Effects of agroforestry systems on pollination services

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Abstract

Mosaic landscapes with hedgerows and agroforestry benefit pollinators, which in turn are needed for crop pollination. Depending on tree age and species, they provide nesting and foraging resources in different quantity and quality and are a source and a refuge for pollinators and their service. As part of the FP7 AGFORWARD project we investigated the added value of agroforestry on landscape scale for wild bees. The research was conducted in eight 1 km^2 landscape test sites (LTS) in north-western Switzerland. The predominant agroforestry system of the region is traditional cherry orchards. Intending to sample contrasting test sites, four LTS were selected with a high percentage area of cherry orchards and four with low coverage. We assessed the spatial distribution of flowering resources and availability of nesting sites to estimate the potential pollination service and we modelled three scenarios: flowering trees, non-flowering trees and without trees on a landscape scale. Flowering and nesting facilities were mapped and the flowering value of cherry trees by counting the amount of flowers on 22 randomly selected trees was assessed. Lonsdorf equations were used to assess the pollinator-habitat interaction. The results indicate that landscapes with agroforestry containing flowering trees increase the provision of pollination services at landscape scale.

Keywords: Agroforestry, Pollination, Biodiversity, Landscape

1. Introduction

Fruit orchards are distinctive features of many regions in Switzerland. Especially the north-western part of Switzerland is known for cherry orchards that are characteristic of the rural landscape (Sereke *et al*., 2015). These traditional agroforestry systems were originally established to fulfil food, fodder and timber needs of humans and enrich the flora and fauna (Nerlich *et al*., 2013; Pimentel *et al*., 1992). The mass-flowering of cherry trees in early spring provides a rich food source for flower visiting insects, especially pollinators such as bees, and in turn fruit yield depends on adequate pollination (Holzschuh, *et al*. 2012; Schüepp *et al*. 2013). As part of the European AGFORWARD research project (www.agforward.eu) we analysed the added value of agroforestry practices on a landscape scale for biodiversity and the provision of biotic ecosystem services, such as pollination services. The aim of the study was to model the potential for pollination service provision in contrasting agricultural landscapes, with high and low agroforestry cover, using traditional cherry orchards as model system. The focus was on the effect of flowering cherry trees versus non-flowering trees. We (1) assessed the spatial distribution of flowering resources and their overlap with estimated availability of nesting facilities to assess the potential pollination service and (2) modelled the effects by means of three scenarios: (A) flowering trees (as potential forage and nesting site), (B) non-flowering trees (only suitable for nesting) and (C) without trees (no forage or nesting potential) on landscape scale.

2. Data and Methods

A typical cherry orchard region in north-western Switzerland was selected for this study. The area was clustered into land cover categories, agroforestry (AF) and non-agroforestry (NAF). Eight landscape test sites (LTS) of 1km x 1km were randomly selected, four AF (20 – 39 % of the LTS are covered by cherry orchards) and four NAF. In the LTS habitat types were mapped using a standardized protocol (Szerencsits *et al*., 2016). Agroforestry trees (cherry, *Prunus avium* (Rosaceae)) were digitalized and clustered into young, medium, and old depending on the crown diameter (Table 1). The spatial distribution of pollination services was modelled based on equations of Lonsdorf *et al*. (2009), which are applied in the INVEST model and were adapted for the analysis. Herein the habitat suitability to host nests and to provide forage was assessed for each land cover category. Afterwards the reachability between potential nest and forage sites was computed based on average solitary bee flight ranges by means of Euclidean distances. Gathmann & Tscharntke (2002) showed, that an ideal foraging range for solitary bees is less than 250 m and in line with Zulian *et al*. (2013) for the European scale, we focused on short flight distance species with a mean realized foraging range of up to 200 m. The availability of floral resources was estimated and mapped as percentage cover of herbs and clover in grassland habitats. To assess the flowering potential of trees, we counted the amount of flowers on 22 randomly selected cherry trees. In adaption to the method of Baude *et al*. (2016) all flowers were measured on young trees, while for old trees representative m^3 were selected, in which all flowers were counted and upscaled to the whole crown volume. The nesting site availability was classified as suitable and non-suitable. Due to the multi-layered vertical structure and the semi-natural habitat character of cherry orchards, the cherry trees were assessed as suitable nesting site in adaption to findings of Bailey *et al*. (2014). Grassland habitats were mapped. The nesting suitability was divided into suitable for ground nesting species and for cavity nesting wild bee species. Finally, the scenario analysis was conducted for three cases. Scenario A was the state of the art assessing flowering cherry trees, which provide potential nesting and foraging resources. In scenario B the forage resource were removed by assuming all agroforestry trees to be non-flowering e.g. cherry trees replaced by coniferous species. In scenario C the nesting and foraging potential was eliminated by removing all agroforestry trees. All results were statically tested using a one-way analysis of variance (ANOVA). The analysis was processed in ArcGIS 10.4 and R.

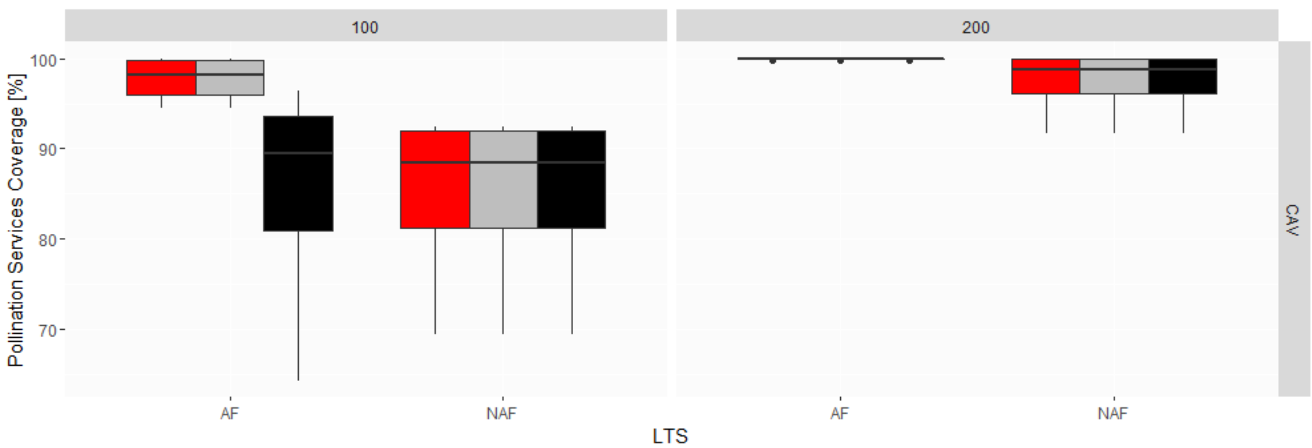
Table 1. The range of flower availability based on 22 measured cherry trees in north-western Switzerland grouped into young, medium and old trees depending on the crown diameter.

Tree Class	Crown Diameter	Canopy Area	Flowers per tree		
			Numbers	Area	Share: Flower area to canopy area
	(m)	(m^2)		(m^2)	(%)
young	2	251.33	0 – 5’500	0 - 4.9	0 - 2.0
medium	5	1570.8	5’500 – 55’200	4.9 - 49.7	2.0 - 3.2
old	8	4021.24	55’200 – 303’000	49.7 - 272.7	3.2 - 6.8

3. Results

We found an average of 1000 (±370) flowers per m^3 crown volume. Table 1 summarizes the results of flower counting for cherry trees. The three-dimensional tree crown volume was theoretically flattened by projecting the area of all flowers on a plane surface. A cherry flower has a diameter of 1.5 to 3.5 cm (Schmid, 2006) and covers an average area of 5 cm^2 (1.7 - 9.6 cm^2). In total between 0 - 6.8 % of the canopy area of each tree is covered by flowers. This “flowering value” was used as input for assessing floral ressources of cherry trees.

Figure 1 visualizes the model outcomes for the different nesting preferences (ground and cavity nesting species) and foraging ranges of 100 and 200 m. The results visualize the difference between agroforestry and non-agroforestry LTS for the different scenario approaches. Overall the area was well covered by pollination services. The coverage rated between 64 % in an AF LTS in scenario C based on a 100 m moving corridor up to a total coverage of the area. Short flight distance species (200 m corridor) covered almost the whole area.



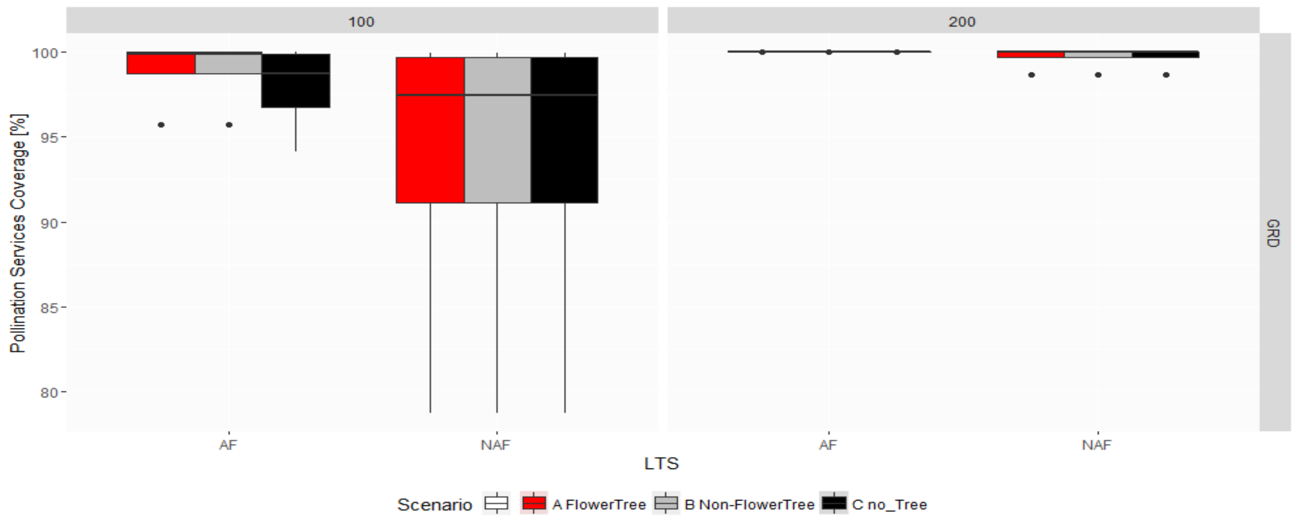


Figure 1. Pollination service coverage (in %) estimated for cavity nesting species (CAV - above) and for ground nesting species (GRD - below) under three scenarios: (A red) FlowerTree with flowering trees; (B grey) Non-FlowerTree- with non-flowering trees; (C black) no_Tree - without agroforestry trees. The calculation was performed for flight distances of bee species of 100 m and 200 m. Four 1 x 1 km agroforestry (AF) landscape test sites were compared to four non-agroforestry (NAF) landscape test sites. The bar graphs indicate mean values (horizontal line), standard deviation (upper and lower limits of boxes), range of values (lines) and outliers (points).

The main contrasts occurred between agroforestry and non-agroforestry sites, wherein the AF LTS showed a significant higher pollination coverage compared to NAF LTS. In all models, the potential for ground nesting species was higher than for cavity nesting species. Scenarios A (with flowering trees) and B (without flowering trees) showed nearly overlapping results, while in scenario C (completely without trees) the overall coverage was the lowest. There were no significant differences between the scenarios.

4. Discussion

Overall,the heterogeneous mosaic-type landscape structure of the study region seems to provide favourable conditions for wild bees and other pollinators. Nonetheless, the scenario analysis indicates that there is a significant added value of agroforestry cherry trees. Compared to NAF LTS, the estimated higher availability of both nesting and foraging resources in close proximity in AF LTS may promote the wild bees and the persistence of their populations in the landscape. These findings are in line with previous studies by e.g. Le Féon *et al*. (2010), Garibaldi *et al*. (2011) and Kleijn *et al*. (2015), who showed that agricultural intensification negatively affects wild bees and other pollinators. Both, the local management and farming system as well as the landscape context are important drivers of these effects (Scheper *et al*., 2013). Apparently, there is a positive relationship between the availability of foraging and nesting resources for wild bees and the pollination coverage in AF LTS and with flowering trees for short flight distances of 100 m, while these differences become weaker for 200 m. Consequently, the transferability of these findings are limited.

Our results indicate that one important aspect of trees is their potential to provide nesting opportunities for cavity nesting bees. While scenarios A and B did not show significant differences, the removing of all trees in scenario C caused a decline of pollination service coverage. This may imply that sufficient quantities of floral food resources are available in the landscape, while nesting resources are limited. Findings of Potts *et al*. (2005) in Mediterranean landscapes underline the importance of suitable nesting sites for pollinator populations. We are aware, that the major beneficiaries are species, which prefer or rely on cherry trees as food resource or nesting site. Nevertheless, the extensive and flower-rich orchard grasslands play an important role as potential foraging and nesting habitat for wild bees.

5. Conclusions

We assessed the added value of agroforestry practices focussing on nesting and flowering resources for wild bees focusing on traditional cherry orchards in north-western Switzerland. Based on a scenario analysis, comparing landscapes with flowering and non-flowering trees, we found that the heterogeneous landscapes are well covered by pollination services, irrespective of the presence of cherry agroforestry, but agroforestry still improved the potential for pollination services at landscape scale. Our findings suggest that agroforestry trees benefit cavity-nesting bees by providing nesting resources in addition to floral resources, but further empirical research is required to confirm the model assumptions and predictions.

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