2
		Hungary	S1, S2	S1
		Italy	S4	S1, S4
		Switzerland	S1, S2	S1
		United Kingdom		
	cgw	France	S2, S4	S2, S4
		Germany		S2
		Hungary	S1, S2	S1
		Italy		S1, S2, S4
		Switzerland	S1	
		United Kingdom		
	cw	France		
		Germany		S2
		Hungary		S1
		Italy		S1, S2, S4
		Switzerland		
		United Kingdom		
cc is significantly less preferred than	cg	France		S1
		Germany	S4	S4
		Hungary	S3, S4	S2, S3, S4
		Italy		
		Switzerland	S3	S2, S3
		United Kingdom	S3	S2, S3, S4
	cgw	France	S1	S1
		Germany	S2, S4	S3, S4
		Hungary	S3, S4	S2, S3, S4
		Italy	S1, S2	
		Switzerland	S3	S2, S3
		United Kingdom	S1, S3, S4	S1, S2, S3, S4
	cw	France	S1, S4	S1
		Germany	S2, S3. S4	S3, S4
		Hungary	S1, S2, S3, S4	S2, S3
		Italy		
		Switzerland	S1, S3	S1, S2
		United Kingdom	S1, S2, S3, S4	S1, S2, S4

Table 5:Significant differences between crop – woody combination and crop – grassy and crop – grassy – woody respectively. A more preferred cw combination has a lower rank than the compared combination, a less preferred cw combination has a higher rank than the compared combination

Combination 1	Combination 2	Country	Season series 1	Season series 2
cw is significantly more preferred than	cg	France	S1, S2, S4	S1, S2, S4
		Germany	S2, S3, S4	S2, S3, S4
		Hungary	S1, S2, S3, S4	
		Italy	S4	S4
		Switzerland	S1, S3	S1
		United Kingdom	S1, S2, S3, S4	S1, S2
	cgw	France	S1, S2, S4	S1, S2, S4
		Germany	S3, S4	S4
		Hungary	S1, S2, S3, S4	
		Italy		S4
		Switzerland	S1	S1
		United Kingdom	S1, S2, S3	S1
cw is significantly less preferred than	cg	France		
		Germany		
		Hungary		S1, S4
		Italy		S1, S2
		Switzerland		S2, S3
		United Kingdom		S3, S4
	cgw	France		
		Germany		S2
		Hungary		S1, S4
		Italy		
		Switzerland	S2	S2, S3
		United Kingdom		S3, S4

Significant differences between combinations

In crop-landscapes as Germany, Hungary, Switzerland and United Kingdom, cc- combinations are significantly more preferred when one of the crop fields is flowering. In Germany, series 2 and season 2 the cc-combination is even more preferred than the cw-combination. In most of the other cases, the cc- combination is significantly less preferred than a combination with an SNH. The clearest case for this are the combinations in the United Kingdom, where the cc-combination are never flowering, and the cc-combinations are never preferred to cg-, cgw- or cw-combinations. Contrastingly there are many non-significant differences between all kinds of combinations in the United Kingdom. In Italy, where olive trees are the focal crop and the adjacent crop, in series 1 there is no significant difference between the cc- and the cw- combination. However, the cgw- combination is significantly more preferred to the cw -and cgw-combinations. In France finally, where the core crop and the adjacent crop are vineyards, the cc-combination is often preferred to the cg- and the cgw-combination but not to the cw-combination. Cg-combinations are significantly preferred to cc-combinations, when the grassy element contains a certain amount of colourful flowers. This is the case for Series 2 Season 2 and Season 3 in Switzerland as well as for Series 1 Season 3 in Switzerland.

In these cases the cgw-combination is significantly more preferred than the cw- combination which is often the most preferred combination.

Table 6:Combinations not significantly differing from each other

Combination 1	Combination 2	Country	Season series 1	Season series 2
cc	cg	Germany		S3
		Italy	S1, S2	S2
		United Kingdom	S1, S2, S4	S1
	cgw	Germany	S3	
		Italy	S4	
		Switzerland	S2	S1
		United Kingdom	S2	
cw	cc	France	S2	S2, S4
		Hungary		S4
		Italy	S1, S2, S4	
		Switzerland	S2	S3
		United Kingdom		S3
	cg	Hungary		S2, S3
		Italy	S1, S2	
		Switzerland	S2	
	cgw	Germany	S2	S3
		Hungary		S2, S3
		Italy		S1, S2
		Switzerland	S3	
		United Kingdom	S4	S2

3.2.1.4 Conclusions

The first raw analyses show that SNH in many cases a significant positive influence on landscape aesthetics, particularly woody elements. This influence seems to be stronger in landscapes with traditional crops than in landscapes with three-dimensional crop elements as vineyards and olive groves. Nevertheless, colourful flowering crop elements are significantly preferred to grassy elements, as grassy elements in most cases are not flowering or not flowering at the same time. This is the case for rape seed, the core crop in Switzerland. An interesting case for flowering corps is Hungary, where the core crop is sunflower, which is flowering in season 3. However, in season 3 and 4 cc is significantly less preferred than cg, cgw and cw. For season 4 the case is clear: the sunflowers are faded. But for season 3, the sunflowers are flowering. However, the adjacent crop is not attractive, so as a combination with grassy and or woody is more attractive. It corroborates previous studies which show, that green elements are preferred to brownish elements (Junge et al., 2015). This finding seems to be true even though cited study was in Switzerland and the sunflower pictures were shown to Hungarian people.

Grassy elements seem to be attractive if they bring additional colour in a (brownish) landscape or if they are flowering. However, flowering grassy SNH are rather seldom. In the United Kingdom there is some flowering in season 3 and there is a flowering grassy strip in season 1. Furthermore, the grassy element in Switzerland is flowering in season 2 and 3, however, this flowering is much more attractive in series 2. At least for European crop landscapes the data suggests, that more flowering grassy elements could enhance landscape attractiveness. For the vineyard and the olive landscapes this cannot clearly be answered as there is no colourful flowering grassy element among the showed pictures and all the pictures of the analysed sites. If there had been flowering grassy SNH, they would have been shown.

As mentioned above, hedgerows play an important role for landscape attractiveness as being three-dimensional elements. Nevertheless, as the case of Series 2 in Switzerland as well as of Series 2 in Hungary shows that also for hedgerows their quality seems to be important for landscape attractiveness. It seems that the preferred woody element should be a regular hedgerow consisting of trees, while a low hedgerow or a hedgerow consisting of trees and bushes is not as much preferred.

The first raw analyses corroborate the hypotheses from literature that colourful flowering, trees and vegetation structure plays an important role in landscape aesthetics. These hypotheses will be analysed with discrete choice models.

Acknowledgements

We thank Oliver Frör and Sören Weiss for their helpful assistance while establishing the questionnaire and during the first surveys. We furthermore thank Caroline Gibert for her support with the translation of the questionnaire for France. Gisela Lüscher gave us precious advices for statistical analyses.

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3.3 Soil erosion

Effects of SNH cover and presence on soil erosion in vineyards (France - 2 CS)

Agricultural intensification at different scales is a major driver of losses of biodiversity in human modified landscapes. The landscape-scale reduction in habitat heterogeneity is known to strongly affect biodiversity and associated ecosystem services. Reduction of soil erosion is an ecosystem service that is particularly interesting in the scientific and policy communities in response to the appreciably greater intensity of precipitation in recent years. Where fields can better absorb moisture, e.g. through soil cover, greater soil organic matter levels and semi-natural habitats that reduce the intensity of water runoff, the amount of water ending up in rivers and causing excess downstream is less. Within the QUESSA project, the reduction of soil erosion was selected as an ecosystem service in Estonia, France and the UK.

Mats were only purchased, set up in fields and data collected in both French sites (2 case studies in Mediterranean and oceanic region). 7 fields in each region (14 values shown in following figures) were selected function of the SNH cover within the vineyards (herbaceous cover) and with different slopes.

Mats were collected 3 times during the season between October 2014 untill May 2015. Data were collected and analysed by Benjamin Joubard and Brice Giffard in Bordeaux Sciences Agro.

Figure 1: Pictures of mats used in the vineyard fields in France.

In the following analyses and figures, the quantity of soil collected in each mat was summed for the 5 mats set up at the top of the field (higher elevation) and the 5 mats at the bottom of each field (or less if some of the mats were destroyed or not found). Mats were collected 3 times during the season between October 2014 untill May 2015. Data were summed between the 3 sessions and the quantity of soil is reported as a difference between top and bottom quantities of soil. Then we transformed the quantity of soil per mat in kg of soil eroded per hectare (a mat equals 35x25cm = 0.875m²).

We then tested the effect of slope (measuring in the fields and in aerial maps), weed cover (categorical factor = yes or no) and region (mediterranean vs. oceanic site) on the quantity of loose soil found in the bottom of each field.

Table 1 : Results of the linear model assessing the effects of weed cover, region, slope and 2 interactions (Weed cover x region and weed cover x slope) on the quantity of loose soil (n = 14 values).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-254.0	2195.2	-0.116	0.911
weed_coveryes	-1128.3	2953.5	-0.382	0.712
regionoceanic	1787.5	1491.1	1.199	0.265
slope	240.3	196.5	1.222	0.256
weed_coveryes:regionoceanic	-1515.0	2043.9	-0.741	0.480
weed_coveryes:slope	223.7	306.1	0.731	0.486

Table 2 : Results of the linear model assessing the simple effects of weed cover, region and slope on the quantity of loose soil (n = 14 values).

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-480.2	1740.0	-0.276	0.7882	
weed_coveryes	-355.4	940.2	-0.378	0.7133	
slope	328.3	153.8	2.135	0.0585	.
regionoceanic	787.4	1030.9	0.764	0.4626	

Any significant effect was first found in the first complex analysis but the simplification of non-significant interactions results show us slight different results. We found a significant and positive relationship between slope of the vineyard fields and the quantity of soil loose (difference between the quantity of soil on mats at the top and at the bottom).

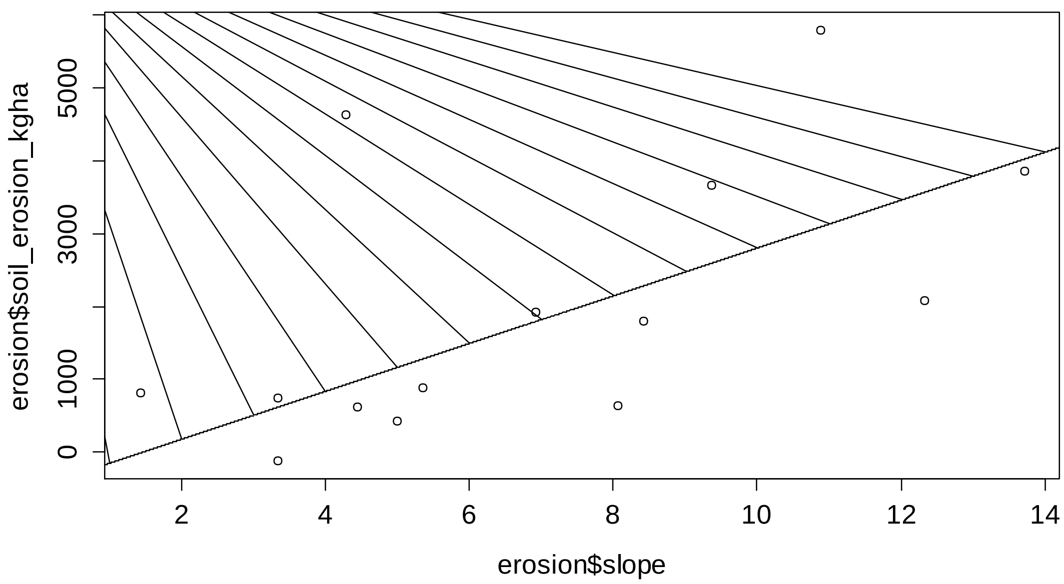


Figure 2 : Relationship between slope of fields (in percentage) and soil loose per field (in kg.ha-1). A significant and positive relationship was found whatever the region and the herbaceous cover in the fields (quantity of soil loose = 328.3 x slope - 480.2, t = 2.135, P = 0.058).

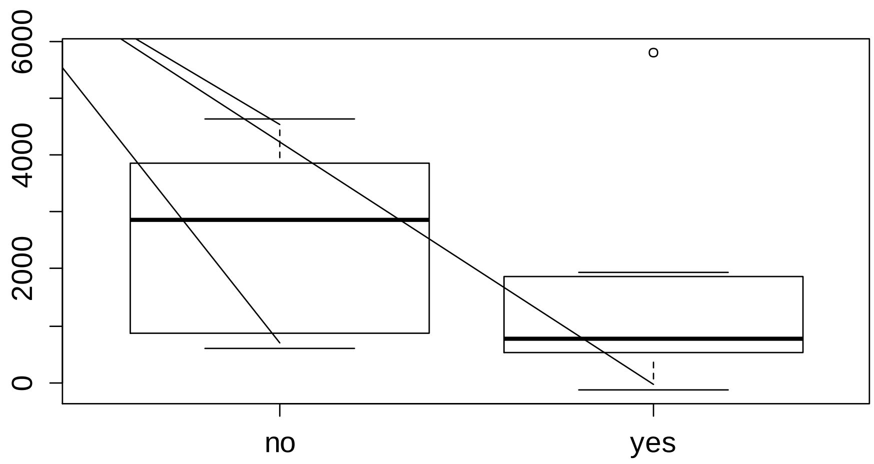


Figure 3 : Effect of herbaceous cover (categorical factor) on soil loose per field (in kg.ha-1).

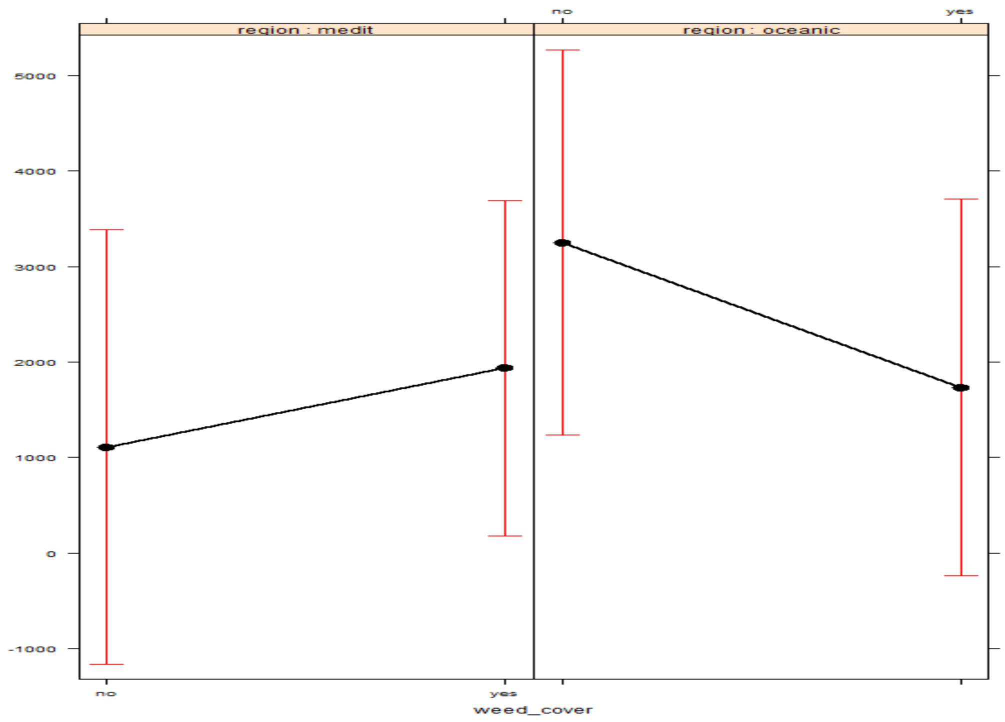


Figure 4 : Effect of herbaceous cover in interaction with region (categorical factor) on soil loose per field (in kg.ha-1).

Any significant effect of herbaceous cover and/or region was found on soil erosion measured using mats (see Table 2, Figures 3 and 4). However, there may be a tendency to measure a higher soil erosion in vineyard fields without herbaceous cover ("no" modality in Figure 3), even this trend was not found significant. This lack of significance may be due to the low number of replicates but further researches should be focused in this particular issue, in particular when working on vineyard or other crop systems with high slopes.

3.4 Soil fertility

3.4.1 Estonia

Authors: Eve Veromann, Gabriella Kovacs, Riina Kaasik

3.4.1.1 Introduction

For the farmers, soil fertility is the most important ecosystem service that influences directly the yield quantity and therefore their income. The loss of soil fertility is an important problem in large areas that have been used for agricultural production for decades and that is a main problem that farmers encounter every day. Fertility loss affects directly biomass and crop production. The aim of this study was to measure the soil organic matter of the soils of focal fields and semi-natural habitats.

3.4.1.2 Methods

The data were collected according to the soil sampling protocol. Samples were taken from focal fields and from woody linear and herbaceous linear habitats. Composite samples consisted of 20 subsamples, collected from several sampling points in the field or SNH. Subsamples were mixed thoroughly and analysed in the laboratory.

Soil organic carbon determination was carried out with dry combustion method by Carbon/Nitrogen analyser.

3.4.1.3 Results

All soil fertility characteristics – C:N ratio, soil organic matter and soil organic carbon – were significantly greater in the semi-natural habitats compared to their adjacent focal fields ($p<0.05$; Figure 1, 2).

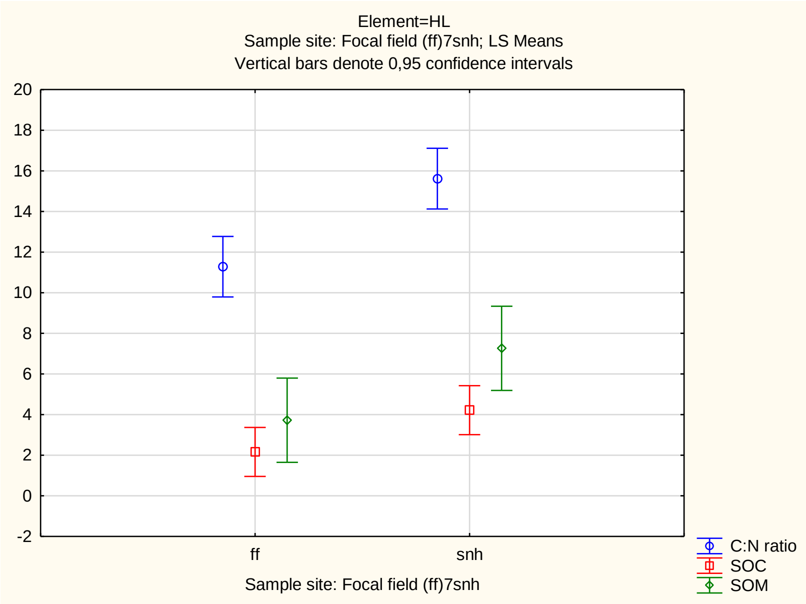


Figure 1. All soil fertility characteristics were significantly ($p<0.05$) greater in the herbaceous linear habitat compared to the adjacent focal field, 2014, Estonia

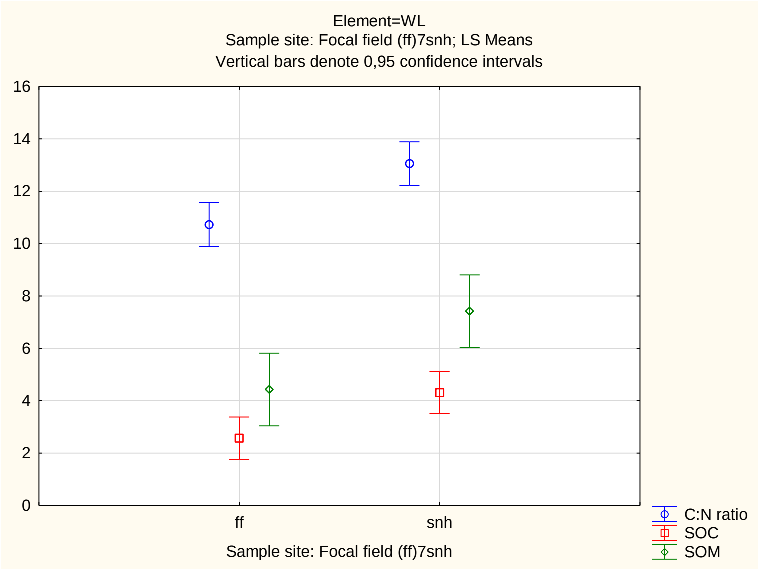


Figure 2. All soil fertility characteristics were significantly ($p<0.05$) greater in the woody linear habitat compared to the adjacent focal field, 2014, Estonia.

Comparing the data of herbaceous and woody linear elements, revealed that C:N ratio was significantly greater in herbaceous linear habitats than in woody linear habitats ($p=0.026$; Figure 3). There were no differences in soil organic carbon and matter between herbaceous and woody linear habitats.

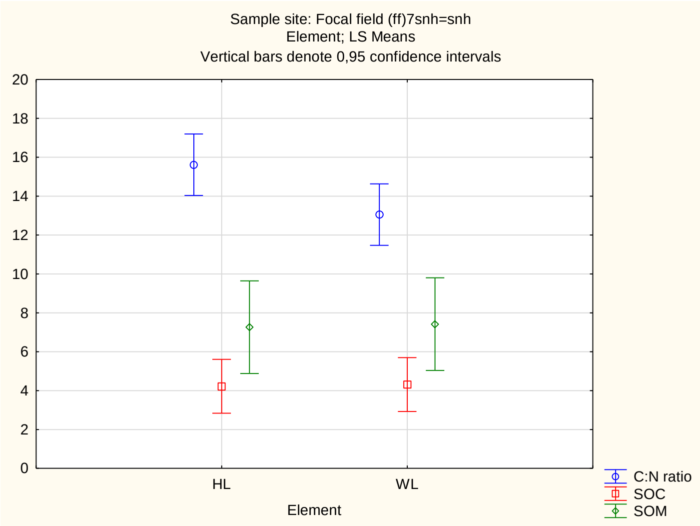


Figure 3. The comparison of soil fertility characteristics in the herbaceous linear and woody linear habitats, 2014, Estonia.

None of the studied focal fields differed from each other in soil fertility characteristics (p>0.05; Figure 4).

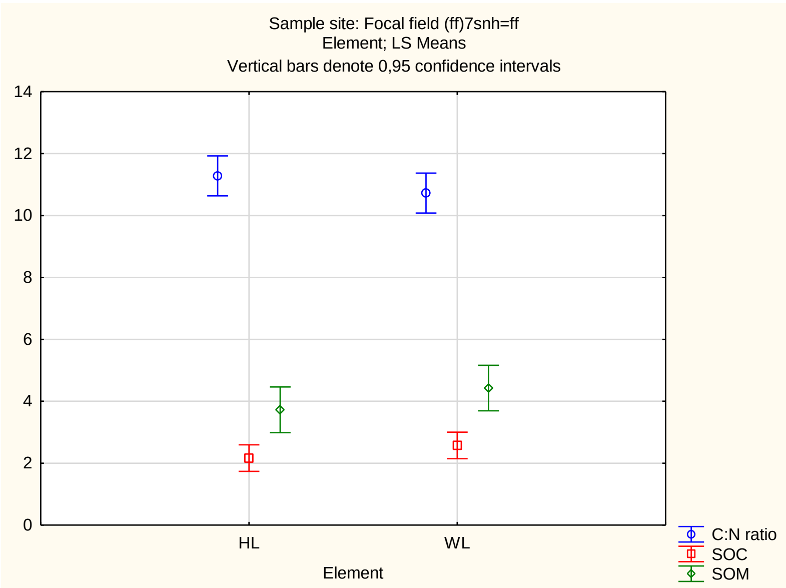


Figure 4. The comparison of soil fertility characteristics in the focal field adjacent to herbaceous linear and woody linear habitats, 2014, Estonia

3.4.1.4 Conclusion

Our preliminary analysis showed that semi-natural habitats contribute to the maintenance of soil organic carbon, soil organic matter as well as carbon sequestration.

3.4.2 Hungary

3.4.2.1 Introduction

Soils provide a wide range of ecosystem services (ESs) (provisioning, regulating, supporting and cultural) that are beneficial and crucial to humankind. These different ESs are due to soil physical (texture, structure, etc.), chemical (total carbon, nitrogen content, E4/E6 ratio, pH, CaCO3, etc.) and biological properties, which all together determine soil fertility (C-storage, water and nutrient holding capacity, etc.).

3.4.2.2 Materials and Methods

In 2013, 18 wheat and 18 sunflower fields were selected in Jászság Region, Central-East Hungary as focal fields (FFs) of the investigation. Moreover, 18+18 landscape sectors with one-kilometer radius were defined with the focal fields and in the centre (Figure 1). In each landscape sector, four different types of semi natural habitats (SNHs) were selected: a woody linear (mainly woody vegetation, minimum 30% of woody cover), a woody areal (mainly woody vegetation, minimum 30% of woody cover), a herbaceous linear (mainly herbaceous vegetation, maximum 30% of woody cover) and a herbaceous areal SNH (mainly herbaceous vegetation, maximum 30% of woody cover).

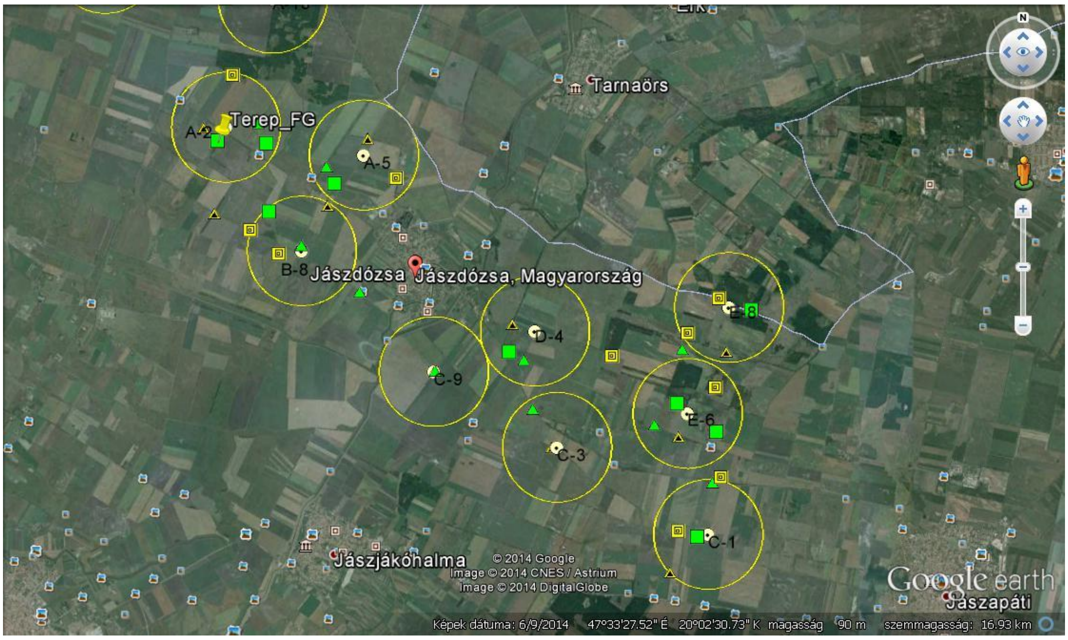


Figure 1. Location of landscape sectors, focal fields and SNHs on QuESSA test areas

Soil Sampling Method

The soil samples from SNHs and FFs were taken in October, 2013. The top 30 cm of soil was sampled along the diagonals. Twenty subsamples were taken from each area (composite sample), the sample was mixed and about one kg of soil was taken to the laboratory for further analyses.

Laboratory Analyses

The soil samples were air dried, crushed and passed through a 2mm sieve for the following analyses: a) pH(H2O), pH(KCl) (potentiomertic measurement); b) CaCO3 content (Scheibler method); c) total carbon and total nitrogen content (dry combustion); d) E4/E6 ratio; and e) saturation percentage (Arany's method).

Tea bag study

The wheat focal fields (FF) of the pest control case study and the adjacent SNHs were investigated in this study in April of 2015. There were six FFs without SNH, six FFs with woody adjacent SNH and six FFs with herbaceous adjacent SNHs in the 18 landscape sectors. The soil samples were taken along the predation transects of each focal field and SNH. Two predation transects (left and right) were designated on the area, 20 meters from each other. Two and 25 meters from the edge of the FF teabags were placed into the soil (Figure 2). Pyramid Lipton Green and Rooibos tea bags were buried into these soils 8 cm deep to determine the decomposition rate of these tea bags in soils under different land use. The time of exposure of these tea bags in the soil was 90 days. Moreover, soil samples were taken from the sample points. If there was adjacent SNH then we also placed tea bags and took soil samples (left and right side) about 2-4 meters from the edge along the transects (Figure 2).

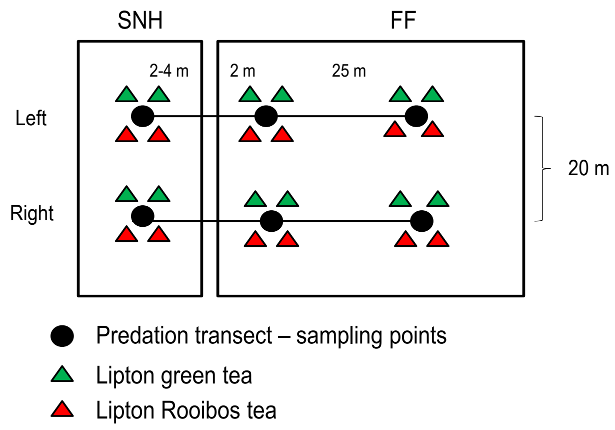


Figure 2. Layout of soil sampling of tea bag study in spring of 2015

3.4.2.3 Results

Total carbon and total nitrogen content

In 2013, the greatest total carbon content values were obtained for the soils of the woody sites (WL: 4,6% and WA: 3,8%), intermediate values for the herbaceous sites (HA: 3,33% and HL: 3,26%), and the lowest values were gained for the agricultural sites (2,6%, Figure 3). The total nitrogen content did not differ significantly among the different land uses (Figure 3). However, the highest value (0,65%) was in the WL SNHs and the lowest value (0,42%) was obtained from the agricultural site.

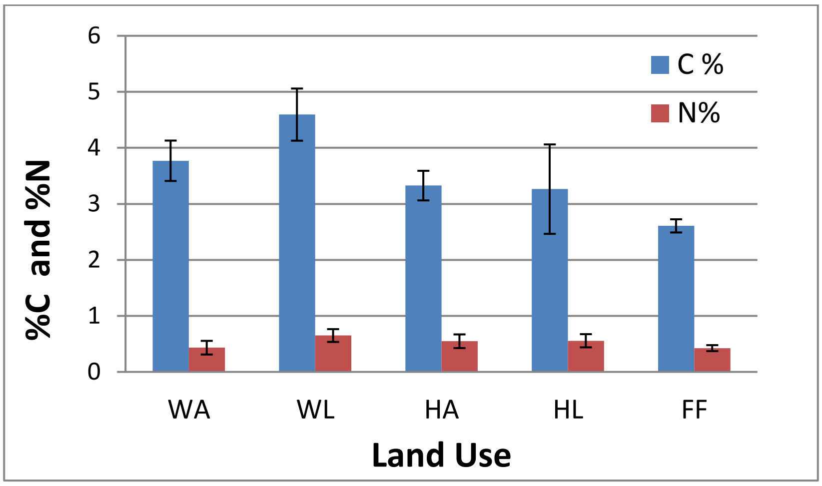


Figure 3. The total carbon and total nitrogen content (Jászság, 2013)

Based on the results of the saturation percentage by Arany's method, we separated the total carbon and total nitrogen values based on their textural classes. Two main textural classes were formed: fine and coarse. The fine textural class contained the heavy clay (HC), clay (C) and clay loam (CL) textures. While the coarse textural class contained coarse sand (CS), sand (S) and sandy loam (SL). We pooled the total carbon and total nitrogen values of the linear and areal elements within the woody and the herbaceous SNH categories (Figure 4). The highest values were obtained in the fine textured soils, particularly in woody SNHs. In case of the coarse textured soils, the highest values were also in the soil samples of woody SNHs (3,4%). The total nitrogen content varied between 0,28 and 0,67% for all samples (Figure 4).

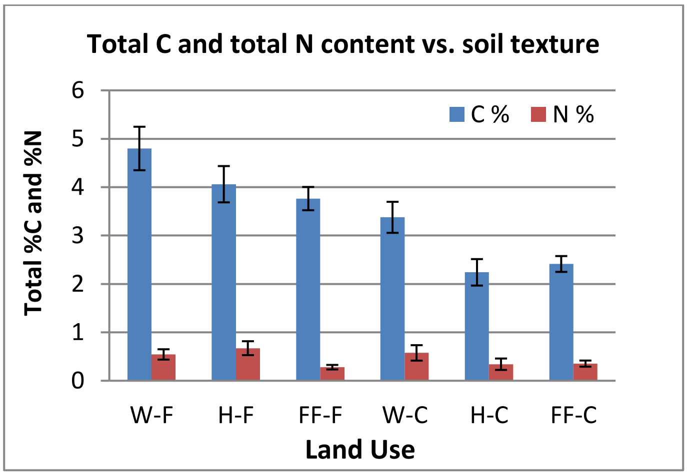


Figure 4. Total carbon and total nitrogen content vs. fine (F) and coarse (C) soil textural classes

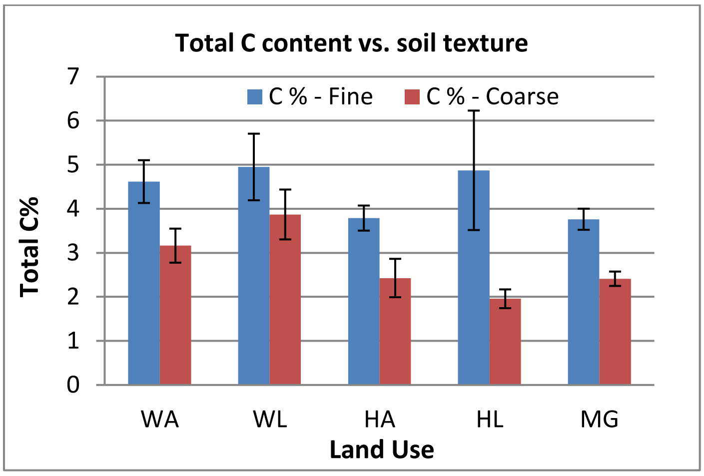


Figure 5. Total carbon content vs. fine and coarse soil textural classes

Comparing the total carbon values in the fine and coarse soil texture groups, the values were always higher – regardless of land use – in the fine textured soils (Figure 5). This finding, that finer textures protect the soil organic carbon (SOC) fraction, coincides with the literature.

Results of Chemical Analyses for the soils samples collected in 2015

The pH(H2O) values were between 5,9 and 6,3 (slightly acidic); and the pH(KCl) values were between 5,04 and 5,5 (acidic). There was not any significant difference among the different land uses.

The soil calcium carbonate content was very low in all land use types (less than 0,5%).

The E4/E6 ratio is used to characterize soil organic matter (SOM), this is the ratio of absorbance at 400 nm and 600 nm of a solution is measured in a UV-VIS spectrophotometer. The higher numbers (7-8) suggest higher amount of smaller molecular weight fulvic and humic acids, while lower values (3-5) refer to larger molecular weight humic acids. Thus, the lower the number, the more complex and larger molecules are present in the SOM fraction. In our samples, all ratios were between 3 and 5, indicating humic acid dominance. We got lower values for the soils of the FFs, but they did not differ significantly.

The total carbon content was the highest in the herbaceous SNHs in soil samples taken in 2015, while it was the lowest in the FFs (Figure 6). In addition, the total nitrogen content showed similar pattern.

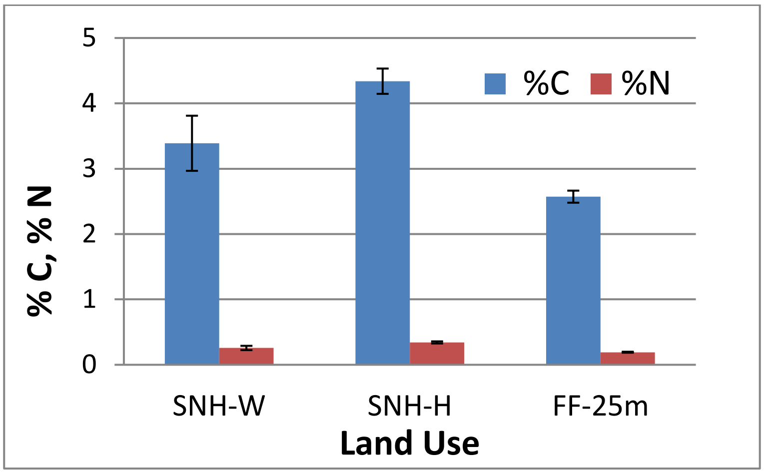


Figure 6. The total carbon and total nitrogen content of the soil samples (2015)

Decomposition rate of tea bags

The weight loss of the tea bags were different for the Green and Rooibos tea (p<0.01); however, the same pattern was not observed for the two tea types. The herbaceous SNH samples resulted lower weight loss for the green tea (p=0.01), while samples closer to the field centre (25m from the edges) had higher decomposition rate of the Rooibos tea (p<0.01, Figure 7)

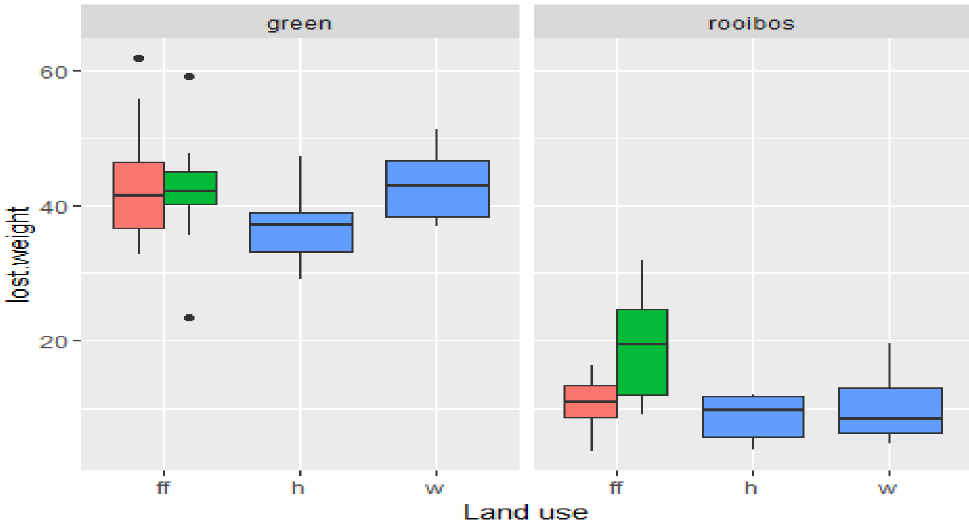


Figure 7. The lost weight of Green and Rooibos tea bags in soil of wheat fields (ff, from 2m (salmon) and 25m (green) from edges) and of adjacent herbaceous (h) or woody (w) SNHs.

The total carbon content of the soil affected the decomposition rate for both tea types (p<0.01, Figure 8): the higher carbon values resulted in lower decomposition rate, and this effect was similar in the two tea types (p=0.63) assuming linear relationship.

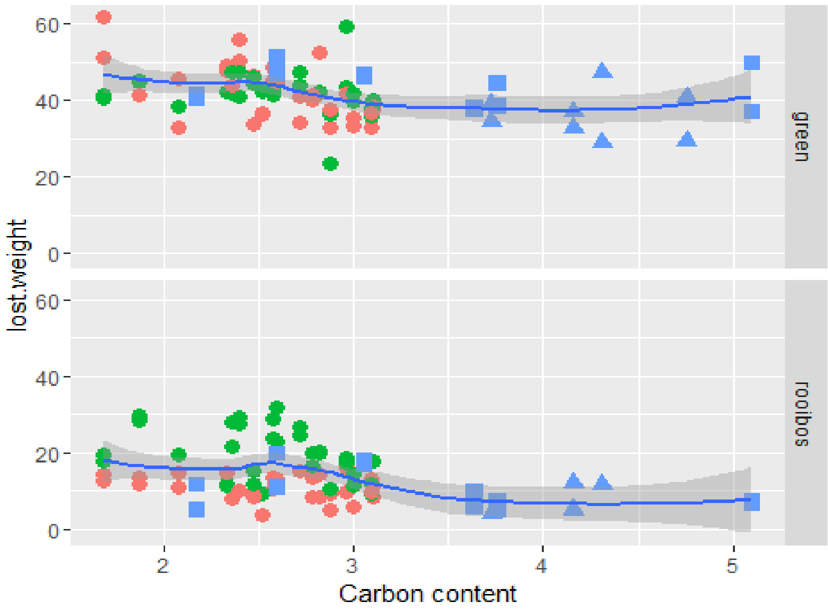


Figure 8. The effect of soil carbon content on lost weight of green and rooibos tea bags placed in wheat fields (circles, from 2m (salmon) and 25m (green) from edges) and of adjacent herbaceous (triangles) or woody (w) SNHs.

3.4.3 France

Author: Brice Giffard

3.4.3.1 Introduction:

Agricultural intensification at different scales is a major driver of losses of biodiversity and associated services in human modified landscapes. Soil carbon levels are under pressure from rotations with cash crops, in which soil organic matter turnover is enhanced by intensive tillage and the ensuing carbon loss is not replenished by crop residues. The same issue also applied to perennial crops where the repetition of tillage or herbicide use may affect herbaceous communities and cover, bringing an increase of soil erosion or a decrease of soil fertility. Indeed, the resulting low soil organic matter content may affect the capacity of the soil to absorb water, which aggravates runoff of water and soil in hilly areas, and causes excess problems at lower altitudes.

The aim of these experiments was to measure soil organic matter content of the soils of focal fields (FF) and semi natural habitats (SNHs) in order to provide a comparative assessment of the nutrient holding and nutrient providing capacity between these habitats. At the same time, we also measure soil decomposition rate using a new technique in order to see difference between vineyard fields and SNHs and its relationship with data acquired through sieve analyses.

Total carbon and nitrogen content were assessed through analyses performed by a private lab for both sites in France as well sieve analyses. Soil samples were taken by French members directly on FF and SNHs of both sites in October/November 2014 following the proposed protocol and the lab's recommendations. All the variables collected are percentages of clay, silt, sand, organic matter, nitrogen, pH, and CaCO3, P2O5, K2O, MgO quantities (g/kg of soil). All this information has also been transferred to vine-growers who can be interested in such analyses.

Soil decomposition rate was measured using tea bags in the SNH and in the focal fields (FF) along a transect of 4 distances from the edge of the SNHs towards the centre of the field (same distances as the WP3 predation protocol) in order to provide a comparative assessment of the soil decomposition rate in all fields of all sites. All this protocol is based on the article of Keuskamp et al. (Methods in Ecology and Evolution 2013). The purpose of the following analyses is to assess differences between regions (Case studies) and/or habitats (semi-natural or fields) on organic matter sequestered in soils (as well as nitrogen content). Soil parameters (not influenced by the management different between SNH and fields) are added as a single covariable (clay content strongly linked to organic matter process).

3.4.3.2 Conclusion

SNH are characterized by a higher organic matter content and nitrogen in the upper layer of soil (and even more in woody areas) whatever the region (Mediterranean or oceanic). Moreover, decomposition rates strongly vary between regions and habitats (Figure 3c). Mediterranean CS showed lower decomposition rates and same positive effects of semi-natural habitats, whereas the rate of decomposition is higher in the oceanic region but similar between habitats tested. These results, although incomplete because of a lack of replicates (only 5 to 6 herbaceous SNHs sampled per region) and of technical expertise on the part of French partners, show however a large body of evidence that semi-natural habitats are particularly important for the higher content of Organic matter of their soils (linked to carbon sequestration) as well as other ecosystem services such as the capacity of the soil to absorb water.

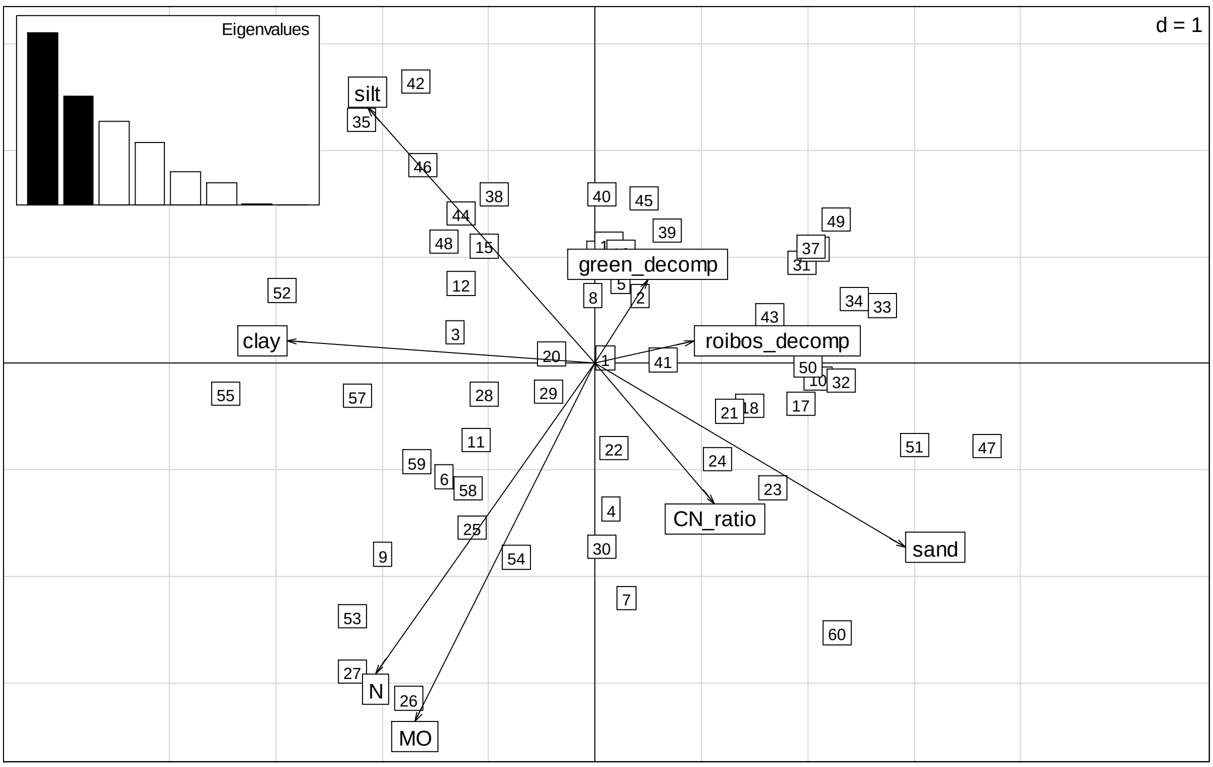


Figure 1: Principal component analysis (PCA) results using the most important soil variables (clay, silt, sand percentages, quantities of Nitrogen [N] and organic matter [MO], C/N ratio) and decomposition rates measured with tea bag decomposition (roibos_decomp and green_decomp). PCA Axis 1 separates sandy vs. clay-loam soils; the second ones are associated with higher nitrogen and organic contents but lower decomposition rates.

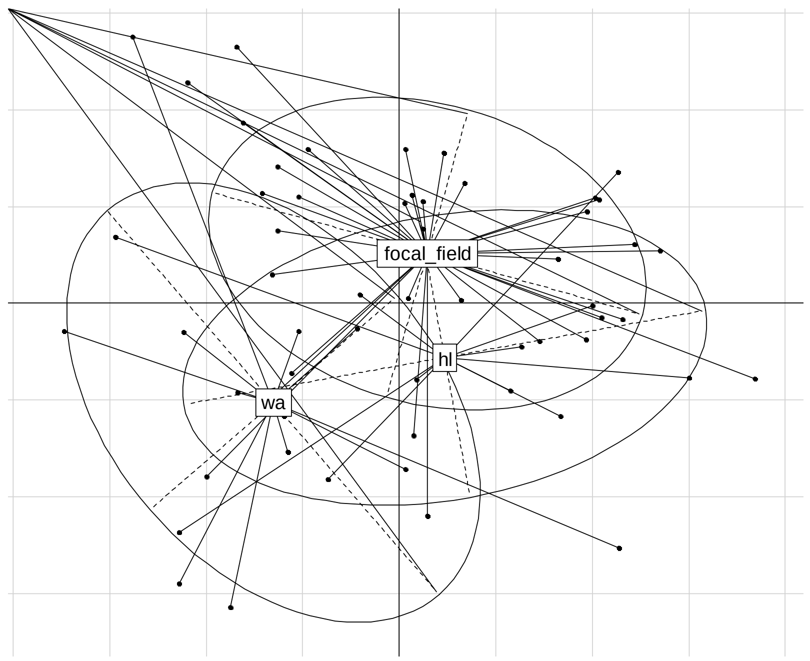


Figure 2: Principal component analysis (PCA) results showing the repartition of samples collected in hl (Semi-natural habitat Herbaceous Linear, n=11), wa (Semi-natural habitat Woody area, n=12) and focal_field (vineyard fields, n=36). Samples collected in semi-natural habitats appear to show higher concentrations of organic matter whereas soils from vineyard fields are strongly associated with higher decomposition rates.

	Region	Habitat	Clay content	Interaction term: Region x Habitat
Organic matter	0.62	**16.73 *** **	3.61	2.92
Nitrogen content	1.18	**18.41 *** **	**9.27 ** **	1.89
C/N ratio	0.03	0.12	**6.71 * **	0.66
Green tea decomposition rate	**44.28 *** **	1.88	0.13	**6.57 ** **
Roibos tea decomposition rate	**8.69 ** **	1.09	2.96	0.01

Table 1: Summary of LM (Linear Models) assessing for the effects of habitat (3 modalities which are Herbaceous linear, Woody area (SNH) and vineyard field), region (two case studies in Mediterranean and oceanic climatic contexts) and clay content on organic matter content, nitrogen content, C/N ratio, and decomposition rates measured on green tea bags and roibos tea bags. Interaction term between region and habitat was tested and removed if non-significant. Statistics shown are F-values associated with asterisks and written in bold when significant (* p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001).

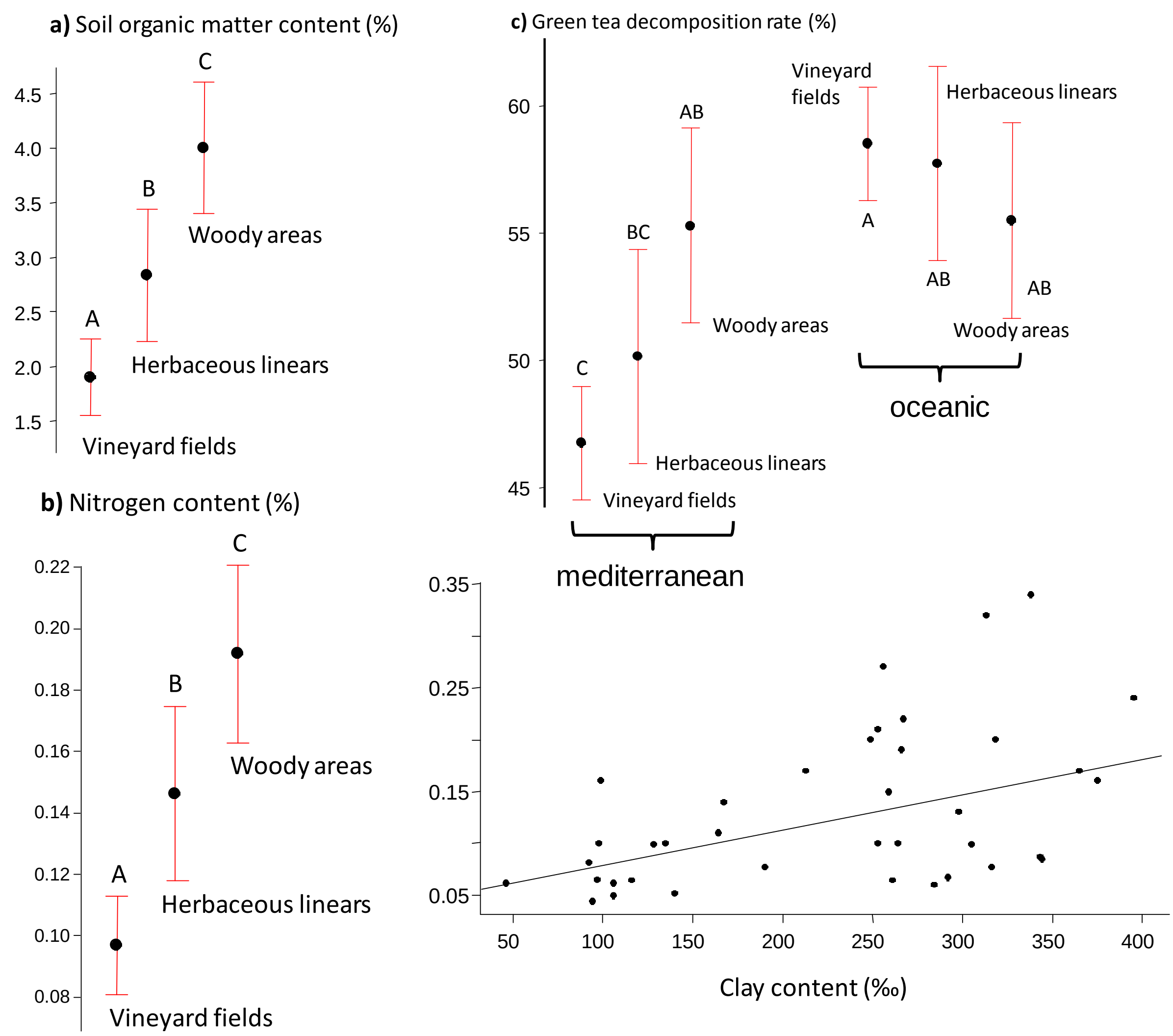


Figure 3: Relationship and/or effect of Region, Habitat and/or clay content on a) organic matter content, b) soil nitrogen content, and decomposition rates measured on c) green tea bags and. Only significant effects highlighted in Table 1 are shown. Different letters indicate significant differences between values (tested using Tukey HSD at $p<0.05$).

3.5 Organic matter storage

Authors: John Holland & David Stevenson

3.5.1.1 Introduction

Semi-natural are typically comprised of perennial vegetation and consequently there is potential for them to accumulate soil organic matter and therefore store carbon (carbon sequestration). Globally soils are the second largest terrestrial store of C after geological pools (e.g. minerals, gas) storing 2500 Pg (1012 kg) of carbon in total (including inorganic carbon). However, intensive agricultural practices including conventional tillage, irrigation and intensive cropping can deplete or alter stocks of soil organic carbon (SOC) in agricultural soils. In this study we investigated whether (1) carbon sequestration an important ecosystem service from SNH on arable farmland? (2) Which habitats are most important for provisioning carbon sequestration on arable farmland? The same SNH as investigated for pest control and pollination were examined along with cropped fields as these represent the predominant land use.

3.5.1.2 Methods

The same 18 landscape sector study sites were used as for the pest control and pollination studies. At each site two wheat fields and SNH were sampled from in total 35 fields, 12 herbaceous linear, 11 woody linear and 11 wood areal habitats. Each sample was a "composite" sample derived from ten soil cores (0-30 cm) taken across each field/SNH being sampled. Within fields samples were taken in an "X" shaped pattern and from linear habitats in a transect. % soil organic matter (SOM) was calculated using loss on ignition. From % SOM data, t C ha-1 for each sample and mean estimates of tonnes of carbon stored for each habitat were calculated and carbon stored per 1 km radius landscape sector using the proportion of each habitat type from GIS data.

3.5.1.3 Results

Mean values of t C ha-1 varied both between sites and within sites, as well as between habitat types. A wide range of mean t C ha-1 was observed but that generally fields had the lowest t C ha-1 of all habitat types for each site, with the exception of two woody linear and one woodland. Median values of t C ha-1 were found to be significantly greater in SNH (144.47 t C ha-1) compared to fields (120.09 t C ha-1) (Mann-Whitney U test: U=358, N1=35 N2=34, p=0.0045). Values of t C ha-1 were compared between all habitat types by mean rank and found to be significantly different (Kruskal-Wallis test: H=13.16, d.f.=3, p=0.004). Herbaceous linear margins had the greatest mean value (171.604 t C ha-1) and post hoc tests revealed that only these had significantly greater mean rank of t C ha-1 than fields, approximately 35% more carbon. Woodland had 30% and woody linear 7.5% more soil carbon than fields. Despite having the lowest mean t C ha-1, across the 1 km study site the fields stored 82% of the soil carbon, woodland 12% and the other habitats <3% (Fig. 2).

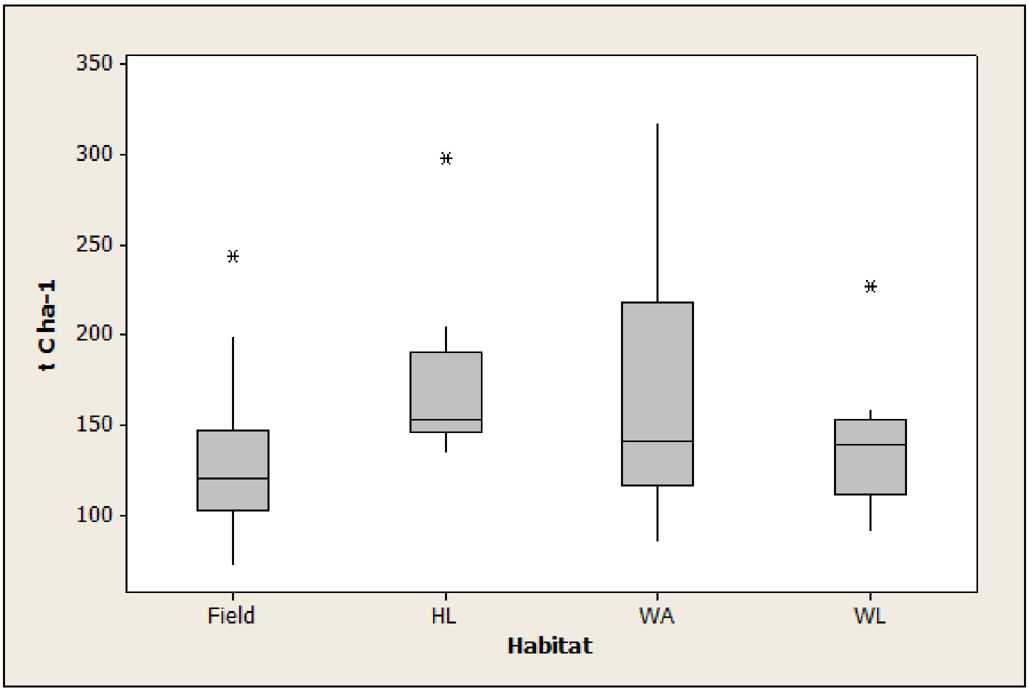


Figure 1. Mean t C ha-1 for fields and individual Semi-natural habitats. HL=herbaceous linear; WA=woody areal; WL-woody linear

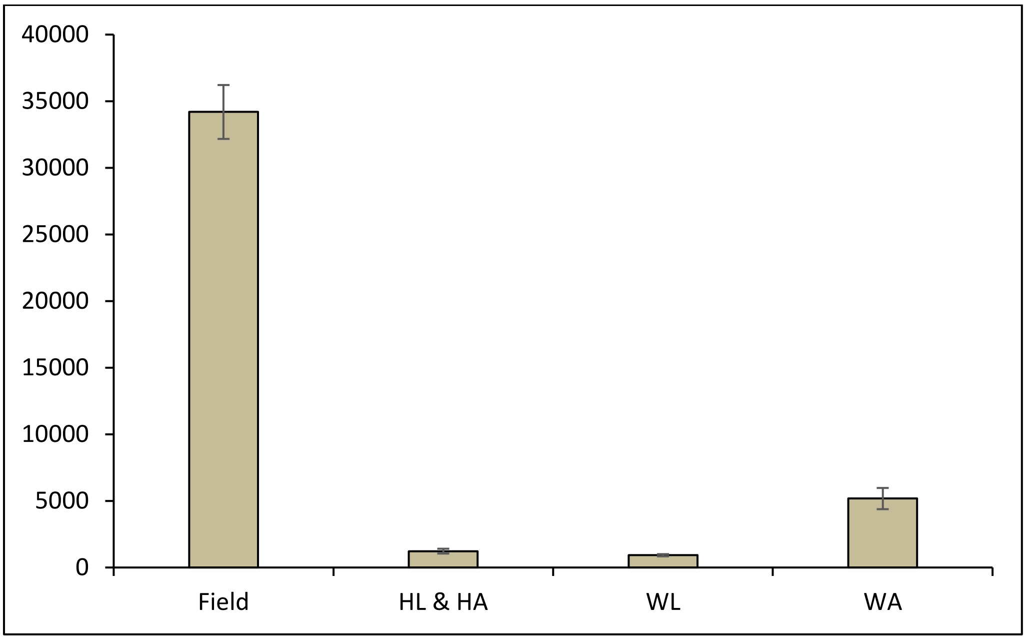


Figure 2. Total carbon stored per 1 km radius landscape sector.

3.5.1.4 Conclusions

The study revealed that the vast majority of soil carbon is stored with cropped fields rather than semi-natural habitats in agricultural landscapes. The UK contains over 6 million ha of cropland, hence there is great potential to increase carbon sequestration by building soil organic matter. Many of Europe's soils have become degraded due to intensive tillage and cropping yet there is potential though conservation agriculture to restore soil organic carbon and improve levels of carbon sequestration. Improving soil organic matter also has many other benefits. These include: 1) providing greater resilience to drought and flooding that can help stabilise yields, 2) reducing the risk of soil erosion and run-off and 3) improving soil workability and thereby reduce cultivation costs and associated carbon emissions.

The herbaceous habitats stored 35% more soil carbon than the fields indicating that permanent grassland could also potentially be important in carbon sequestration. Further carbon will be stored in the above ground vegetation of SNH and this is likely to be highest for woodland, potentially storing up to 20.2 kg C m-2. Overall up to ~60% of the carbon in forest ecosystems may be stored within live and dead stands of trees. Of the all the SNH types the greatest variability between sites occurred for woodland. In addition, the highest level of soil carbon was recorded in for a woodland site (317.653 t C ha-1) showing there is potential to make improvements. The variation may be due to differences in the age, level and composition of tree cover.

The implications of these findings are that future policy must recognise that both fields and SNH are important for carbon sequestration. Research on carbon sequestration has traditionally focused on agricultural fields, which are important for carbon sequestration, as the results from this study have shown. Techniques to improve carbon sequestration in fields are already known, including low or no tillage, improving carbon sequestration in agricultural soils would also bring a secondary benefit of improving crop yield. This has been referred to as a "win-win" policy which could mitigate climate change and aid global food security for a growing global population. SNH, however are also important for provisioning carbon sequestration. Research is lacking on SNH and carbon sequestration. In particular research is needed on how carbon sequestration can be improved in SNH. Additionally, work is needed to understand the effects of management techniques on carbon sequestration from SNH.

3.6 Biodiversity conservation

3.6.1.1 Aims

Biodiversity is an ecosystem service which is globally threatened. The conservation of biodiversity is essential for the preservation of the intrinsic value of species. Moreover, biodiversity is important to support ecological services in agriculture. Here, we aim to evaluate the importance of different seminatural habitat types and the landscape complexity for alpha and beta diversity and for species of conservation concern. This preliminary analysis focused on carabids in the UKL case study, but for publication as much taxonomic groups in as much case studies as possible should be integrated. The research questions are:

1. How do different semi-natural habitat types differ in their conservation value in terms of alpha diversity, beta diversity and number of species of conservation concern?
2. Is the conservation value related to the landscape complexity?
3. [Are the patterns consistent across taxa (and European regions)?]

3.6.1.2 Methods

Data

All relevant data (determination up to species level) of WP 2 sampling can be used. Here we used the pitfall trap data of carabids in the UKL case study.

Diversity measures

We used observed species richness as a measure for alpha diversity. Beta diversity was divided into temporal and spatial beta diversity. We calculated temporal beta diversity by additive partitioning as the difference between total observed species per plot and mean species richness per plot per sampling interval. Spatial beta diversity between seminatural habitats of the same type was analysed by calculating the mean distance to group medians using multivariate homogeneity of dispersions based on the Sorensen-index (betadisper).

Data analysis

Species richness, temporal beta diversity and spatial beta diversity were related to semi-natural habitat type ‘SNH’ (factor with four levels: HA, HL, WA, WL) and landscape complexity ‘LAND’ (continuous and expressed as % SNH in 1 km radius around the focal SNH) and their interaction with linear mixed models (lmer). We included region as random effect, because four different SNH were always located within one agricultural region and therefore spatially not independent. The number of endangered species (species of the regional red list) followed a poisson distribution and was related to SNH and LAND using generalised linear mixed models with region as a random effect. Since overdispersion was detected we used a quasi-Poisson model (glmmPQL). Significance of explanatory variables was tested with subsequent ANOVA (Anova).

Species composition was related to SNH and LAND and their interaction with permutational multivariate analysis of variances (adonis). To account for the nested design we used region for strata. Species composition was visualized using NMDS.

3.6.1.3 Results

SNH had a significant effect on species richness, temporal beta diversity, spatial beta diversity and the number of red list species (Tab. 1). Species richness, temporal beta diversity and number of red list species were higher in herbaceous SNH than in woody ones (Fig. 1). In contrast, spatial beta diversity (community variation) was higher in woody SNH than in herbaceous ones (Fig. 1).

Species composition of carabids was significantly related to SNH ($F = 3.26$, $P < 0.001$, $R^2 = 0.13$) and LAND ($F = 2.71$, $P = 0.022$, $R^2 = 0.04$) (Fig. 2).

Tab. 1: Response of species richness, temporal beta diversity, spatial beta diversity and the number of red list species of carabids to seminatural habitat type and landscape complexity and their interaction.

	SNH		LAND		SNH:LAND	
	Chi2	P	Chi2	P	Chi2	P
Species richness	13.71	**0.003**	1.09	0.296	0.66	0.883
Temporal beta diversity	12.02	**0.007**	2.18	0.139	0.78	0.854
Spatial beta diversity	11.86	**0.008**	2.50	0.114	3.26	0.353
Red list species	9.72	**0.021**	1.82	0.178	3.04	0.386

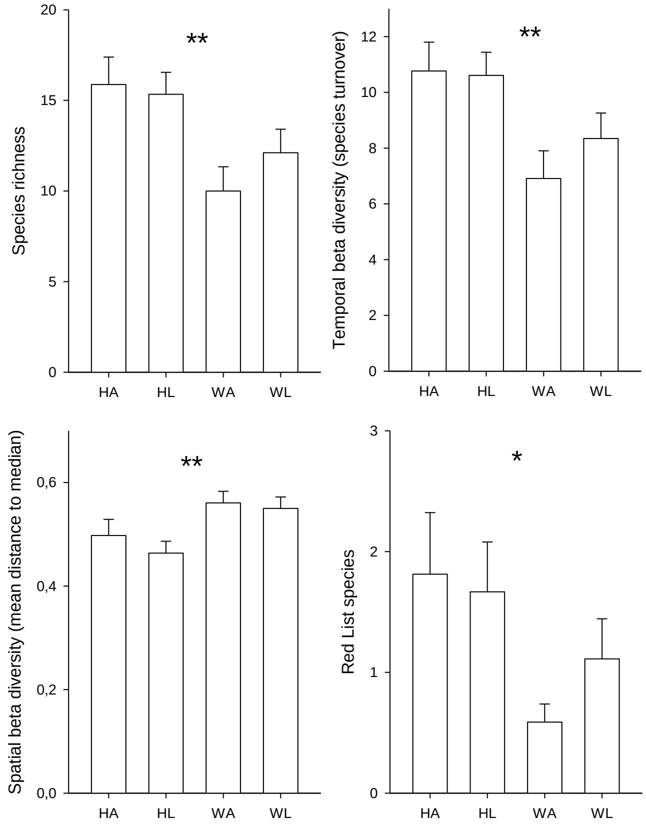


Fig. 1: Comparison of species richness, temporal beta diversity, spatial beta diversity and the number of red list species of carabids in four different seminatural habitat types.

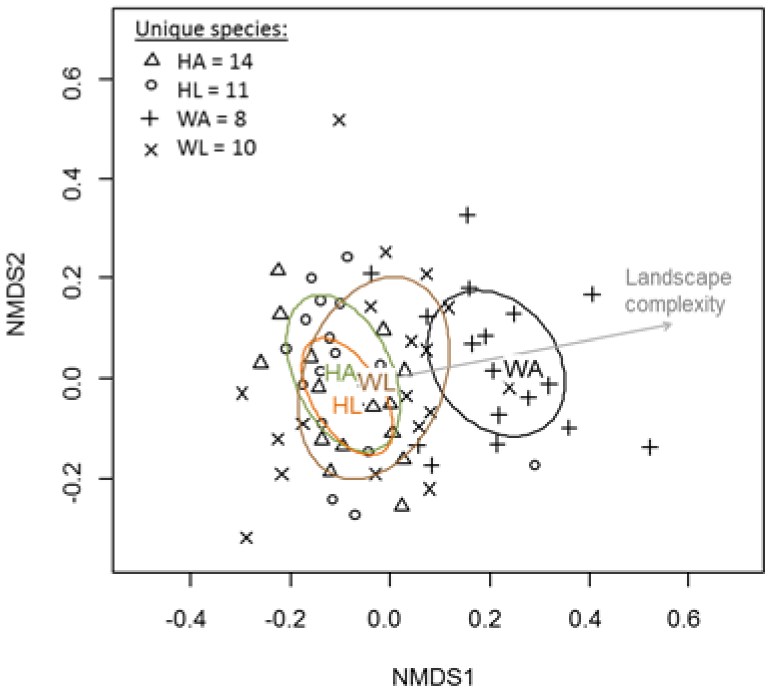


Fig. 2: Seminatural habitat type and the landscape complexity were significantly related to species composition of carabids in seminatural habitats.

3.6.1.4 Conclusions

Our preliminary analysis showed that seminatural habitats contain several species including species of conservation concern. Therefore, seminatural habitats can be important for species conservation in agricultural landscapes. The conservation value thereby differed among seminatural types. Herbaceous elements are important for endangered species and support a high species richness and temporal beta diversity. In contrast, woody elements showed higher spatial beta diversity, i.e. community variation among woody elements is higher than in herbaceous elements. Interestingly, landscape composition had no effect on species richness, beta diversity and the number of endangered species. Hence, even in simple landscape seminatural habitats have a high conservation value for carabids.

3.7 Weed invasion (disservice)

Authors: Anna-Camilla Moonen, Stefano Carlesi, Zita Dorner, Mihály Zalai

Published: Semi-natural habitat types provide different disservices in terms of weed infestations in European arable fields. In: proceedings of the 7th International Weed Science Society Symposium, Prague 19-25 June 2016. p. 102.

3.7.1 Introduction

QuESSA focusses on quantification of ecosystem services from SNH to the main European cropping systems. However, farmers often refer to SNH as source of weeds and pests. The impact weeds have on the crop is mainly through competition for resources such as water, nutrients and light. The competitive capacity of weeds depends on their growth habitat and life strategies and therefore not all weeds are equally competitive. At the same time, also crops differ in susceptibility to the presence of weeds. Another important aspect of weed management is the risk that weeds establish in the field more permanently through build-up of the weed seedbanks and or rhizomes. Determination of the way in which weeds propagate provides important information on the disturbance level of the cropping systems and is useful for decision making on the most effective weed management strategy. It is therefore important to identify weeds at genus or possibly at species level. The aim of this work was to quantify if weed cover and community composition depend on 1) the type of SNH adjacent to sunflower fields and 2) the amount of SNH present in the landscape sector. We hypothesised that weed invasions in the FF will be higher adjacent to herbaceous SNH than next to woody elements because woody vegetation is less adapted habitat for species of disturbed habitats, while the effect is generally limited to the outer 10-15 m of the field. We also hypothesized that the impact of SNH type on the weed community composition is limited and that sunflower management is more important.

3.7.2 Methods

In 2014 and 2015 a total of 62 sunflower fields were selected in Italy and Hungary and these are the same focal fields used for determination of pollination service provided by SNH. Weed composition was determined by scoring density and percentage cover of the species in 14 1m2 plots in each field about 3 weeks after the main weed management practices were performed in the crop. The plots were positioned along 2 transects, 10 m apart, at increasing distances into the field. The usual 4 distances foreseen in the Quessa protocol were not considered relevant for measuring weed invasions from the adjacent SNH into the field and therefore more plots were added especially in the crop edge, summing up to a total of 7 distances from the border to the field centre (1, 2, 10, 15, 25, 50 and 75 m).

Weed species richness in the sunflower fields and log-transformed weed cover data for species and for trait groups ((*annua*l monocot, perennial monocot, *annua*l dicot, perennial dicot, perennial dicot or monocot with rhizomes) were analysed with MANOVA to determine single effects and interactions between the factors ‘Country’, ‘Year’, Distance from field margin’, and ‘Adjacent SNH type’. Weed species composition was analysed with PCA/RDA of the arcsine-transformed data and forward-selection of the explanatory variables included.

3.7.3 Results

Species richness

Species richness in sunflower was not related to proportion of SNH in the landscape sector surrounding the focal field (r=0.156; n=62) neither to adjacent SNH type (P=0.29).

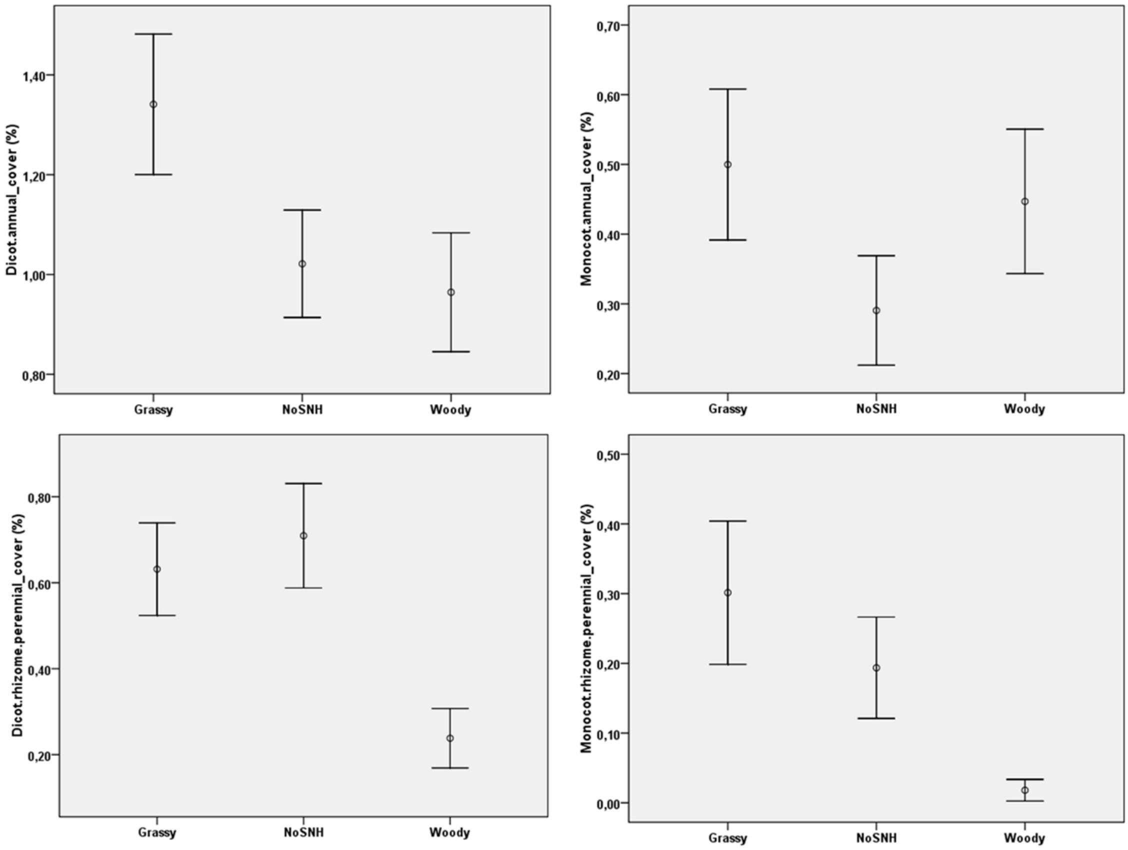
Weed cover of trait groups

The most abundant trait groups were Species of the trait groups *annua*l monocots and dicots and rhizomatous monocots and dicots showed the highest cover. Weed species cover was generally higher in Italian sunflower fields than in Hungarian ones, and cover was higher in 2014 than in 2015. This may be explained by the high rainfall levels in 2014. Weed cover was significantly higher for all trait groups at 1 m from the field margin, but cover was not related to distance from 2 m to the field centre. The main weed trait groups responded differently to adjacent SNH type (Figure 1) and total weed cover is highest adjacent to grassy margins and lowest adjacent to woody SNH. The crop-to-crop situation has intermediate weed densities.

Table 1. P-values resulting from MANOVA of weed trait group cover for the factors ‘Country’, ‘Year’, Distance from field margin’, ‘Adjacent SNH type’ and all interactions.

Trait groups	Country	Year	Distance	Adj_SNH	Country * Adj_SNH	Dist * Adj_SNH	Year * Adj_SNH	Country * Year	Country * Year * Adj_SNH
MA_cover				0.00			0.00	0.00	
DA_cover		0.00	0.02	0.00	0.00		0.00	0.01	0.00
MRP_cover	0.00			0.00			0.00	0.03	0.04
DRP_cover	0.00	0.03	0.00	0.00		0.01		0.04	0.00
MOP_cover	0.00		0.01			0.01		0.04	0.04
DOP_cover	0.00	0.04	0.00			0.00		0.04	0.04
DW_cover									
Total_cover	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.00

Figure 2. Log+1 transformed 5 cover of the trait groups demonstrating a significant difference between the SNH types.



3.7.4 Weed community and weed species in relation to SNH

A number of weed species have different abundance according to the adjacent SNH (Table 2). As expected only few species increase next to woody elements, with the exception of Ambrosia artemisiifolia in Hungary and *Chenopodium album* in both countries. Grassy margins instead affected the presence of most *annua*l dicots, while the crop-to-crop situation stimulated the presence of rhizomatous dicots.

Table 2. Species-environmental factor correlation coefficients resulting from Redundancy Analysis. Only species with a negative or positive correlation to a specific SNH type have been listed.

Species	Trait group	Woody	Grassy	NoSNH
Atriplex.prostrata	DA		0.16	
Chenopodium.album	DA	0.12		
Fallopia.convolvulus	DA	-0.12		
Picris.echioides	DA	-0.21	0.38	-0.18

Polygonum.aviculare	DA		0.40	-0.44
Polygonum.lapathifolium	DA	-0.27		0.18
Sinapis.arvensis	DA	-0.20	0.34	-0.16
Xanthium.strumarium	DA	-0.15	0.28	-0.14
Ambrosia.artemisiifolia	DA	0.36	-0.31	
Hibiscus.trionum	DA	-0.20	-0.13	0.32
Stachys.*annua*	DA			0.12
Calystegia.sepium	DRP	-0.29		0.21
Cirsium.arvense	DRP	-0.38		0.34
Convolvulus.arvensis	DRP	-0.29	0.16	0.13
Raphistrum.rugosum	MA	-0.15	0.29	-0.16
Digitaria.sanguinales	MA	0.17	-0.22	
Echinochloa.crus.galli	MA		0.18	-0.26
Cynodon.dactylon	MRP	-0.50	0.41	
Equisetum.spp	Other		0.13	

Redundancy analysis of the trait group abundances showed that the explanatory variables accounted for 16% of variation in trait group composition. ‘Country’ accounted for 8%, ‘Woody SNH’ for 4.6% and ‘proportion of SNH in landscape sector’ for 2.5%. If focal field management information is added, another 10% of variability in species data can be explained. Especially organic farming and tillage intensity affect weed species composition in sunflower.

3.7.5 Conclusions

- Weed abundance is higher only at 1m distance from the field margin. From 2 m onwards, weed cover is not affected by distance from the SNH.
- The % of SNH in the landscape sector has no effect on weed species richness in sunflower but does affect species composition (2.5% variability accounted for).
- Weed species richness in sunflower is not affected by adjacent SNH type.
- SNH typology affects weed species composition and abundance in sunflower fields:
    - Fields adjacent to woody elements have a lower abundances of pernicious weed species, especially of *annua*l dicots and rhizomous species, and in general over weed cover is lower. Therefore, woody SNH provide less disservices from a weed management point of view.
    - Fields adjacent to grassy elements are less likely to be responsible for invasions of Digitaria sanguinalis and in Hungary for Ambrosia artemisiifolia and Hibiscus trionum.

Overall we can say that the disservice provided by SNH in terms of weed abundance is very limited and woody elements seem to decrease weed cover. On the other hand, woody elements may have a negative effect on crop yield in the first few meters due to root competition and shading (see pollination case study in same fields). However, if fields a sufficiently large, this may not have a huge overall impact on total yield, and the slight negative effect may be compensated by reduced weed abundances. This was confirmed based on yield estimates per field provided by the farmers (see presentation IWSS) where total yield in the focal field appeared higher near woodland than near other SNHs.

3.8 Bird damage (disservice)

Other services: Bird damage in the Netherlands 2014 and 2015

Author: Herman Helsen

3.8.1 Introduction

QuESSA aims to quantify ecosystem services and will focus on sustainable agriculture with high quality production. Special focus is on the management of semi-natural habitats and on-farm biodiversity to optimise ecological services. Besides supplying desired services like pollination and natural control of pests, field margins and other SNH can potentially provide undesired disservices. The Dutch pear orchard case study assesses the potential impact of surrounding SNH on bird damage as an ecological disservice.

3.8.2 Methods

We used three different approaches to assess the importance of bird damage

- Social assessment: the disservice bird damage was one of the ecosystem services discussed with fruit growers during the assessment of ecological services (WP 3.8)
- Quantitative assessment: in 2015 we included bird damage as a quantitative parameter in the evaluation of the harvested fruits
- Qualitative assessment: the fruit growers participating in the project provided information on the presence or absence of bird damage in 2015

3.8.3 Result

Social assessment

In all discussions with individual and groups of fruit growers the bird damage was mentioned as an important disservice of SNH. Perception of severity differed between growers. For some of them the risk of bird damage is the main reason to remove hedgerows near their fruit orchards.

Quantitative assessment

The quantitative assessment of bird damage on harvested fruit provided a very low number of damaged fruits. On each farm about 200 fruits were assessed in 2015. In a total of 4300 fruits only 5 showed bird damage. Four came from the same orchard S and one from orchard Z. In conclusion, this assessment revealed a level of less than 0.2% damaged fruits.

Qualitative assessment

Information provided by the growers is summarized in the table below. Data are not restricted to the part of the orchard where the Quessa assessments took place but are related to their entire business. Twelve out of 17 growers observed damage caused by birds. Three growers specified the location where they observed most bird damage: in the orchard close to the forest (2 growers) and in the rows near the hedgerow (1 grower). Ten out of 17 growers received a financial compensation from the Dutch government for the bird damage.

Table 1: Bird damage assessment on 18 Dutch orchards, information provided by growers (0=no, 1=yes)

Orchard	% SNH	% woody SNH	Bird damage in 2015	Refund	Amount of damage
J	9.1	1.0	1	1	
V	1.5	1.2	0	0	
G	1.6	1.6	0	0	
Q	5.2	2.4	1	0	
P	3.2	2.8	1	1	
N	3.6	3.0	1	1	
K	7.3	3.5	1	1	
H	10.2	3.5	1	1	
L	6.3	4.8	0	0	
M	5.3	4.9	1	0	
R	11.3	6.5	no data	no data	no data
S	8.6	8.6	1	1	1900 kg/ha
T	13.3	9.6	1	1	1000 kg/ha
U	13.4	10.2	0	0	
X	12.8	11.9	1	1	2000 kg/ha
W	22.8	17.4	1	1	
Z	19.2	17.7	0	0	
Y	21.0	17.9	1	1	4000 kg/ha

3.8.4 Discussion

Damage on fruits caused by birds is a severe disservice in Dutch fruit orchards. For many growers this causes a negative perception of SNH like forest and hedgerows close to their orchards.
Our approach to directly assess the bird damage on the harvested fruits did not provide reliable data on actual damage in the orchard. The damage is clearly underestimated, as growers tend to remove damaged fruits while performing other activities in the orchard.
Information provided by the growers provides better insight in the extent of the appearance of bird damage. Although growers strongly relate bird damage to the presence of woody vegetation, this is not reflected by the percentage of woody SNH in the 1 km landscape sector. Factors that may play a role are the distance from the woody SNH to the orchard and the species composition, structure and height of the woody SNH.

3.9 Conclusions other ecosystem services

Beside main ecosystem services pollination and natural pest control 6 (including bird damage) other ecosystem services that are potentially mediated or influenced by SNH were measured. The perceived **aesthetic value** of landscapes was investigated in six European partner countries (Switzerland, Germany, United Kingdom, Hungary, France and Italy). First analyses showed positive influence of woody SNH consisting of regular tree hedgerows on landscape aesthetics. Nevertheless, colourful flowering crop elements were significantly preferred to grassy elements. These preliminary results corroborated results of other studies that colourful flowering, trees and vegetation structure play an important role in landscape aesthetics. In France effects of SNH on **soil erosion** was measured, but any significant effect of herbaceous vegetation was found. Measures of **soil fertility** in Estonia, France and Hungary suggested that SNH contribute to the maintenance of soil organic carbon, soil organic matter as well as carbon sequestration. SNH were characterized by a higher organic matter content and nitrogen in the upper layer of soil, suggesting that SNH are particularly important for the higher content of organic matter of their soils. The study about **organic matter storage** in England revealed that the vast majority of soil carbon is stored with cropped fields rather than SNH in agricultural landscapes. The herbaceous habitats stored more soil carbon than the fields indicating that permanent grassland could also potentially be important in carbon sequestration. Further carbon will be stored in the above ground vegetation of SNH and this is likely to be highest for woodland. Additional work is needed to understand the effects of management techniques on carbon sequestration from SNH. **Biodiversity conservation,** an additional potential ecosystem service provided by SNH, was measured in Germany. As SNH contained species of conservation concern, SNH in the agricultural landscape require particular attention. The conservation value differed among SNH. Herbaceous elements were important for endangered species and support a high species richness and beta diversity. In contrast, woody elements showed a higher community variation than herbaceous elements. The amount of SNH at landscape level (i.e. landscape complexity) had no effect on species richness, beta diversity and the number of endangered species. The measurement of disservices provided by SNH are of crucial importance to evaluate their contribution towards sustainable agriculture. Therefore the provision of **weed invasion** by SNH was measured in Italy and Hungary. Weed abundance induced by SNH in crop fields was very limited and woody elements had tendency to decrease weed cover. However, woody elements may have a negative effect on crop yield in the first few meters of a field due to root competition and shading. If fields are sufficiently large, this impact may be compensated by reduced weed abundances. Damage on fruits caused by birds is a severe disservice in Dutch fruit orchards. For many growers this causes a negative perception of SNH like forest and hedgerows close to their orchards. Although growers strongly relate bird damage to the presence of woody vegetation, this is not reflected by the percentage of woody SNH in the 1 km landscape sector.

4 Appendix

Table S1. Qualitative summary table of all investigated country-crop-ecosystem service combinations of QuESSA. + = SNH increases the ecosystem service, - SNH reduces the ecosystem service, 0 = no effect of SNH on ecosystem service detected, NA = data not available / not measured, values in brackets show effects on service providers if no effect on ecosystem service was found.

ES	cty	investigated crop	Proportion SNH in the surrounding landscape	locally bordering SNH			interaction LS x adj
				WL	HL	others?	
pollination	CH	oilseed rape	+	+	+	NA	+
pollination	UK	oilseed rape	0	0	0	NA	0
pollination	IT	sunflower	(-)	(-)	(-)	NA	0
pollination	DE	pumpkin	+	+	+	NA	0
pollination	EE	oilseed rape	0	(+)	(+)	NA	0
pollination	NL	pear	0	0	0	NA	0
pollination	HU	sunflower	0	0	0	NA	0
pest control	CH	oilseed rape	+	0	0	NA	0
pest control	UK	wheat	HA + WL/WA -	-	+	NA	0
pest control	IT	olive	+	NA	NA	garrigue +	0
pest control	DE	pumpkin	(+)	0	0	NA	0
pest control	EE	oilseed rape	+	0	+	NA	0
pest control	NL	pear	0	0	0	NA	0
pest control	HU	wheat	0	0	0	NA	0
pest control	FR	vine	0	0	0	NA	0
Landscape aestethic	EU	oilseed rape	+	+	+	NA	0
Soil erosion	FR	vine	0	0	0	NA	0
Soil fertility	EE	oilseed rape	0	+	+	NA	0
Soil fertility	FR	vine	0	+	+	NA	0
Soil fertility	HU	wheat	0	0	0	NA	0
organic matter storage	UK	wheat	NA	+	+	WA+	NA
Biodiversity conservation	DE	pumpkin	0	+	+	NA	0
weed invasion	IT	sunflower	0	-	-	NA	0

weed invasion	HU	sunflower	0	-	-	NA	0
Bird damage	NL	pear	0	(+)	0	NA	0