Wild bee species and farming practices in horticultural farms in Madrid

– Finding paths towards agroecological transitions

Diversidad de abejas silvestres en huertas de Madrid, buscando caminos para una transición agroecológica.

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Abstract

Farms and its different management practices have substantial effects on biodiversity, with the consequent impact on the supply of certain ecosystem services such us pollination. Wild bees provide pollination services in small scale horticultural farming, which is key element to determine and improve farm production but also to the maintenance of ecosystem´s diversity. In this study we aim to identify which species of wild bees can be found in small horticultural farms in the northern area of Madrid and to analyse how its diversity is influence by agricultural practices and by the elements of the surrounding landscape. In addition, we deepen in the agricultural practices carried out in small scale horticultural production and farmer's perception about pollination importance. By doing so, we aim to get a perspective of the agroecological transition in Madrid and the management of agroecological practices from farmer´s perspective.

To characterize the farms and to obtained information about the agricultural practices we carried out semi-structured interviews. Farmers showed awareness about the importance of pollination and wild bee communities for the development of their crops and other wild plants. Their perception on the effect of agricultural practices on pollinators match with the scientific data, being wild flowers, aromatic plants and the conservation of natural edges the practices that most influences pollinators. Farm management is rather similar within each other since all of them are small horticultural producers located in the same area. In order to quantify the differences within farms, we gave quantitative scores to the agricultural practices measuring impact and time of application.

A total of 16 horticultural farms were sample using the pan-trapping method during the flowering period of the horticultural plants to collect wild bees. Surrounding landscape composition was analysing with satellite imagery to identify the different elements present around the farms. In total, 109 wild bee species were identified with individuals from the six bee families present on the Iberian Peninsula. The most predominant genera are *Lasioglossum*, belonging to the Halictidae family, which are characterized by nesting in soils. The results indicated that the element with most influence on wild bee species richness is sparsely vegetated soil, followed by the presence of forest areas. These areas might correspond to potential areas of nesting sites for wild bees.

This thesis aims to contribute to better understanding of the agoecological transition in Madrid and to highlighted the importance of this small scale farming areas to promote biodiversity and landscape diversity.

Keywords: agroecology, agroecosystems, agroecological transition, wild bees, small scale farming, landscape, horticulture

Preface

During my bachelor degree in environmental science I learnt how agriculture is one of the main drivers of change in our world, how it has been shaping our landscapes, biodiversity, culture and the way we perceived food. At the same time, I have always been fascinated by traditions and culture around rural areas and how people is able to maintain knowledge alive by practicing traditional agricultural practices. Driven by my personal motivation I decided to continue my education and to be “specialize” in agroecology. Within the wider term of agroecology, I am more interested in alternative ways of producing food and in the study of these complex socio-ecological systems.

The Master programme of agroecology explores the term of agroecology in its different forms (practice, science and social movements) and from different scales and perspectives. We learnt in different courses how important is the study of the agroecosystems from the combination of social and natural sciences points of view. This is highly important since agroecosystems are systems where there are complex interactions between humans and nature. I also think a key part of agroecology is to understand it as a transdisciplinary, participatory and action based approach.

Since by background was not related to agronomy I decided to take some courses at BOKU University (Vienna) to have deeper knowledge and more technical knowledge. After that, I decided to come back to my region to developed my master thesis there. This decision brought me closer to the agrarian systems of my region and the agroecological movement that was happening in Madrid at that point. I had the opportunity to join a team working with pollinators and honey bees in agroecosystems and its synergies with agricultural activity. Soon I decided to write my master thesis about this topic, which was a perfect combination of two of my favourite topics, agroecoloy and biodiversity. This thesis helped me to understand how is the perspective of farmers and what kind of barriers are they facing. Indeed, this thesis was the starting point of a great interest and passion for the unknown world of pollinators and the diversity of wild bees in the Iberian Peninsula.

During this stage, I had the opportunity to developed personal and professional skills which have allow me to begin understanding these systems. I have learned that in order to understand it, the first step is always to listen from humility point of view and from the desire to learn from them. Also, the opportunity to study abroad is from my point of view the most recommended experience that helps you to understand how the word works.

My admiration and gratitude for the people who cultivate the land continues growing, and hopefully it will never stop.

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Abbreviations

CAP	Common Agricultural Policy
ES	Ecosystem services
FAO	Food and Agriculture Organization
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
SLU	Swedish University of Agricultural Sciences

1. Introduction

1.1. Agricultural industrialization

Over hundreds of generations, agriculture was the main activity for humans, evolving relatively slow. This development led to the transformation of wild plants into the vegetables, fruits and grains we know nowadays. During the 18th and 19th centuries agricultural innovation started to develop rapidly and have been progressively disconnected from their solid elements (Van der Ploeg, 2006). Following technological advances in the 20th century, yields per hectare of staple crops increased drastically. Consequently food prices decreased, hunger was partially reduced, and the population continued increasing (Matson *et al.*, 1997; Cervantes-Godoy *et al.*, 2014). This agricultural industrialization or green revolution led into the present-day agriculture, which targets the maximization of production and maximization of profit (Gliessman, 2014), leaving aside the impact on earth and long-term consequences. In our current agrifood system, the same characteristics that constitute industrial agriculture (technology, innovation, practices) have also undermined the basics foundations of agriculture, such us fertile soils, genetic diversity, traditions, water quality and availability or regulation of ecosystem services (Tilman, 1999; Power, 2010; Tscharntke *et al.*, 2012). This situation leads us to think that the system that is able to deliver food today, which is indispensable for the continuity and quality of human life, it cannot assure it to do it over long term (van der Ploeg, 2016).

There are seven practices that are the backbone of the conventional or industrial agriculture: intensive tillage, monoculture, application of synthetic fertilizer, irrigation, chemical pest and weed control, manipulation of plant and animal genomes and factory farming of animals (Gliessman, 2014). All the impacts and costs of agriculture are not only problematic because they are not sustainable but because they have a huge impact in the present on humans and on ecological systems on which we rely on (Matson *et al.*, 1997; Power, 2010; Cumming *et al.*, 2014). The following figure shows the seven main practices of conventional agriculture and some of the effects that we are already facing (Figure 1).

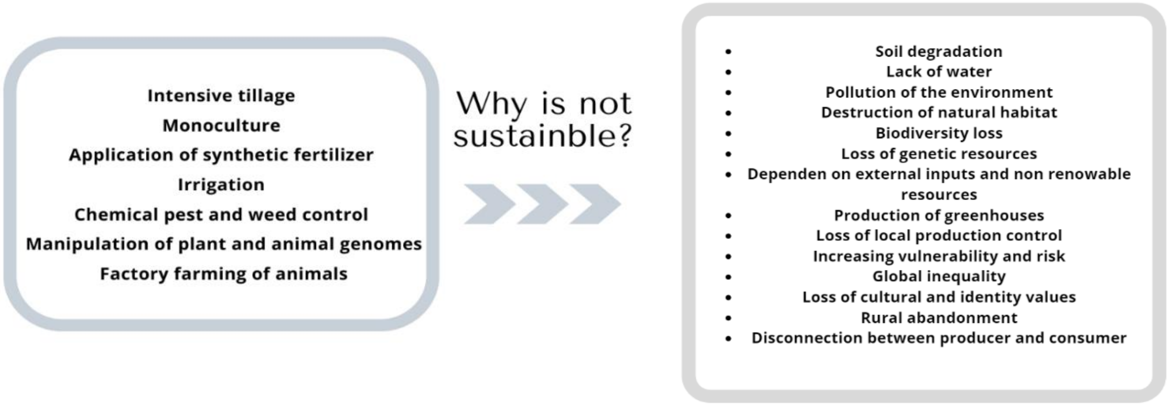


Figure 1. Seven practices of conventional agriculture and some of the consequences they are generating. Information from Gliessman, 2014.

In addition to the impacts listed above, at local scales there might be other consequences. The farming sector in Madrid is characterised by the intensification of the agriculture, individualistic mind-set, masculinisation of rural areas, changes in the Mediterranean diet, discredit of the profession, disconnection among agents of the value chain and lack of cooperation with other sectors. Indeed there are major difficulties in the access to land for new farmers, despite the fact that there is a lot of land that has fallen into disuse (Morán Alonso, 2015; García-Llorente *et al.*, 2019).

1.2. Agroecology

In response to the intensification and specialization of the Green Revolution, there was a gradual increase of environmental awareness and ecology in the fields. It is at the beginning of the 20^{th} century when the word of agroecology starts to emerge as an alternative from the globalized and industrialized agrifood system (Méndez et al., 2013; Gliesmann, 2007). Nevertheless, is from 1970 to 2000 when agroecology is not only considered a scientific discipline but also emerged as a social movement and as a set of practices. Since then, agroecology not only concern crops, animals, and farms, but the entire food system, all the process from the seed to the table need to be into account (Gliessman, 2007). One of the objectives of agroecology is to embrace and drive the entire food system in a more resilient and sustainable direction.

According to Food and Agriculture Organization (FAO) (2018) “Agroecology is an integrated approach that simultaneously applies ecological and social concepts and principles to design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while taking into considerations the social aspects that need to be addressed for a sustainable and fair food system”. This approach is based on a bottom-up and territorial processes where local knowledge, science and practice are essential to solve local problems. It seeks for holistic and long-term solution empowering producers and communities. Since agroecology has many interpretations and definitions, FAO proposes 10 elements that are interlinked and interdepend to help to understand it (FAO 2018):

1. Diversity
2. Co-Creation and sharing knowledge
3. Synergies
4. Efficiency
5. Recycling
6. Resilience
7. Human and social values
8. Culture and food traditions
9. Responsible governance
10. Circular and solidarity economy

1.3. Spanish agroecosystems

An agroecosystem is an ecosystem which is managed and modified to have agricultural production. This concept includes sets of inputs, outputs and interconnections of its parts, but it also incorporates social systems (Power, 2010).

Agriculture covers much of the earth´s surface, and it plays a unique role in both the supply and demand of ecosystem services (Swinton *et al.*, 2007). Spanish agroecosystems cover over the 60% of the national territory, which makes essential to study their situation for the protection of our territory. There has been an assessment of the current situation of ecosystem services (ES) in Spain, including the ones provided by the agroecosystems (EME, 2011). The table 1 shows 26 ES that have been assessed, their current situation and their tendency.

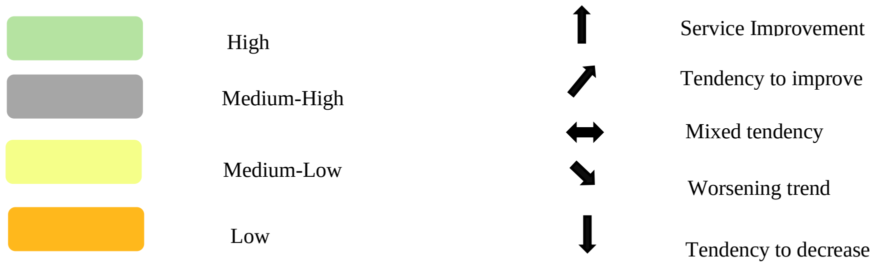
The evaluation shows that 68% of the ecosystem services are not in a stable conservation situation. The capacity of the conventional agriculture to provide food is stable and organic agriculture is increasing in area and production (Gomez Sal, 2012). Gene pool, which refers to the agrodiversity, shows a very alarming deterioration over the last 30 years. This means that the dependency on companies that supply seeds, pesticides and fertilizers is also increasing. Regulating services are the most affected by agriculture intensification, being soil fertility and morfosedimentary regulation in the worst place- increasing dependence on imported mineral raw materials-. Although agricultural water use efficiency and biological control methods tend to improve. Cultural ES have a contradictory situation, some of them are increasing -aesthetical and recreational values- associated with an urban demand. On the other hand, sense of place and local ecological knowledge are decreasing due to the deterioration and abandonment of rural areas (Gómez Sal, 2012).

Although the territorial weight of agroecosystems remains, their structure, function and content are not the same, which is essential for determining human well-being. The common agricultural policy (CAP) is one of the main drivers of the last decades, which have motivated the specialization and reduction of the number of farmers and farms. In general, there is a lack of reliable scenarios for the future. Clear and sustainable plans need to be directed, taking advantages of the potential services that can contribute to the quality of life, providing strong incentives to return to the rural environment (EME, 2011; Gomez Sal, 2012).

Number of farmers is decreasing every year, especially those running a small farm. On the other hand, average size farm is increasing every year (Soler, C. and Fernández, 2015). More land cultivated by less farmers has an important impact not only on the environment (loss of agricultural landscapes, local varieties, water and soil pollution, etc.) but also social (loss of identity and culture, tradition and local knowledge) and economic implications. It is essential to keep developing farming practices that are respectful with the environment and people, but it is also essential to find ways to maintain rural life.

Table 1. Ecosystem services provided by Spanish agroecosystems. It shows their current situation and their tendency. Adapted from (Gomez Sal, 2012).

Type	Service		Situation
Supply	Food	Conventional	↑
		Green Houses and intensive irrigation	↑
		Organic agriculture	↗
	Fresh water		↔
	Raw materials		↘
	Energy	Wood	↘
		Wind and solar power	↗
		Biofuels	↘
	Genetic pool		↓
	Natural medicines and active agents		↓
Regulation	Local climatic regulation		↔
	Local air quality regulation		↔
	Water regulation		↑
	Morphosedimentary regulation		↓
	Soil formation and fertility		↓
	Regulation of natural disturbances		↔
	Biological control		↑
	Habitat for endangered species		↑
	Pollination		↘
Cultural	Scientific knowledge		↗
	Ecological local knowledge		↘
	Cultural identity and sense of place		↑
	Spiritual enjoyment		↗
	Aesthetic value		↗
	Ecotourism and recreational activities		↑
	Environmental education		↗



1.4. Pollination and polinators in Agroecosysmtes

1.4.1. Polination and pollinators state

Pollination by wild animals is one of the ES considered in danger (EME, 2011). It refers when animals move pollen grains from the male part of a flower (stamen) to a compatible female part (stigma) and fertilization might occur. This movement of the pollen can happen between an anther and a stigma of the same flower, different flowers but same plant individual (self-pollination) and different flowers and different plants individuals (cross-pollination) (IPBES, 2016). Most flowering plants depend on vectors to move pollen, which can be animals, wind, water, humans, etc. Thus, animal pollination is essential to the sexual reproduction of 90% of angiosperms plants or flowering plants, even though is difficult to predict an exact number (Kearns et al., 1998; Ollerton et al., 2011). It is widely known that pollinators are key element to sustain biodiversity on Earth and to contribute the functioning and integrity of most terrestrial ecosystems (Aizen et al., 2008). It is important to highlight then, that the decline of pollinating species can lead to a decline of plant species (Biesmeijer et al., 2006).

Pollinators refers to animals that move pollen between flowers or within flowers. They visit flowers to collect and eat nectar, proteins, vitamins, for mating, laying eggs, or collect oils or resins (Misiewicz and Shade, 2015; IPBES, 2016). In this process of traveling from flower to flower, pollination happens. There are many animal species that pollinate plants, in which the majority are invertebrates (beetles, bees, flies, wasps, antes and butterflies) but there are also birds, mammals and reptiles (IPBES, 2016). This animal-plant interaction it might be one of the most ecologically important ones, because without pollinators many plants would not have seed and be able to reproduce, and without plants providing rewards (such us pollen or nectar), many animal populations would decline (Kearns, Inouye and Waser, 1998).

It is known that bees are the most abundant and diverse pollinator. There is an estimation of over 20000 species of bees on Earth (Michener, 2007). Flies also play an important role in pollination with around 120000 species known, but not all of them being effective for pollination. Bees are the pollinator with most agricultural importance, mainly honey bee's species (*Apis mellifera* and *Apis cerana*), but also bumble bees, stingless bees and solitary bees. Honey bees were mainly managed to obtain honey and wax production, but nowadays its management has grown worldwide with pollination goals.

Pollinators are not equally efficient, and honeybee is not always the most appropriate pollinator. Relying on one managed species (the honeybee) for agricultural pollination is risky, especially when other more specialist and diverse pollinators are known, like the wild bees (Garibaldi et al., 2011, 2013). To have an appropriate pollination over time and space, species diversity is needed. This diversity will stabilize the ecosystem service against disturbance with different responses to variables among species and with responses to the same variable by different species at different scales. Functional diversity within species is also important to improve pollination quality (Winfree and Kremen, 2009). That is to say, diversity is required to complement each other resulting in a better pollination overall (Blüthgen and Klein, 2011).

It also fair to mention local communities and indigenous people, who in some cases have developed their societies with biocultural associations with pollination and pollinators (Hill *et al.*, 2019). They also have an essential role on influencing biodiversity and indeed pollinators. Pollinators enrich societies with honey, food, medicine, ceremonies, rituals, and oral traditions (IPBES, 2016). Sadly, there is a huge loss of indigenous and local knowledge on sustainable bee management.

1.4.2. Pollinators in agriculture

As it is mentioned in the previous section, some ecosystem services, such as pollination or seed dispersal, are provided by mobile organism that are moving within or between habitats. These organisms deliver services locally, but their dynamics are affected by landscape level. This kind of ecosystem services have direct and indirect values, corresponding with regulating, supporting and cultural roles. For instance, some direct values is the increase in food production, and indirect value would be the reproduction of wild plants (Kremen *et al.*, 2007).

Pollination affect fruit and seed quality and quantity of many crops, but there is a lack of precise and detailed studies to understand until which extend pollinator limitation is affecting global agricultural production (Klein *et al.*, 2007; Aizen *et al.*, 2008, 2009). Williams (1994) studied European crops, and estimated that 84 % (out of 264 crops) improves fruit or seed quality and quantity with the presence of pollinators. Roubik (1995) carried out a similar study with tropical crops, in which 70 % of them are improved by animal pollination. In many scientific literatures it is mentioned that one third of total food production depends on animal pollination, but this data is still in debate. According to Klein (2007), 35% of global plant-based crop production partially benefits from animal pollination and according to Aizen et al., (2009) 10% of the total crops depends fully on pollinators.

When the decline of wild bees was known, there was an assessment of the potential loss in terms of economic value. Based on the calculations of dependence ratios from Klein et al. (2009), Gallai et al. (2009) quantify worldwide insect pollination of about €153 billion. This value refers to approximately 9,5 % of the crops used for human consumption. Though is important to state that numbers can vary since economic agents might change (Ghazoul, 2007). Indeed, it will vary among different regions since land and crop management and diversity of bees is different. The regions that appear more vulnerable are Middle East Asia, Central Asia, East Asia and non-European Union countries. Generally northern countries appear with higher vulnerability, which might influence trades between north- south. It should also be noted that the average price of crops non-dependent on animal pollination (like cereals, sugar, roots and tubers) is five time less that the pollinator-dependent crops (Gallai *et al.*, 2009).

Pollination shortage is trying to be solved differently, like adding other inputs or by substituting pollinators with technical alternatives (Klein *et al.*, 2007). The decrease in yield it is being compensate by large expansions of the cultivated area. The cultivation of pollinator-dependent crops has expanded faster than the non-dependent crops, due to our diets and globalization in food trade (like avocado, blueberry, cherry, raspberry and plums). It increased by 60% from 1961 to 2006. It is important to mention that these crops seem not to increase in yield as fast as among non-dependent or less dependent crops. So this depletion in pollinators can manifest in an increase in demand for agricultural land to meet growing global consumption, which will have the respective impact on nature and indeed, in pollinators (Aizen *et al.*, 2009).

1.4.3. Pollinators trend and drivers of change

In the last decades, there is growing perception among science and society that pollinators are declining. This concern is coming from reports mainly about honey bees (*Apis mellifera*) in North America and Europe, and more recently about some other native species. Nevertheless, according to Aizen and Harder (2009), the number of colonies of honey bees is increasing since 50 years ago. Indeed, other managed species for pollination like *Osmia*, *Mechachile*, *Anthophora* and *Bombus* are also increasing. It should be emphasized that half of the data about pollination declines are collected just from 5 countries (Australia, Brazil, Germany, Spain and USA). In contrast, only 4% of studies are from Africa. Hence, this is an important geographic bias to take into account when we talk about worldwide pollination decline (Archer *et al.*, 2014). Likewise, most invertebrate pollinators have not been assessed at global data.

According Aslan (2013), 16,5 % of vertebrate pollinators are threatened with global extinction. There is not a global Red List for pollinators, but the European Red List says that 9 % of European wild bees and 9 % of butterflies are threatened. However, it is highlighted in the IPBES (2016) that European bees data is insufficient to make IUCN assessments, and usually the number of threatened species appears higher in national level than the regional ones. But there is a clear evidence that wild bees and butterflies' populations are changing in abundance, diversity and occurrence at local and regional level, having negative impacts on wild plants.

Nowadays one of the main challenges regarding pollinators is to understand how pollinators which can move large distances, respond to global change (climate change, land-use intensification, farming systems…) across different spatial and temporal scales. Climate change is already bringing changes in rainfall, temperature, wind patterns, air pollution among others, having for instance effects like mismatches between plants and pollinators (Roulston and Goodell, 2010). Different pollinator species respond differently to all perturbations, so diversity functions as a buffer because it increases the chances for pollination to occur (Winfree and Kremen, 2009). Some species will be able to adapt to climate change, but it will have irreversible effects on spatially restricted populations or on species that do not have the capacity to move fast enough (González-Varo *et al.*, 2013).

Land use changes is one of the main drivers, leading to changes in the land cover and configuration, having thus a negative effect on pollinator abundance, richness and indeed, diversity. It results in landscape fragmentation, habitat loss and degradation of resources like flowers and on connectivity. But they are also influenced by local scale such us farm management practices (Benton, Vickery and Wilson, 2003) and by regional scale like the surrounding landscape (Kremen *et al.*, 2007; Kennedy *et al.*, 2013). At regional level, habitat fragmentation and decreasing landscape heterogeneity are related with the loss of biodiversity in farms (Steffan-Dewenter *et al.*, 2005; Klein *et al.*, 2007).

At local scale, land management like agricultural practices will determine pollinators community and its dynamics in different farms systems (horticulture and agroforestry systems, arable and grassland). As in landscapes, increasing heterogeneity within fields and farms will improve pollinator status. Farming practices like tillage, use of pesticides and fertilizers, grazing and mowing, irrigation system and monocultures are influencing the service of pollination, and other ecological functions. Creating a system based on agroecological principles and small agricultural systems with practices like intercropping, cover crops, fallowing, crop rotation, polyculture, agroforestry, hedgerows between others, will have the potential to improve and promote not only pollinators and pollination but biodiversity conservation and farmers livelihood (Altieri, Funes-Monzote and Petersen, 2012).

Most agricultural land is managed with a short-term vision with individual perspectives. But collective management is essential to promote pollination and to provide long-term sustainability of our agricultural system. To achieve so, collaboration of landowners is required to obtain landscape level conservation and the optimal benefits on the provision of pollination services. These benefits will be greater than the ones achieve by individual efforts (Goldman, Thompson and Daily, 2007; Stallman, 2011).

1.5. Aim of the master thesis

This master thesis aims to better understand wild bee species diversity in horticultural production. Having in mind the variety of multiple factors that impact pollinators, this study is focus on factors at local scale in a specific area of Madrid region. To do so, local management of the farms and landscape characteristics are analysed to understand how they influence wild bee species diversity. In this thesis we try to answer the following research questions: Which agroecological practices are being implemented by farmers (1)? Which wild bee communities can be found in small horticultural farms in the north area of Madrid (2)? and, How farming practices and landscape structures are affecting wild bee species richness (3)?

As part of this study, we aim to get a perspective of the agroecological transition in Madrid and the management of agroecological practices from farmers' perspective. This research is part of a wider project carried out by an Operational Group called Api-Agro Symbiosis - the symbiosis between beekeeping and agricultural production for environmental and socio-economic sustainability; linked to the Rural Development Plan of the Community of Madrid for the period 2018-2021.

2. Methods

2.1. Study area and farm selection

The study area is located in the northern part of Madrid region within an agricultural region called *Lozoya-Somosierra*. This area represents 15,7 % of the surface of Madrid community and it has 47 municipalities, as shown in Figure 2.

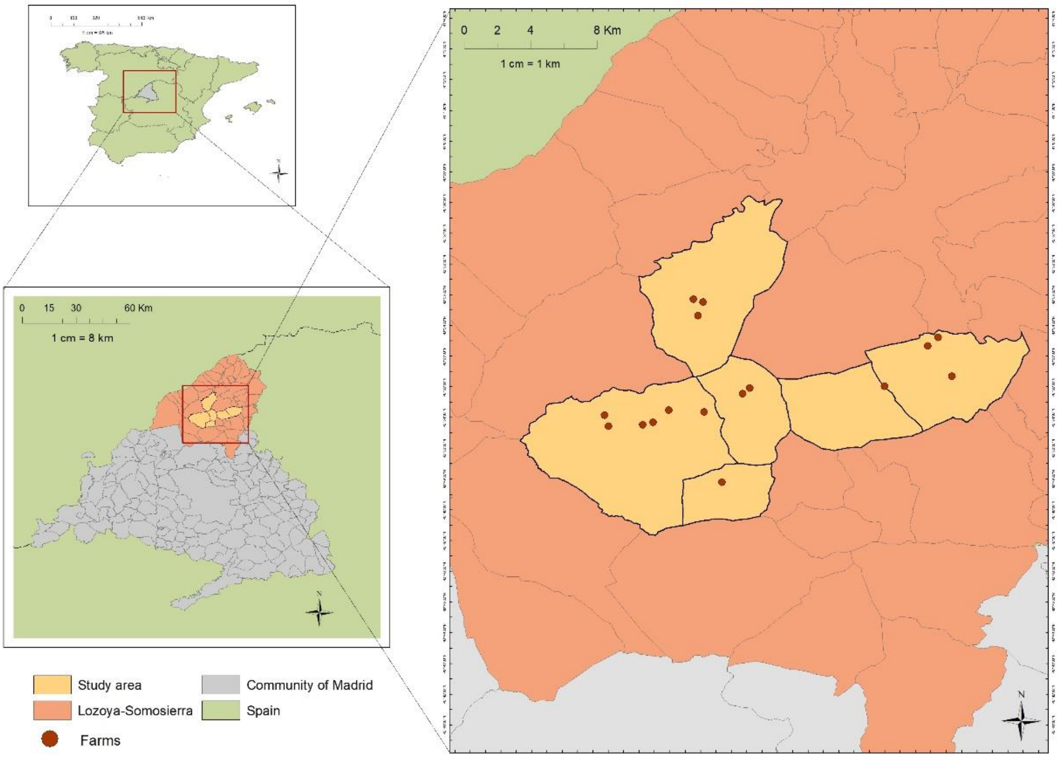
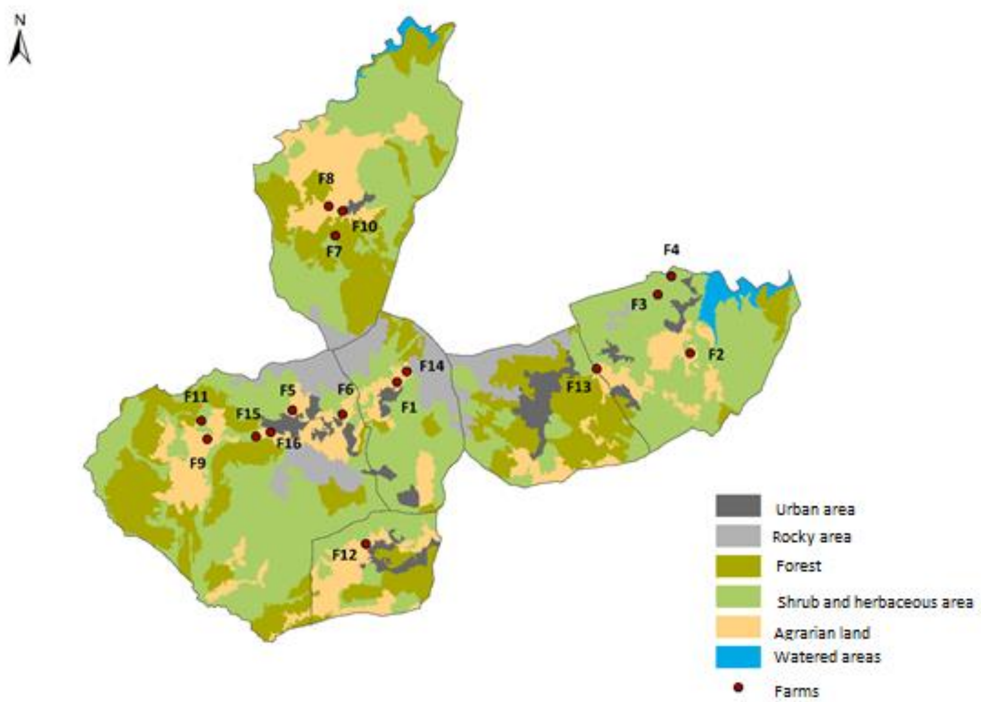


Figure 2. Location map of the study area where the farms are situated

In this region there are two distinct areas, the most extensive one is a mountainous area on ancient siliceous rocks where the main activity is livestock production. The other area is a calcareous zone with agricultural land, mainly covered with cereals, vineyards and olive trees (Aceituno, 2010). All the selected farms are in the siliceous area, within a granite landscape characterised by pastures and semi-natural habitats where there are some reforested areas with pine trees. We did not select farms from the two areas because the ecosystems are rather different and so we reduced the number of environmental variables which could affect bee diversity. In this area, agriculture has always been a marginal activity due to the climate and the shallow soils, but horticultural family gardens *(''Huertas*" in Spanish*)* has always been maintained for self-supply (Acín Fanlo, 1996). Nonetheless, in the last decade the number of horticultural production initiatives have increased. A total of 16 farms were selected in the granite area, all of them were at least 400 meters apart (to ensure independence between farms) and mainly engaged in horticultural production. The farms area located in different municipalities: Navalafuente, Bustarviejo, Valdemanco, Garganta de los Montes, La Cabrera and El Berrueco (Figure 3).

This region is around 70 km from Madrid city, but it has not high population density. Next to this area there is a national park (*Guadarrama*) which brings more tourism and daily visits to the area

Figure 3. Location map of the study area with the six municipalities where the farms are located. In the different colours the different ecological areas are represented following Corine Land Cover.



2.2. Structure and development of interviews to farmers

➢ Research question 1: Characterization of farms and agricultural practices

To characterize the selected farms and to deepen into their agricultural practices carried out by each farmer, a structured face to face interview model was designed. The interview has the following thematic blocks: Farm and farmer characterization (i), crops and agricultural practices (ii); collaboration (iii) where we asked about people involved in the project; the perception of pollinators (iv) where questions were focus on their opinion on the importance and the factors that influence them; and the last section was on socio-economic characteristics (v) (See the whole interview in the Annex).

The most extensive section is the block of crops and agricultural practices (ii). In this section we asked about the agricultural practices that they were applying, how they did it and for how long they had been doing it.

We asked about common agricultural practices: animal breeding, crop association, crop diversification, crop rotation, cover crops, beehives installation, natural edges, aromatic plants, drip irrigation, fallow, light/no tillage, nest-boxes for pollinators, fertilizers, pest control and weed control. Those practices were grouped into three categories or index to characterize the farms:

- ❖ Biodiversity index: It includes practices which are linked to and have an effect on biodiversity and habitat conservation such us crop diversification**,** installation of nest boxes for pollinators, natural edges and planting aromatic or melliferous plants.
- ❖ Production index: It encompasses practices with influence on horticultural production such us pest and herb management, crop association and inclusion of animals.
- ❖ Soil index: It includes practices that have a positive or negative impact on soil, like ploughing, fallow land, fertilisation, green covers and crop rotation, and irrigation system.

We calculated these three indices for each farm considering the level of application of the farming practices and the time that it has been applied. Some of the agricultural practices might be also related with more than one index, but decided to grouped them to use these indexes as explanatory variables for statistical analysis. After the field visit, the practice of natural edges maintenance was excluded from the analysis because it was difficult to quantify them. On the rest of farming practices, majority were applied in all farms, even though there were some differences in time and application. To give them a value we first categorised each practice based on the degree of application and its impact that rank from 0 to 1. Then, we multiple the degree of application and the time, having a value for each agricultural practice that rank from 0 to 1.

In order to take into account the time of application, we categorised it as follows:

Table 2 Values given to the practices depending of the application of time

Years applying the practice	**Weighted value of application time**
Less than 2 years	0.25

Between 2 and 5 years (5 not included)	0.50
Between 5 and10 years (10 not included)	0.75
More than 10 years	1.00

For some of the practices there was not a gradient of application, but only yes/no application. Those practices are crop association, crop rotation, cover crop, fallow, nest-boxes for pollinators and weed and pest control (1=YES, 0=NO).

For the rest of the practices the gradient of application was categorised as follows:

Table 3. Gradients of application of each of the practices and the value given to the practices depending on their degree of application

Practices' application degrees	**Practice value**
Animal breeding	
-No animals in the farm	0.00
-Animals in the farm as a way of diversification of the farm activity	0.50
-Animals in the farm as a way of diversification and taking part in other functions (weed/pest control, as fertilizers…).	1.00
Crop diversification	
-Weighted value of the number of products grown at each farm (the maximum was 50)	Products grown (n)/50
Aromatic plants	
-Weighted value of the number of aromatic species planted at each farm (the maximum was 10)	Aromatic species (n)/10
Drip irrigation	
-Flood irrigation	0.00
-Drip irrigation combined with other(s) type(s) of irrigation	0.50
-Exclusively drip irrigation	1.00
Cover crop	
-No fallow	0.00
-White fallow (bare soil)	0.25
-Green fallow (covered by weeds) of short duration	0.50
-Green fallow	0.75
-Green fallow grown with leguminous	1.00
Tillage	
-Ploughing tool: moldboard plow	0.00
-Ploughing tool: disk plow	0.33
-Ploughing tool: rotovators	0.67
-Ploughing tool: hand implements	1.00
Fertilizers	
- Weighted value of the number of practices to provide nutrients at each farm (maximum was 5)*	Practices for fertilizers(n) / 5
Weed control	
-Weighted value of the number of practices to avoid weeds at each farm (maximum was 3)*	Practices for weed control(n) / 5
Pest control	
-Chemicals	0
-1 practice applied	0,25
-2 practice applied	0,5
-3 practice applied	0,75
-4 practices or more applied	1

*The diversity of practices applied in the farms related with fertilizers, weed control, and pest control are:

- Fertilizers: sheep, goat, cattle and hens' manure, vermicomposting, nettle and other plants ferment, compost, limestone amendments, diatomaceous earth, ashes, shell flour, liquid seaweed fertilizer, bokashi, forest biorganisms which are inoculated in rice, milk (just one of the farmers – he applied 1L of milk/5 litters of water).
- Weed control: manual control, hoe, mulching.
- Pest control: hand control, horsetail plant, nettle fermentation, potassium soap, tansy plant, plants fermentation, nin oil, comfrey plant, sulphur, mixed of hot pepper with nettle and water, garlic and onion fermentation, mixture of vinegar and grain alcohol, potatoes extract, spintor.

2.3. Pollinators sampling

➢ Research question 2: Which wild bee communities can be found in small horticultural farms in the north area of Madrid?

We surveyed for bees using pan traps to analyse their species richness. This consisted of three plastic bowls painted with UV colours (yellow, blue and white) filled with approximately 400 ml of water and few drops of soap to break the surface tension. Different pan trap colours aim to attract different bee species (Geroff et *al*., 2014; Martin *et al.*, 2020). These plates were placed on metal structures at the height of the surrounding vegetation or crops (Figure 4). This is an efficient and common bee sampling method which is prove to suit in different habitat types (Leong and Thorp, 1999).

Figure 4. Left picture shows the metal structure with the pan traps placed at the height of the plants around. Right picture shows the pan traps after 48h period with the pollinators in it.

As shown in Figure 5, on each farm there were a total of 6 sampling points (each with three pan traps), three of them in the centre of the production area and another three on the edge. The distances between the pan traps were not always the same since every plantation is different and we had to adapt the setting to the terrain. Although the bowls were always placed with a minimum distance 10 m apart from one another.

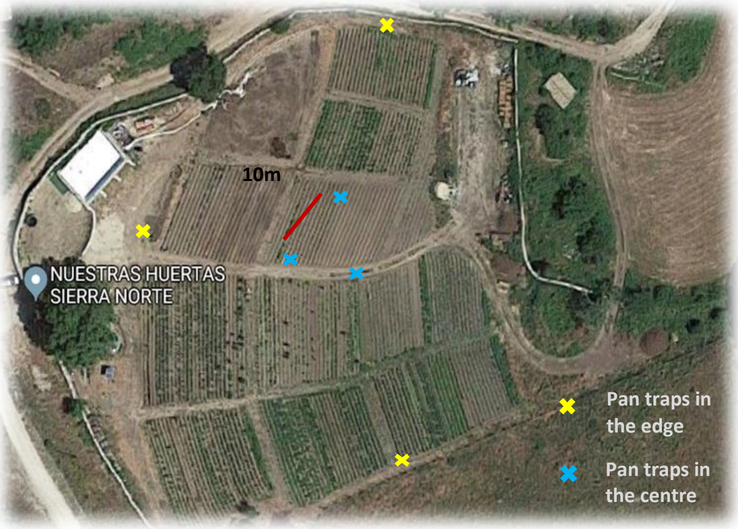


Figure 5. Aerial image that illustrates how pan traps are distributed in one of the farms. Three of the pan traps are in the centre and three are in the edge. Source: Google Satellite viewer

The sampling was carried out in June 2019 when most of horticultural plants were in their flowering stage. Pan traps were placed for 48 hours and all the farms were sampled during the same week to have climatic conditions as similar as possible and thus avoid possible bias. Then, all captures were stored in 70 % ethanol until they could be prepared for identification (dried, fluffed and pinned). Only wild bees were dry, which were identify at species level. We excluded from the analysis the counts of *Apis mellifera* L., 1758, as being a domestic species, it is possible the presence of beehives around the farms.

2.4. Cartographic analysis of the landscape

Landscape composition was mapped in each of the farms. A buffer of 400 meters around the sampling sites (farms) was delimited, which was established as the minimum distance between properties to select the farms. This radius was chosen because species richness of bees is affected at small spatial scales, around 300 to 750 meters (Steffan-Dewenter *et al.*, 2002; Neumüller *et al.*, 2020).

The cartographic data used comes from the National Plan for Aerial Orthophotography (PNOA), which has been processed for analysis using ArcMap 10.7.1 software. The digital aerial orthophotographs from Madrid Community are dated on summer 2018, a year before the analysis, with a resolution of 25-50 cm approximately.

The areas around the farms were tessellated in detail to obtained maximum information to later group them into different categories. In these areas different land uses and the main vegetation covers have been tessellated, differentiating: oak and ash forest, holm oak, pine forest, grassland for livestock, wet grassland, hayfields, rocky outcrops, areas with little vegetation or degraded soil, urban areas, roads, sand tracks, vegetable gardens or other crops and water surfaces (See table 4 and figure 6). The area of these categories was used to calculate the Shannon index to assess landscape diversity as another explanatory variable for the analysis. Crops, shrubs, trees and meadows can constitute an important foraging and nesting resource for pollinators. Thought we consider garden houses as an urban infrastructure, because different authors remark they can hardly be utilized by wild bees (Zhao, Sander and Hendrix, 2019).

Table 4. Landscape units differentiated when tessellated the radius of 400m around the different farms. These variables were used for a prior analysis and to calculate the Shannon landscape index.

Landscape Unit	Description
Pine forest	Pine trees, majority of them were not naturally growing there but an artificial plantation. Only found *Pinus sylvestris* and *Pinus pinaster*.
Deciduous forest	It corresponds to areas with deciduous trees. There is a mixed some species, mainly *Fraxinus angustifolia*, and *Quercus pyrenaica, but also some Salix atrocinerea.*
Quercus forest	It corresponds to areas with deciduous trees. Mainly cover with *Quercus pyrenaica*. It differs from the previous one because in the photographs appears as a homogenous tree mass.
Riberian forest	It corresponds to areas around water surfaces like small rivers. Mainly with the species of *Salix atrocinerea, Fraxinus angustifolia, Alnus glutinosa* and *Populus spp.*
Lavender shrubland ("Cantuesar").	It corresponds to aromatic shrubs formations, mainly with the species of *Lavandula stoechas* and *Thymus spp*.
***Rockrose* shrubland ("Jaral")**	It corresponds to a shrubs formation of *Cistus ladanifer*. It is also accompanied by other species like *Lavandula stoechas*, *Citissus scoparius* and *Daphne gnidium*
Pastures	Herbaceous areas with communities composed mainly of herbs where cattle graze directly. Tracks of livestock easily seen with lines in the photograph.
Mowing meadows	Grass is allowed to grow during spring to be mowed in early summer before it gets dry. Sometimes these meadows are irrigated to obtain winter fodder. It was distinguished in the photographs because of machinery tracks to cut the grass. (Luceño & Vargas, 1991; Aceituno, 2010)
Wet meadows	It corresponds to grassland areas but you can easily see in the photographs that the green is more strong. They are associated with humid areas.
Rocky outcrops	These rocky areas are very characteristic of this region because of its proximity to the mountains. It is a special ecosystem which provides shelter to plants and animals (Luceño & Vargas, 1991).
Arizonian trees	Small areas with trees planted usually around the houses, from the family of *Cupressaceae*.
Urban areas	It corresponds to areas with buildings or human infrastructure. Even though it also includes some green areas like house gardens.
Roads	Pavement roads
Sand tracks	Unpaved roads

Vegetable gardens	Small plots cultivated for self-consumption of vegetables with similar characteristics to the ones that we have sample
Areas with sparse vegetation or bare ground	It corresponds to areas where some patches with little vegetation and bare ground areas on the soil can be easily seen in the photographs.

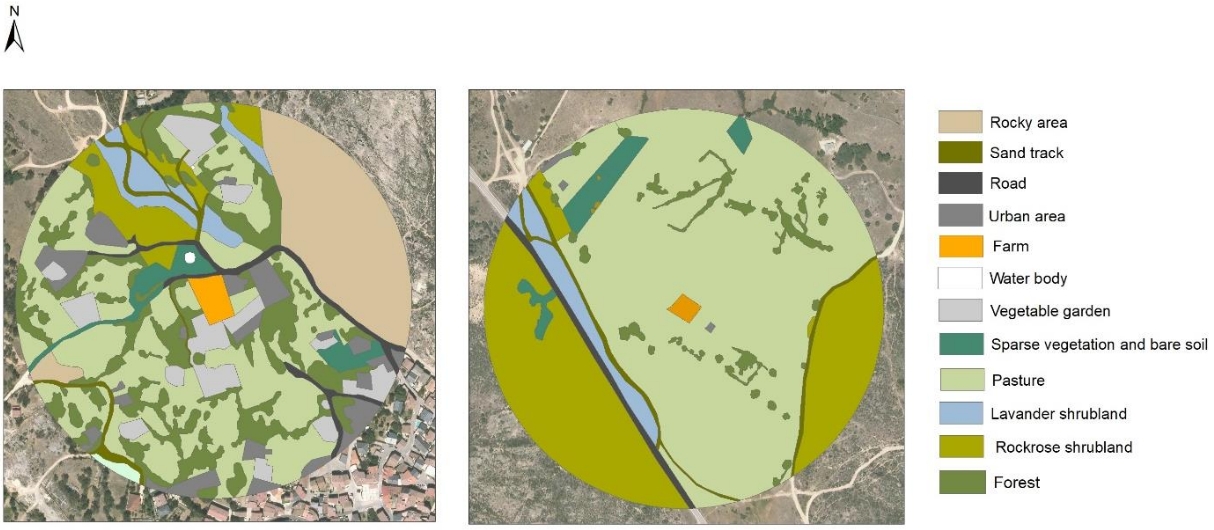


Figure 6. Two different examples with the tessellated areas around the farms where the different landscape units can be seen. Left map correspond to the farm with lower Shannon index related to the landscape (H`=1,215). The right map corresponds to the farm with higher Shannon index (H`= 2,134).

2.5. Data analysis

Research question 3: *How farming practices and landscape structures are affecting wild bee species richness?*

Firstly, data exploration was performed prior to analysis. We tested the dependency or independency between landscape variables using simple linear regressions. We have grouped the ones had a clear dependency (p-values >0.1) if they have ecological sense, for instance the different kind of forest (pine, deciduous, quercus and riberian) were grouped in just one variable called forest. We also calculated the minimum distance in to watered areas and to other horticultural farms by the Euclidean distance of vectors from the epicentres of the farm to these areas with the tool “Euclidean distance” from ArcMap 10.7.

With the identification of wild bees, abundance, species richness and Shannon index were calculated for the different horticultural farms, excluding from the counting the presence of *Apis mellifera*. Different scientific literature (Wilson et al., 2008) indicates that pan trap method used is not valid for measuring the abundance of wild bees, so it was considered appropriate to remove the abundance data from the analyses. Therefore, the statistical analyses have only focused on species richness values.

Instead of using the values given to the agricultural practices, we tested the correlation with the three index we have (biodiversity, soil and production index), which are the result of the summary of the different practices. Since no correlation was found with the index, individual values of the practices were also tested to see if there was any correlation with species richness. We tested the effect of selected variables (management index and landscape units, see Table 5) on species richness of wild bees using linear regressions (p-value >0,1), and then we calculate generalised linear model (GLM) with a Poisson distribution error to identify the variables most closely related to species richness. To do so we used the R package "MASS" (Ripley et al., 2019).

Model selection was made using the second order Akaike Information Criterion (AICc), which is suitable for small sample size, as is our case (N=16). The R package used was "AICcmodavg" (Matteson and Langellotto, 2010; Mazerolle, 2017). The models with an AICc difference >2 from the most parsimonious model (the lowest value of AICc) were not considered further to decide the reality of the data.

Table 5 Variables used for the statistical analysis to see which ones are related wild bee species richness.

Landscape Unit	Description
Forest	It corresponds to pine, deciduous, oaks and riparian trees
Pasture	It corresponds to the meadows found in the area (excluding the wet meadows) with the presence or not of livestock.
Sparse vegetation and bare soil areas	It corresponds to areas where some patches on the soil can be easily seen in the photographs.
Distance to watered areas	Distance to areas with water or with indications that the water was present (maybe not visible) like in the wet meadows or riparian trees.
Distance to vegetable gardens	Small plots cultivated for self-consumption of vegetables with similar characteristics to the ones that we have sample
Landscape heterogeneity	Shannon landscape index calculated with the variables of Table X.
Farm size	Total cultivated area
Biodiversity index	It includes the values given to the practices of crop diversification, installation of insect hotels and planting aromatic and melliferous plants.
Production index	It includes the values given to the practices of pest and herb management, crop association and inclusion of animals
Soil index	It includes the values given to the practices of ploughing, fallow land, fertilisation, green covers, cover crops and irrigation system

3. Results

3.1. Farm characterization: production model and agricultural practices

Agriculture is not a main activity in the northern area of Madrid, but small horticulture production, mainly for self-sustaining, is still maintained. The 16 selected farms are a sample of the type of horticultural farms that still exists, all of them keep some of their production for self-consumption. Though, only half of them (N=8) have a professional orientation and sell their production thought different channels. Regarding their production model, eight of them considered themselves to have an agroecological production integrating different farming practices, and the other eight were ecological but not certified.

The oldest farms are the ones oriented only for self-consumption, while six out of eight farms that produce to sale, have started their agricultural activity in the last 5 years (see Table 6) focused on agroecological management. They used different market channels to sell their products, being the most common at local markets, direct sales on the farms and thought barter or exchange

Table 6. Study areas and municipalities where farms are located, production model, purpose of the project and starting year.

ID	Municipality	Production Model	Ratio women/People involve	Purpose	Project start
F1	Valdemanco	Agroecological	1/2	Professional	2015
F2	El Berrueco	Agroecological	1/3	Self-sustaining	2015
F3	El Berrueco	Agroecological	2/6	Professional	2011
F4	El Berrueco	Agroecological	2/6	Professional	2017
F5	Bustarviejo	Ecological	1/4	Professional	2016
F6	Bustarviejo	Ecological	1/4	Professional	2016
F7	Garganta de los Montes	Ecological	0/1	Self-sustaining	Before 2000
F8	Garganta de los Montes	Ecological	1/2	Self-sustaining	Before 2000
F9	Bustarviejo	Ecological	0/1	Self-sustaining	2012
F10	Garganta de los Montes	Ecological	0/1	Self-sustaining	Before 2000
F11	Bustarviejo	Ecological	0/1	Self-sustaining	2009
F12	Navalafuente	Agroecological	2/4	Professional	2015
F13	El Berrueco /La Cabrera	Agroecological	0/1	Self-sustaining	2002
F14	Valdemanco	Ecological	0/1	Self-sustaining	2017

F15	Bustarviejo	Agroecological	0/5	Professional	2014
F16	Bustarviejo	Agroecological	0/5	Professional	2011

Farm´s size do not vary much, all of them are below 1 ha (between 550 m^2 and 9700 m^2), being the smallest the self-consumption ones. Professional projects involve more people comparing with the self-consumption ones which are majority managed by one person. Indeed, most of the professional projects have an agroecological orientation (6 out of 8), so in the agroecological projects there are more people involved. Among all farms there was a total of 58 people involved, of which only 11 of them were women (18,9 %).

Table 7. Farm and farmers characterization

	x̄ / %	SD
Farmer´s age	49,37	15,68
Farm size (m^2)	3160,39	3024,50
Years of production	14,12	18,45
People working per farm (average)	2,93	1,9
Women working at the farm (%)	18,9	
Motivation for being a farmer (%)		
- Hobby	43,75	
- Income supplement	18,75	
- Consume their own products	12,5	
- Tradition	6,25	

3.2. Perception of pollinator importance and threats

Majority of farmers (87,5%) believed in the necessity of bees for the development of their crops and other wild plants. When asking about their opinion in pollinators trend, 50% answered that bees are declining and 18,75 % thought that bees are stable in the area since they have not perceived any changes in the local population. It is important to highlight that in these two first question we did not make the difference between wild bees and honeybees, so we referred just to bees as broad term. Nonetheless while asking them if honeybees have an influence on wild bees, 37,5% of respondents said no and 37,5% that they did not know, while 25% of them said that honey bees have a negative effect on wild bees because they compete for the same resources (see Table 8).

Table 8. Farmers perception on the importance of bees for their plants, their current state and influence of honeybees on wild bees.

Questions from the interview		% Total responses (N=16)
Are bees essential for the development of your plants?	Yes	87,5
	No	12,5

	Don´t know	-
Do you think pollinators are stable/increasing/declining/don´t know in your area?	Stable	18,75
	Increasing	6,25
	Declining	50
	Don´t know	25
Do you think honey bees have an influence in wild bees?	Yes, positive	-
	Yes, negative	25
	No	37,5
	Don´t know	37,5

Farmers perception on potential threats to bees are rather similar within respondents. Most farmers perceive climate change, loss of natural habitat and pesticide application as the most important threats to bees. On the other hand, the only two factors that were observed by some farmers with no effects on pollinators are: agricultural practices (by 6,25 %) and the use of hybrid seeds (by 25%), 20 % did do not know (see Figure 8).

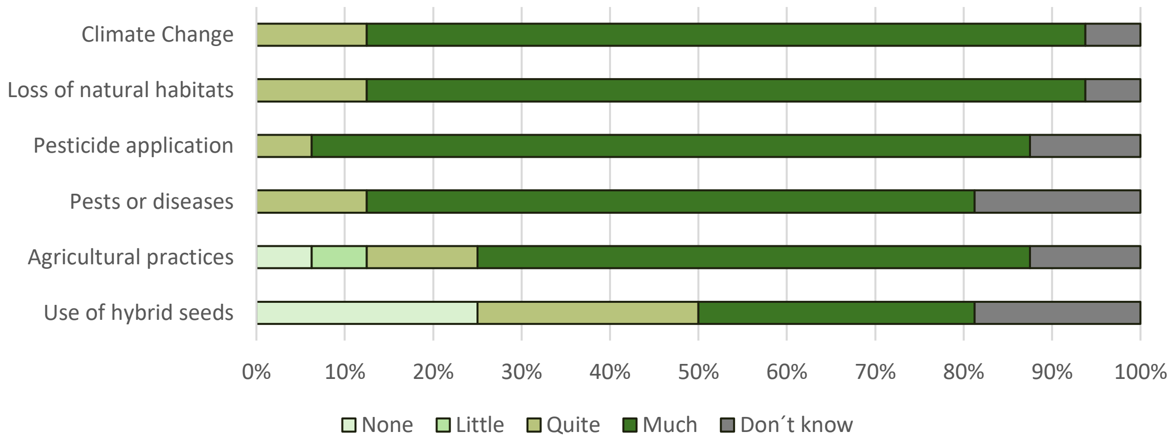


Figure 7. Farmers perception regarding drivers of change affecting bees

Regarding farmers ‘perception on the positive and negative effects of different agricultural practices on pollinators (Figure 8), respondents show similar opinions. What stands out is that farmers perceived as beneficial to pollinators wildflowers (93,75 %), water infrastructure (81,25 %), melliferous flora (81,25 %). Following those beneficial practices are natural edges (75 %), green fallow (62,5 %). On the other hand, pesticide application (93,75 %) and herbicides (81,25) were considered the most harmful practices for pollinators, followed by monocultures (62,5 %). Tillage (50 %) and installation of bee hives (43,75) are considered quite indifferent practices to bees. The used of hybrid plants is the practices were farmers are more hesitant about its effects on pollinators (43,75 %).

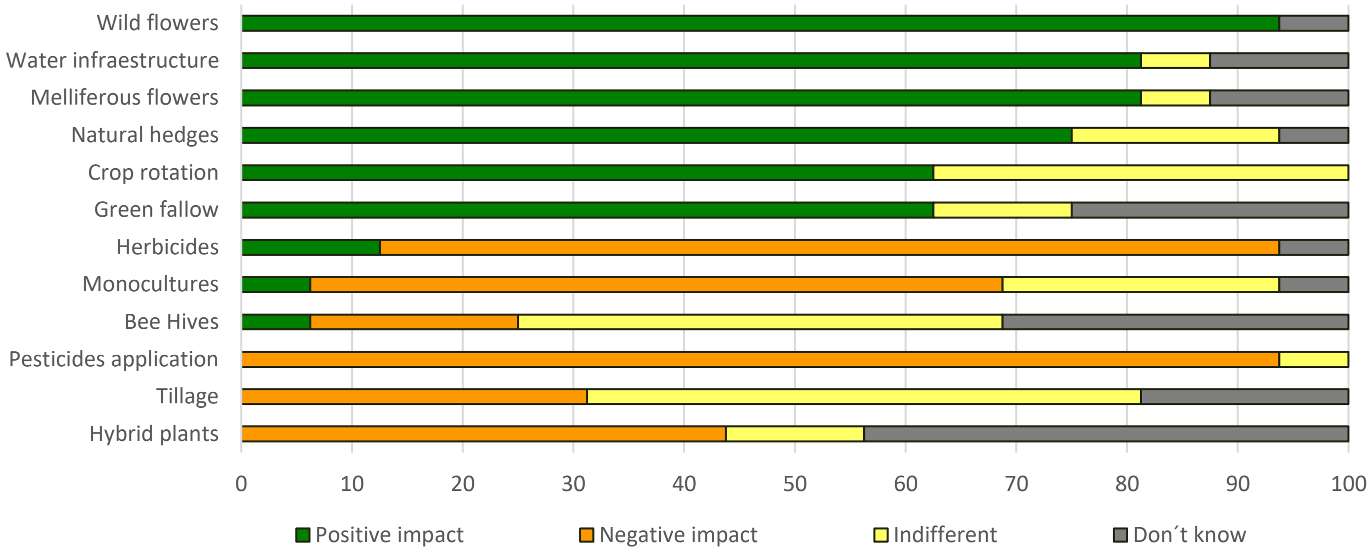


Figure 8. Farmer´s perception on the effect of agricultural practices on pollinators

3.3. Agricultural practices applied by farmers and indices

3.3.1. Agricultural practices

Overall, farmers applied 62,5 % of the 15 agricultural practices we asked about. The management practices which were applied by all the horticultural farmers are tillage, natural fertilizer and weed control. Tillage was applied by different ways (tractor, motor hoe, hoe, double-handle pitchfork) to prepare the soil and facilitate roots growth. Farmers used local manure as a natural fertilizer and weed control was done by hand, mulching, hoeing or with brush cutting machine. Besides this, the most frequently adopted practices were crop diversification (93,75%), pest control (93,75%), and crop rotation (87,5%). Following these practices, aromatic plants, drip irrigation and preservation of natural edges were practices that were applied for more than 50 % of farmers (Figure 9).

The agricultural practices which were less applied by farmers (<50 % of farmers) are (in descent order of application): crop association, green cover, fallow, animal breeding, bee hives and nest-boxes for pollinators. In the case of fallow, all farmers were aware of the positive impact of leaving the land rest for few months or season, nonetheless they claimed that they have very small farming area so they cannot leave part of land unproductive. Regarding bee hives and animal breeding, it would require higher workload and more space which majority of them do not have. In case of green cover, the main reason was the lack of knowledge about the technique itself and its benefits to soil, though in one case it was also mentioned the access to seed mix in small quantities is not accessible.

A minority of farmers (9,5 %) indicated their willingness to adopt new practices. Nest-boxes for pollinators was the most mentioned one (50 %) because it requires low resources and extra workload, followed by bee hives (25%) and crop association (18,75 %).

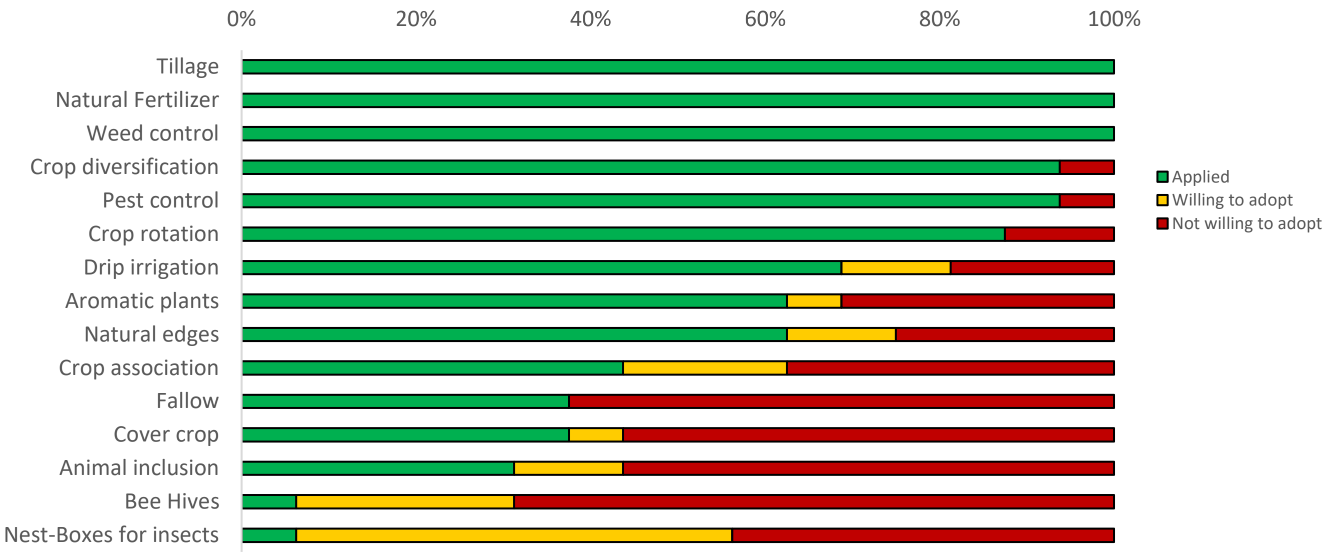


Figure 9. Agricultural practices that farmers are applying (green), that could adopt (yellow) and that they are not willing to adopt (red)

3.3.2. Calculation of agroecological index for biodiversity, production and soil

The three different index (biodiversity, soil and production) created by grouping the agricultural practices and its average value per farm in can be seen in the table 9.

Table 9. This table shows the average value of the three different indexes (biodiversity, production and soil indexes). This indexes are calculated with by the agricultural practices applied by farmers. The better performance of practices is related with soil index since it has the highest value (0,38).

	Horticultural farms (N=16)
Biodiversity index ($\bar{x}$)	0,23
Production index ($\bar{x}$)	0,31
Soil index ($\bar{x}$)	0,38

Comparing the different index within all horticultural farms, in average, soil conservation index is the higher one followed by production index. This reveals that practices related with soil are the most applied ones in horticultural production. For instance, the farm with the higher value (F3) has homemade bike hoe to have a superficial soil movement, they use manure from local livestock if needed and have incorporate green cover crops and annual crop rotation. By contrast, farmers with lower value realized practices with negative impact on soil as heavy soil ploughing during long period of time.

The value of the production index shows that it is between the other two indices ($\bar{x}$=0,31). The farm with the highest value has different crop associations (lettuce-tomatoes, maize-beans, strawberries-garlic), weeds were controlled by hand, and he has a complex and natural pest control system with the help of hens helping at the same time to fertilize the soil. Related with these practices, crop association and the inclusion of animals in the production system were the practices least applied by farmers. Only three of the total number of farms had hens for egg production, pest control and to use their excrements as a fertilizer.

Biodiversity index has the lowest average value (x̄= 0,23), which means that the practices in this index were less applied by farmers. The farms with the highest value is because they have high diversification of crops and aromatic or melliferous plants in the farms. As it can be seen in the figure 9, only one farm has nest-boxes for pollinators. There are some farms with a value close to 0 because they only had crop diversification of the practices included in this index.

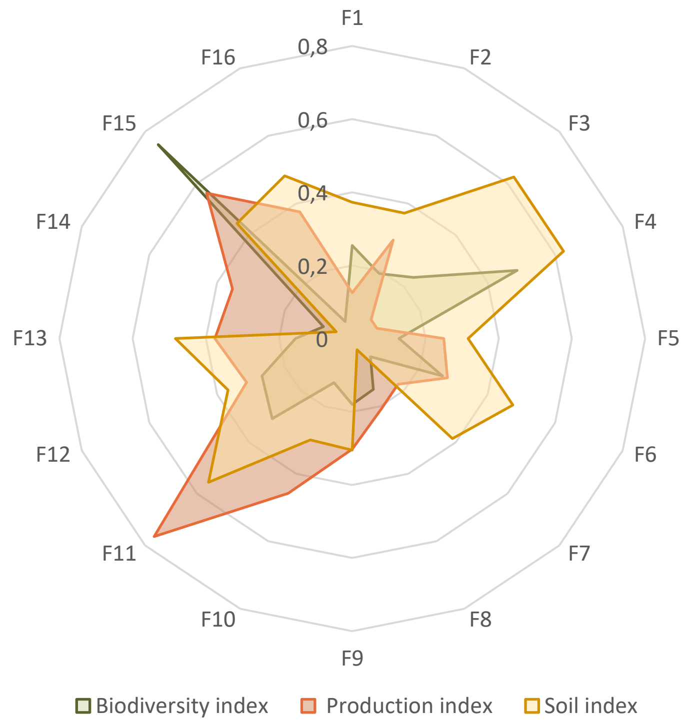


Figure 10. The graphic shows the values (from 0 to 1) of the three different indexes (biodiversity, production and soil index) given to the different farms (n=16). The indexes were created with the values of the agricultural practices applied at each of the farms. Green colour represents biodiversity index (conservation of natural edges, nest-boxes for pollinators, aromatic plants and crop diversification), yellow colour is soil conservation index (ploughing, fallow, fertilization, green cover, crop rotation and water management), and red colour represent production system (pest and herb management, crop association and animal inclusion).

3.4. Wild bee results

Abundance, species richness and Shannon index has been calculated for the different horticultural farms (Table 10), excluding from the counting the presence of *Apis mellifera*. Regarding the species richness, the average value is 34,3 species per farm with a standard deviation of 6,63 which means that there is not much variability between the species richness found at the different farms. The farm with the highest specie richness has 47 different species, while the farm with the lowest one has 24 species. When looking at the individuals, there is much more variability within the farms (SD=111,57), and an average of 226 individuals found per farm.

Table 10. Amount of individuals, species richness and the Shannon diversity index in the 16 horticultural farms

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
Individuals	**118**	**106**	**189**	**411**	**192**	**227**	**283**	**333**	**209**	**422**	**160**	**67**	**107**	**144**	**339**	**311**
Species richness	**31**	**25**	**29**	**33**	**34**	**30**	**47**	**41**	**38**	**38**	**33**	**24**	**27**	**36**	**44**	**39**
Shannon index	**2,77**	**2,67**	**2,53**	**1,81**	**2,57**	**2,47**	**2,96**	**2,73**	**2,80**	**2,65**	**2,77**	**2,45**	**2,21**	**2,67**	**2,60**	**2,44**

A total of 109 species (3618 individuals) belonging to 26 different genera were collected within all the horticultural farms (see Annex). The most predominant family was Halictidae with 3229 individuals (which means 89,24 %) followed by Apidae family with 162 individuals (4,47 %). The most species rich genera in the sampling was *Lasioglossum* Curtis, 1933 with 30 different species, followed by *Halictus* Latreille, 1804 with 11 species, and then *Andrena* Fabricius, 1775 with 10 species. The 30 species of the genus *Lasioglossum* Curtis, 1804 are 68 % (2467 individuals) of the total number of bees founded; it is important to highlight that 994 individuals are the same species, *Lasioglossum albocinctum* Luke, 1849.

Individuals of the six families present in the Iberian Peninsula were founded in the sampling (Table 11). Although the Melittidae family it was only present with 10 individuals of the species *Dasypoda argentata* (Panzer, 1798), and regarding Megachilidae family, there were only 48 individuals.

Table 11. Six bee families pesent in the horticultural farms during sampling with the amount of individuals found. We found bees with different nestings need (canes, dry wood, cavities, stems, soils). Nonetheless majority of bees found nests in soils (95%).

Family	% individuals (n=3618)	**Nesting type**	%individuals (n=3618)
Andrenidae	3 %	Canes, dry wood, cavities, stems	4 %
Apidae	4,46 %	Soil	95%
Colletidae	2%	Parasites	1 %
Halictidae	89,24 %		
Megachilidae	1 %		
Melittidae	0,3%		

Most of the genera found belong to bees that nests in soils (95 %) and only 4 % (Xylocopa Latreille genera, 1802, Ceratina Latreille 1802, Megachile Latreille 1802 and Anthidium Fabricius 1804) nest above ground, such as dry wood, canes , or stems (Ortiz-sanchez, 2018) (see Table 11). In relation with its behaviour, it is unknown if many of the bees found are solitary or eusocial. Social bee's species are included within the families of Apidae and Halictidae, thought of the latter only some species of the genera Halictus, Latreille 1804 and Lasioglossum, Curtis, 1833. As we have mentioned before, majority of bees found belong to these two genera, so we can expect that many of bees in our farms have social behaviour.

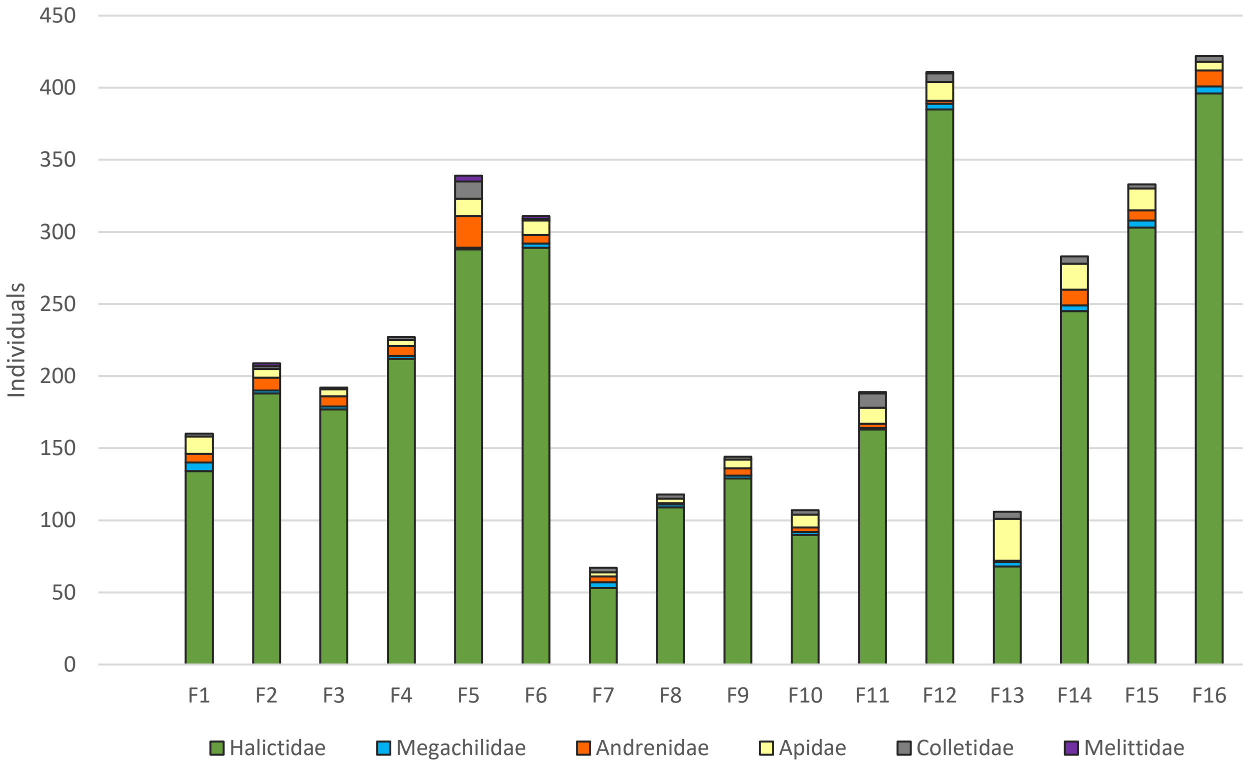


Figure 11. Distribution per family bee at the different farms. It is common to all farms that the predominant genera are Halictidae; the second most found genus per farm varies between Apidae and Andrenidae. The farm with least number of bees had 67 individuals

3.5. Landscape and farming practices effects on wild bees

We found that species richness responds more to landscape elements than to the agricultural practices applied by farmers. There is a positive correlation with two variables of the landscape pattern, sparse vegetation and bare soil areas and forest area (see Table 12). Landscape heterogeneity, pasture areas, distance to watered areas, distance to farms and farm configuration (farm size) did not show correlation with species richness.

Table 12. Pairwise relation among our 10 predictor variables. There are variables related with landscape elements (sparse vegetation and bare soil areas, forest, pasture, distance to water areas, distance to other farms), farm characteristics (farm size), and agricultural practices (biodiversity, production and soil index). It can be seen already that species richness seems to have a positive correlation with sparse vegetation and bare soil areas and with forest areas.

	Species richness	Landscape heterogeneity	Sparse vegetation and bare soil	Forest	Pasture	Farm size	Distance to water	Distance to farms	Biodiversity index	Production index	Soil index
Species richness	**0**	0,864	**+0,002**	**+0,045**	0,931	0,834	0,251	0,941	0,890	0,623	0,264
Landscape heterogeneity		**0**	0,702	0,903	0,252	0,294	0,672	0,531	0,820	0,731	0,245
Sparse vegetation areas and bare soil			**0**	0,224	0,613	0,972	0,520	0,756	0,774	0,977	0,739
Forest				**0**	0,064	0,178	**+0,003**	**+0,016**	0,308	0,814	0,716
Pasture					**0**	0,959	0,564	0,705	0,721	0,542	0,784
Farm size						**0**	0,613	0,340	0,058	0,306	0,524
Distance to water							**0**	0,126	0,953	0,147	0,886
Distance to farms								**0**	**+0,017**	0,947	0,123
Biodiversity index									**0**	0,439	0,116
Production index										**0**	0,971
Soil index											**0**

Regarding the models, two different models including sparse vegetation and bare soil areas and forest area were equally parsimonious (Table 13). The percentage of sparse vegetation and bare ground areas in combination with forest area around the farms seems to influence wild bee species richness since counted ΔAICc values lower than 2. Models including other variables that had a ΔAICc values higher than 2 were not considered as influencing variables on wild bee species richness. In relation with farming practices, we did not find significant relation with management index variables, so they were not included in the model to explain our response variable of species richness

Table 13. GLMs for species richness and response variables. The first four predictors (marked in bold) counted ΔAIC values lower than 2 and therefore, were considered as influencing variables. Abbreviations: AICc = Second order Akaike Information Criterion, Δ AICc = Difference between AICc to the next most parsimonious model

Response variable	Explanatory Variable	AICc	ΔAICc
Wild bee species richness	Sparse vegetation areas and bare ground	100.945	**0**
	Sparse vegetation areas and bare ground+ forest	102.618	**1.67**
	Sparse vegetation areas and bare ground + landscape heterogeneity	103.705	2,75
	Sparse vegetation areas and bare ground + pasture	103.85	-
	Sparse vegetation areas and bare ground + distance to farms	103.94	-
	Sparse vegetation areas and bare ground + farm size	103.97	-
	Sparse vegetation areas and bare ground + distance to water	106.253	-

4. Discussion

4.1. Agroecological transition in Madrid

The importance of agroecology has been recognized globally. Also in Spain, agroecology is becoming more solid in its three different forms (as a science, movement and practice) (Wezel *et al.*, 2009; Gallardo-López *et al.*, 2018), being an holistic concept which is contributing to the transition of our agri-food system. The concept is also entering into political sphere in Spain, though it has a long way to go being a decisive factor for an agroecological transition (Márquez-barrenechea *et al.*, 2020). Madrid region which has a large metropolitan area with 6.7 million inhabitants (2019), who exerts an important pressure on the surrounding systems, as in the peri-urban agricultural space and in the rural environment (Yacamán Ochoa, 2018). Madrid has lost 15 % of its utilised agricultural area and 33.5 % of agricultural farms in a period of time of 10 years (from 1999 to 2009) (Soler and Fernández, 2015). Although sometimes is forgotten, agriculture plays an important role in the region at landscape level covering 28 % of the territory (del Valle J. et al., 2018).

Despite the agricultural situation in Madrid, the demand of local and agroecological products is increasing, which should be taken as an opportunity to favour and to move towards more sustainable food system. On the other hand, in Madrid organic and agroecological farmers experience a positive trend with an increase of alternative and innovative projects (Simón-Rojo *et al.*, 2020). Some of these initiatives have shown an important awareness and support from the public institutions (García-Llorente *et al.*, 2019), some of them being initiated by farming sector (Simón-Rojo *et al.*, 2020). This increase in the small scale farming sector is especially important as it is counteracting the trend to decrease agricultural farms. The characterization of our farms support this this trend since 6 out of 8 of our agroecological projects were developed in the last 5 years. There are two technical reports analysing the development of agroecological production in the Community of Madrid, one from 2013 (del Valle, 2015), which is focus only in horticultural sector (including here fruit sector) and the more recent one from 2019 (del Valle J. et al., 2018). In 2013, del Valle (2015) counted 37 horticultural active projects and in 2019 there were 59, which means an increase of 22 projects in 6 years. Important to highlight that 40 % of the agroecological production in Madrid correspond to horticultural production (del Valle J. et al., 2018), which occupies 3 % of the surface area of the region (25.937 ha) (MAPAMA, 2015). This means that within the agroecological sector horticulture is particularly important.

4.2. Agricultural management at the farms – Which practices are willing to adopt?

At farm scale, farmers have the opportunity to make a decision about which management and agricultural practices want to implement in their land. Farmers can influence the surrounding landscape and the biodiversity around and in the farm with these practices (Aviron *et al.*, 2007; Klein *et al.*, 2007; Home *et al.*, 2014). Agricultural practices applied in the sample of farms are rather similar within each other since all of them are small scale horticultural production located in the same area. The characteristic or feature that most differentiates these farms is the length of time that soil has been in production, some of them are relatively new (<5 years), while others have been in production for more than 50 years. For the calculation of the indices it is therefore assumed that the impact of an agricultural practice will be greater in those that have been applying it for a longer time. Indeed, the farms are relatively small (<1ha), which is important to take into account when measuring the impact of agricultural practices in the environment.

- Soil agricultural practices

Annual crops as horticultural production is, requires an intensive management of the land. For instance, ploughing and tillage are predominant agricultural practices for preparing the soil for the crops, which implies soil disturbance every year. Our results show that majority of farmers were aware of the negative impact on soil, even on wild bees (31 % of farmers perceive this practice as negative to wild bees), but in the interviews they claim the need of this practice in horticulture to facilitate roots growth and water retention and to get rid of weeds. To minimize the impact, some do it with a hoe or by double-handle pitchfork, they assume that "it is a bigger effort at the beginning but it last more and in the coming years the damage on the land is lower". Regarding the other practices included in the soil agricultural index (cover crops, crop rotation and fallow land), the farmers who applied them had the motivation of restoring and maintain soil quality. For instance, five of our farmers used cover crops over winter time as part of a crop rotation (mix of seeds like mustard, oats and vetches) in order provide nutrients and structure to the soil. Few farmers claim that rainfalls are really low and the soil is sandy, so it is important to keep the soil with plants to maintain humidity. Instead of planting the covers, others had fallow land with natural plants growing over winter. This have been prove by several studies (Palomo-Campesino et al., 2018), which reveals that soil fertility will be improve by having minimum disturbance or no-tillage, or by using permanent cover crop via green cover or mulching (Vincent-Caboud *et al.*, 2017). Mulching, mainly with straw and other plant residues was also applied during summer time to retain for longer the water in the ground. They main reason of farmers who were not applying fallow land or green cover is because they cannot leave part of their land unproductive since they have very small farming areas. The lack of space and the difficulty of access to land is commonly known as one of the main barriers for the development of this kind of agroecological projects (Soler and Fernández, 2015; del Valle *et al.*, 2018). Additionally, several studies assessed that fallow land and cover crops are not only beneficial for soil fertility but for enhancing biodiversity in agroecosystems, carbon sequestration, climate regulation, erosion protection and pest control (Kaye and Quemada, 2017; Zhou Yang , Zhu Honghui, 2017; Palomo-Campesino, González and García-Llorente, 2018; Robleño *et al.*, 2018; Zhao, Sander and Hendrix, 2019).

The practice of tillage, which is carried out by all of our farmers, is recognised by different studies as one of the most negative ones to soil structure and soil life (Holland, 2004). According to Vincent-Caboud et al., (2017) no tillage management is more common in south of Europe and cover crops are widely extended in north Europe. Humid and cool conditions in the north increases difficulty of non-tillage implementation, while in the south due to warm, dry and wind conditions the practice of intensive tillage provokes soil degradation and soil water loss. Due to water-limited southern climate, cover crops are more difficult to establish and can compete with cash crops. This represent trades-off of incorporate sustainable practices and how these practices need to be adapted according to local conditions. Regarding all soil practices applied in the farms, our results reveal a good knowledge among farmers of how to decrease the negative impact on soil by implementing other practices.

- Biodiversity practices and advantages of diversified agroecosystems

Diverse agroecosystems with broader functions are better prepare to overcome changes in environmental and social conditions (Matson *et al.*, 1997). Agrobiodiversity management is a key element to ensure future agricultural production. Thus, agricultural crop diversification maintains agrobiodiversity and builds resilience in agricultural systems. Several studies claim that crop diversification improves the resilience of a system by suppressing pest outbreaks and pathogens transmissions, it buffers crop production and mitigates weather variations (Wezel *et al.*, 2014). By having wide diversity of plants and crops we will maintain greater diversity of animal species with natural enemies that will provide long-term pest suppression. Since climate fluctuations have increased, diversified agroecosystems are more important. Changes in precipitation and temperature have important effects on crop developments, especially during flower and fruit development periods. All of our farms have a great diversity of crops, the farm with more variety has more than 50 varieties of plants while the farm with lower number has 10 different crops.

According to Palomo et al. 2018, who made a literature review about ecosystem services provided by agricultural practices, crop diversification not only provides regulating ecosystem services (pest control, soil fertility, pollination) and provisioning ecosystem services (fodder, food) but cultural ecosystem services as the aesthetic value. A clear example within our farms is that one of them has open access because in their aims of the project is to create an agro botanical garden where people can walk within the different crops. Including thus another cultural service provided by the farm as the educational value.

Crop diversification has not only environmental and ecological benefits, but it is also a strategy for ensuring economic viability in small scale farms. Some of our farmers have direct sale or sell thought consumer’s groups, so they need also diversification to provide different options to their consumers. Diversification of agroecosystems not only includes crop diversification but diversify the functions and strategies for guarantee the sustainability of small scale farms. It is also seen in the literature as a key element to maintain small scale farming and as an alternative to scale and specialization strategies which are more economically vulnerable nowadays (Reganold and Wachter, 2016; Roest, Ferrari and Knickel, 2018). There are different kinds of diversification, such production, processing or other activities like agro tourism. In our case, our farmers are only focus on agricultural production, and their main strategy chosen is direct retailing to consumers at the farm, to restaurants or to consumer groups. A farmer claimed that in this way they are more connected with the community and react rapidly to the changes in their consumptions.

Our results show that the majority of our farmers realize agricultural practices which are beneficial for biodiversity, and indeed for pollinators, even though there are some agricultural biodiversity-friendly practices not as well accepted by all farmers. For instance, even the majority of our farmers leave some of the herbaceous plants in the farms, some of them (25 %) were not willing to adopt this practice due to lack of space and knowledge about its benefits. Different studies show that the maintaining of natural elements like herbaceous plants or bushes within the fields or around promotes biodiversity conservation (Van Vooren *et al.*, 2018). In the Mediterranean area, there are many wild plants which are aromatic ones, so a farmer mentioned that they leave the natural plants because they are aromatic and attracts beneficial insects. Majority of our horticultural farmers (82 %) were aware of the positive impacts of aromatic flowers in their farms. The ones who were not willing to have aromatic plants are the smaller ones and with self-sustaining focus.

At regional level, delivery of ecosystem services is affected by landscape dynamics, which is directly impact by the different farms management. Thus, cooperation and collective management between different actors in a territory will have more effective impact at landscape level compared to an individual action. Different studies claim that pollination is one of the ecosystem services that needs a collective management since wild bee’s populations requires large patch of habitats or many small patches (Goldman, Thompson and Daily, 2007; Stallman, 2011).

4.3. Wild bee assemblages in horticultural farms

We found that, overall, a total of 109 wild be species spanning six families were found in the horticultural farms. This number corresponds to 10 % of all known species in the Iberian Peninsula (approximately 1105 species) (Ortiz Sánchez, 2011). There is no updated list of bees occurring in the different Spanish regions, but there is a study from this region with the bee species found in the 80`s (Pérez-íñigo Mora, 1981). In this study a total of 300 bee species occur in the area where our farms are located, representing approximately three times more than the number we found. This is normal because bee richness observed in crops are always a small fraction of the whole fauna of bees in the studied region (Kleijn *et al.*, 2015; Rodrigo Gómez *et al.*, 2021).

The comparison of our results with others focusing on species richness might be biases due to the variability of methods used. Indeed, previous studies on horticultural production in the Mediterranean territory are scarce. The published data found are studies focused on the study of pollinators of specific monocultures and not on polycultures as horticultural farms are here. For example, Rodrigo Gómez *(*2021), recorded also a great diversity of bees in watermelon, melon and almond crops, spanning 98 species of wild bees obtained by different sampling methods. In watermelon and melon fields (but not in almonds), *Lasioglossum* genus was particularly predominant. Hevia *et al.* (2016) captured 68 wild bee species using pan trap method in drove roads adjacent to sunflower crops, being *Lasioglossum* again by far the most abundant genus (representing 88 % of all wild bees).

Our results are comparable with the studies mentioned above, Halictidae is also the most common family with 89 % of wild bees being from this family. It is particularly abundant as in the rest of the studies the genus *Lasioglossum* (with 30 species found), followed by *Halictus* and *Andrena*, this last one form another family bee (Andrenidae). So according to our data and other studies, *Lasioglossum* genus plays an essential role in the pollination of the horticultural plants, which makes particularly important to study their behaviour. In our study there two main species with special importance due to the amount of individuals found, *Lasioglossum albocinctum* (994 individuals) and *Lasioglossum malachurum* (437 individuals). Majority of bees from Halictidae family are solitary bees that excavate their nests in sandy and clayey soils, sometimes forming large aggregations of nests in the same area (Molina, C. & Bartomeus, 2019). It is unknown whether the species *Lasioglossum albocinctum* is a solitary or eusocial bee, while numerous studies found that *Lasioglossum malachurum* is a eusocial bee which establish their colonies in the subterranean nests in spring (Wyman and Richards, 2003; Polidori *et al.*, 2010). Thus might be the explanation why we found that amount of individuals in specific farms, which were surrounded by sunny spaces devoid of vegetation for nest construction. The number of individuals found of *L. albocinctum* and its familiarity to *L. malachurum* might let us think that is also a eusocial bee, it should be noted that there are still no studies to prove this. Both species are considered polylectic, so they collect pollen from a wide range of plant species (Molina, C. & Bartomeus, 2019), what fits as well with the diversity of plants in the farms.

It also important to notice that different studies suggests that below-ground nesting species bees to not tend to create their nest in crop field where there is tillage (Williams *et al.*, 2010; Appenfeller, Lloyd and Szendrei, 2020) This information let us think that since in horticultural farms there is soil disturbance, the surrounding areas plays an essential role for nesting habitats of majority of our bees.

Another important factor to take into account is the period of time when the bees were collected, which correspond to the flowering period of time of the horticultural plants (July). According to Pérez-Iñigo Mora (1981) *Lasioglossum* genus is an early emerging species typical from this period of time. So according to the abundance found in our study and in our studies, *Lasioglossum* genus plays an important role in the pollination of the horticultural plants, which makes particularly important to study their status and behaviour.

4.4. Sampling method

Adequate selection of sampling method when surveying wild bees is needed to explore pollinators abundance and diversity. The most common methods are sweep net, transects and floral observations plots, but there are others as vane traps, baits, aspirators and trap nests (O'Connor *et al.*, 2019; Prendergast *et al.*, 2020). There is variation in the effectiveness between methods, so the scientific recommendation is to use a range of methods to reduce biases and to come as close to reality as possible, because no one sampling method can fully represent wild bee community. In this study, pan trap method was chosen taking into account sampling efforts, skill require and cost of implementation (logistics and resourcing implications), which is consider an standardize method useful for comparisons (Wilson *et al.*, 2008). By using this method, we could cover all time slots since bee species can differ along the day (and some even night). Indeed, different studies argued that the obtained data from pan traps is independent of expertise, while the number of species found in transect walk carry out by people without experience will be biases due to lack of technical training.

In our study we have also taken into account limitations and drawbacks associated with the method used. Some studies claim habitat can impact the success and suitability of the sampling method used. In flowering crop fields there has been a negative relation between species catch rates and flower density due to “competition” between pan traps and flowers (Cane, Minckley and Kervin, 2000). Though other studies show positive effects (Wood, Holland and Goulson, 2015). Therefore, having in mind that our objective is to study wild bees in horticultural farms, in which majority of plants are flowering plants dependent on pollinators, is important to have these caveat in mind when interpreting results. Indeed, when studying horticulture production it might be interesting to characterize plant-pollinator approach by identifying which species are delivering the service of pollination, which is not possible with pan traps (Gibbs *et al.*, 2017).

Pan traps also might influence catch rates and species composition, stating that the method used should change according to the taxonomic group at the study. For instance, different studies suggest size of the body bee as a factor influencing species accumulation in pan traps, smaller ones falling than more than larger ones (like bumble bees) because flight efficiency increases as body size increases being easier for them to escape (O’Connor *et al.*, 2019; Hudson, Horn and Hanula, 2020). There might be more unknown reasons why some bees are more inordinately attracted than others. This is supported with our data since in our study 78 % of our bees correspond to the family Halictidae, specially from the genus *Lasioglossum spp*. which is characterized by small body bees. Since we have only used one method we cannot assume our data represent the pollinating bee community in our given location. Abundance data is not accurate reach with pan trap method (Wilson *et al.*, 2008), for instance in our case abundance of *Lasioglossum spp*. might be overestimate. Therefore, for our analysis we have only used species richness of wild bees by using pan trap method.

4.5. Landscape elements and farm management effects on wild bee communities

Although it is widely recognised that farmers influence biodiversity, biodiversity is also affected by conditions out of farmers control, like the farm settings (e.g. altitude, landscape context) (Tscharntke *et al.*, 2012; Stoeckli *et al.*, 2017). We evaluated the effect of different landscape elements and different agricultural indices (table 12) on species richness of wild bees on 16 horticultural farms. Two elements of the landscape have correlation with species richness found in the sample, area with sparse vegetation or bare soil and forests areas. Although our data do not show it, numerous studies have concluded that the management of the farm and the intensity of the agricultural practices have a decisive effect on biodiversity and more concrete on pollinators community (Nicholson *et al.*, 2017; Neumüller *et al.*, 2020).

Our farms perform similar agricultural practices, which can make it difficult to see the effect of the them on the species richness. In order to make their differences visible we have created the three different indices that combined different practices. There are studies that analyse the effect of these practices at the individual level (Le Féon *et al.*, 2010), but we were more interested in measuring whole farm management, instead of constraining the farms to binary categories (e.g. organic vs. agroecological). Indices can provide more holistic vision of the farm and better characterize their local management heterogeneity (Nicholson *et al.*, 2017), and different authors have been used them to analyse bee species diversity as well (Le Féon *et al.*, 2010; Nicholson *et al.*, 2017; Stoeckli *et al.*, 2017).

Farm characteristics or farm heterogeneity like field size influence as well biodiversity, which will be benefit by decreasing crop field size. Different empirical studies show that more species richness is found in agricultural landscapes with smaller fields, even though there might be different responses among taxa (Aviron *et al.*, 2007; Fahrig *et al.*, 2015; Martin *et al.*, 2020). Martin et al., (2020) evaluated the relative effect of individual farming practices versus farmland heterogeneity (crop diversity and farm size) and they found that farmland heterogeneity can have similar (or sometimes more) effects than farming practices used in individual crop fields. This means that farming practices can have different effects on biodiversity depending on the size of the field and the diversity of crops. Our data supports that agricultural farming practices effect is also influence by farm size. Our farms (<1ha) are usually smaller than the ones found in the scientific literature where the agricultural practices have a clear effect on wild bees. There might be different reasons why our practices do not show an effect on species richness, might be because our farms do not realize negative agricultural practices or because their area is quite small so the negative effect on wild bees is minimum.

To survive, bees populations need a sufficient amount of resources of nectar and pollen as well as suitable nesting sites (Michener, 2007). Therefore, different studies determine that flower availability and frequency within the field has a clear effect on wild bee species richness (Lanner *et al.*, 2020; Neumüller *et al.*, 2020). In our study flower availability was assumed by counting the diversity of crops on the farms and the aromatic plants (both in blooming period) but the amount of wild flowering plants within the farms was not explicitly measured, which needs to be taken into account for future studies. In addition to pollen and nectar, wild bees require nesting substrates, soils with specific conditions for belowground nesters (or empty stems or cavities in wood for aboveground nesters) and nesting materials like the mud or leaves for the construction (Molina, C. & Bartomeus, 2019). Majority of studies are focus on flora resources because nesting sides are hard to locate and many nesting needs are still unknown (Sardiñas, Ponisio and Kremen, 2016). Bare ground has been linked to the abundance and species richness of belowground nesting bees (Potts *et al.*, 2005; Sardiñas and Kremen, 2014). Our model also concurs with these results, species richness of wild bees found in the horticultural farms are related with the area of bare ground around the farms. The study of these bare ground areas should be done more in depth to conclude this. Sardiñas et al. (2014) has proposed to use the percent bare soil of an area as a proxy for nesting habitats of ground nesting wild bees. Winfree (2010) highlight the need of assessments of nesting resources to understand better the ecology of bees.

5. Conclussions

In Madrid, agroecology has begun to be introduced into the predominant agri-food system in its different forms. The farms analysed in our study are a small sample of how new initiatives are emerging in recent decades fit into the concept of agroecoloy taking part of the transition towards more sustainable food system.

This study shows farmers awareness of the importance of wild bees for the correct functioning of their agroecosystem and on the potential impact of their practices to them. Theses agroecosystems are spaces that harbour a great agrodiversity which are managed by a wide variety of agroecological practices. This means that a great diversity of wild bees can be found in these areas. Our results indicate that landscape elements around the farm plays an essential role to the diversity of wild bees. Specially, areas with sparse vegetation and bare soil are related with higher diversity of bees in small scale horticultural farms. These areas might be a key ground nesting resources for ground-nesting wild bees. Our results provide empirical data of the importance of landscape management to improve local biodiversity in horticultural farms, which will result in better production and long-term stability. Since landscape elements are key to maintain diversity of bees, collective management of the land is important to promote to pollination and to provide long-term sustainability of our agricultural system. To conclude, agroecological transition needs to be promoted in Madrid to maintain our biodiversity, landscape multifunctionality and rural areas.

At last point I would like to mention that it is unwise to consider pollination only as a service to human life consumption, first because of its indirect effects on ecosystems and biodiversity but also because their intrinsic value and beauty of these living beings.

6. References

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8. Appendix 1

8.1. Questionnaire to farmers

Date ___________ START TIME ____________ PLACE ____________________ INTERVIEW Nº_____

I. Farm and farmer characterization

1. What kind of relationship do you currently have with the agricultural sector?
   - ☐ I am producer on an exclusive basis. For how long? ____
   - ☐ I am partially tied producer. For how long? ___________________________________
   - ☐ I am not professionally dedicated to agriculture, but I do it as a hoppy/income supplement/maintain the family tradition/ consumption of my own products/others. For how long? , ____
   - ☐ Others

2. How do you consider your production model? :
   - ☐ Conventional
   - ☐ Integrated
   - ☐ Agroecological
   - ☐ Ecological no certified
   - ☐ Ecological
   - ☐ Others __________________________________

3. What do you do with your horticultural production? (Multi-response)
   - ☐ For self-sufficiency
   - ☐ Barter or exchange
   - ☐ Direct sale in the farm
   - ☐ To families in organized baskets
   - ☐ In local markets
   - ☐ To schools/hospitals/residences
   - ☐ To restaurants
   - ☐ Through cooperatives
   - ☐ Large-scale commercialization
   - ☐ Through internet
   - ☐ Others:

4. How long have you been working on this farm? ____

5. Do you know if this farm has had any other previous use or management? For how long? ____ __________________

6. How many hectares does this farm have? __________ Could you tell me the polygon and parcel number according to the SIGPAC register? ____

7. Do you have beehives on the farm? Yes / No. What are the reasons for having bee hives? ____

8. Do you know if there is any beehives nearby? _____________ How far is it from here? ________________________ Do you have contact with the beekeeper? ____________________________

9. Would you be interested in installing beehives? Yes/No Why? ____ ____

II. Crops , agricultural practices and ecosystem services

10. Do you produce the whole year?.

11. What kind f crops do you have? How many m2 per crop? ____ ____ ______________________________

Could you please indicate in the table below which agricultural practices you apply on this farm and why you do or do not apply them? If you do apply them, could you give details on the management of each of them (e.g. depth of tillage, type of fertiliser and frequency of application, frequency of crop rotation and rotational cropping, machinery used, etc.) and since when do you apply them?

The practices asked are: tillage, weed control, pest control, drip irrigation, natural edges, fallow land, animal inclusion, nest-boxes for insects, crop rotation, cover crops, aromatic plants, fallow land and presence of bee hives.

III. Collaboration

12. How many people work on this farm (including yourself)? ______________ Are there any women in the team? Yes / No. How many? ____

13. How many people are involved in the project and are there any women? Yes / No How many?? ______________

IV. Pollinators perception

14. Do you consider pollinating insects necessary for food production?
    Yes__ No _____ Why?

____

What crops do you have that depend on pollinators?__________________________________

15. Do you think there is any harm associated with pollinating insects? YES _No__Which ones?____
    ____
    ____

In the absence of pollinators, how much would you say the production of your orchard decreases?

PERCENTAGE DECREASE IN PRODUCTION		
a	No	
b	< 25%	
e	26-50 %	
f	51-75%	
g	>75%	

16. During the last 15 years, do you think pollinating insects in your area are stable, increasing or declining, don't know?____
    ___

If there is a decline, to what extent do you find this worrying?

Not at all___ A little___ A lot__ A great deal__ NS NC

If you consider that there is a lack of pollinators, do you use any kind of treatment to make up for the lack of pollination in your crops? Yes ____ Which ones? ________________
No _____

17. How do you think each of these factors influences pollinators?

Factores		nothing	A little	Quite	A lot	NS/NC
a	Insecticides					
b	Hybrid seeds					
e	Agricultural practices					
f	Unnatural predators					
g	Loss of natural areas					
h	Parasites and diseases					
i	Climate change					
j	Other:					

Which of the following agricultural practices or operations are beneficial or detrimental to pollinators?

Agrarian practices		Harm	Benefitial	Indifferent	NS/NC
a	Tillage				
b	Planting of flowering honey plants (e.g. aromatic)				
e	Spraying with pesticides, in particular insecticides				
f	Crop rotation				
g	Presence of fallow farms nearby				
h	Spraying with herbicides				
i	Preservation of boundaries				
j	Proliferation of monocultures				
k	Use of hybrid/transgenic varieties				

l	Leaving wildflower areas between crops				
m	Introducing beehives				
n	Water storage infrastructure				
l	Other:				

V. Socioeconomic variables

18. Where do you live? ____

19. Could you tell me your year of birth? ______________________________

20. Could you tell me up to which stage of your education?

21. Approximately how many hours of work per week do you spend on agriculture? ________________

22. Are you formally registered as a producer? Yes / No. If yes, how are you register
23. What approximate percentage of your net monthly income comes from farming?
    - ☐ <10 %
    - ☐ 11-50 %
    - ☐ 50-90 %
    - ☐ >90 %

8.2. Species of wild bees

The coming table shows wild bee species found at the horticultural farms:

	GENDER	
ANDRENIDAE	♀	♂
Andrena (Chlorandrena) abrupta Warncke, 1967	9	
Andrena (Holandrena) variabilis Smith, 1853	5	
Andrena (Melandrena) albopunctata Warncke, 1972	3	
Andrena morio Brullé, 1832	12	1
Andrena (Plastandrena) pilipes Fabricius, 1781	1	2
Andrena (Taeniandrena) ovatula	1	
Andrena (Thysandrena) hypopolia Schmiedeknecht, 1884	5	
Andrena (Zonandrena) flavipes Panzer, 1799	30	2
Panurgus (Panurgus) banksianus Warncke, 1972	6	2
Panurgus (Panurgus) calcaratus ssp.lagopus Warncke, 1972.		20
Andrena sp.	2	
Microandrena sp.	4	
APIDAE		
Xylocopa (Copoxyla) iris ssp.uclesiensis Pérez, 1901	16	
Xylocopa (Rhysoxylocopa) cantabrita Lepeletier, 1841	5	1
Xylocopa (xylocopa) violacea Linnaeus, 1758	10	2
Ceratina (ceratina) cucurbitina (Rossi, 1792)	38	8
Ceratina (euceratina) chalcites Germar, 1839	9	2
Ceratina (Euceratina) chalybea Chevrier, 1872	1	
Ceratina (Euceratina) cyanea (Kirby, 1802)	16	3
Ceratina (Euceratina) dallatoreana Friese, 1896	5	
Nomada bifasciata Olivier 1811	1	
Eucera pulveracea Dours, 1873	8	3
Anthophora (Heliophila) fulvodimidiata Dours, 1869	1	1
Amegilla (amegilla) quadrifasciata (de Villers, 1789)	11	
Amegilla (microamegilla) fasciata Fabricius, 1775	3	
Bombus (thoracobombus) pascuorum (Scopoli, 1763)	4	
Bombus (Bombus) terrestris ssp. Lusitaniscus Krüger,1956	6	6
Nomia diversipes	3	
COLLETIDAE		
Hylaeus (Abrupta) cornutus Curtis, 1831	1	1

Hylaeus (Hylaeus) communis Nylander, 1852	2	
Hylaeus (Koptogaster) punctualissimus Smith, 1843	1	
Hylaeus (Lambdopsis) annularis (Kirby,1802)	2	1
Hylaeus (Paraprosopis) clypearis (Schenchk, 1853)		1
Hylaeus (Prosopis) confusus Nylander, 1852	3	
Hylaeus (Prosopis) variegatus (Fabricius, 1798)	12	12
Hylaeus (Spatutarella) hyalinatus Smith, 1843	1	
Hylaeus spilotus Förster, 1871	1	
A Hylaeus sp.	1	
B Hylaeus sp	4	
Colletes sp.	21	
HALICTIDAE		
Halictus (Halictus) brunescens (Eversmann, 1852)	2	
Halictus (Halictus) crenicornis Blüthgen, 1923		2
Halictus (Halictus) maculatus Smith, 1848	6	1
Halictus (Halictus) quadricintus (Fabricius, 1776)	97	
Halictus (Halictus) scabiosae (Rossi, 1790)	75	1
Halictus (Halictus) sexcinctus (Fabricius, 1775)	4	
Halictus (Seladonia) gemmeus Dours, 1872	8	
Halictus (Seladonia) seladonius (Fabricius, 1775)	1	
Halictus (Seladonia) smaragdulus Vachal, 1895	84	2
Halictus (Seladonia) Subauratus (Rossi, 1792)	208	1
Halictus (Vestitohalictus) pollinosus Sichel, 1860	7	
Lasioglossum (Evylaeus) albipes/calceatum (Fabricius, 1781)	5	3
Lasioglossum (Evylaeus) brevicorne (Schenck, 1869)	12	
Lassioglossum (Evylaeus) glabriusculum (Morawitz, 1872)	13	
*Lassioglossum (Evylaeus) griseoleum (*Morawitz, 1872)	5	
Lasioglossum (Evylaeus) ibericum Ebmer, 1975	25	
Lassioglossum (Evylaeus) interruptum (Panzer, 1798)	160	
Lassioglossum (Evylaeus) malachurum (Kirby, 1802)	437	1
Lasioglossum (Evylaeus) mediterraneum (Blüthgen, 1926)	205	
Lassioglossum (Dialictus) morio (Fabricius, 1793)	8	
Lassioglossum (Evylaeus) nigripes (Lepeletier, 1841)	6	
Lasioglossum (Evylaeus) pauperatum (Brullé, 1832)	82	
Lasioglossum (Evylaeus) pauxillum (Schenck, 1853)	31	
Lassioglossum (Euylaeus) politum (Schenck, 1853)	1	
Lassioglossum (Evylaeus) punctatissimum (Schenck, 1853)	3	
Lasioglossum (Evylaeus) pygmaeum (Schenck, 1853)	1	
Lassioglossum (Dialictus) smeathmanellum (Kirby, 1802)	1	
Lassioglossum (Evylaeus) subhirtum (Lepeletier, 1841)	10	

Lasioglossum (Evylaeus) transitorium (Schenck, 1868)	9	
Lasioglossum (Evylaeus) villosulum (Kirby, 1802)	3	1
*Lasioglossum (Lasioglossum) albocinctum (*Lucas, 1849)	994	1
Lasioglossum (Lasioglossum) bimaculatum (Dours, 1872)	53	
Lasioglossum (Lasioglossum) discum (Smith, 1853)	34	
Lasioglossum (Lasioglossum) laevigatum (Kirby, 1802)	3	10
Lassioglossum (Lasioglossum) leucozonium (Schrank, 1781)	239	14
Lassioglossum (Lasioglossum) sexnotatum (Kirby, 1802)	1	
Sphecodes alternatus Smith, 1853	1	
Sphecodes puncticepts Thomson, 1870	5	7
Halictus (Halictus) sp.	249	
Lasioglossum (Evylaeus) MF A	18	
Lasioglossum (Evylaeus) MF B	15	
Lassioglossum (E.) MF C	54	
♂ Lassioglossum (E.) sp.	3	
Sphecodes sp.	1	
Lasioglossum sp.	6	
MEGACHILIDAE		
Lithurgus (Lithurgus) chrysurus Fonscolombe ,1834	3	5
Lithurgus (Lithurgus) cornutus (Fabricius, 1787)	6	9
Lithurgus cephalotus	3	
Chalicodoma (Pseudomegachile) ericetorum (Lepeletier, 1841)	1	
Megachile (Eutricharaea) pilidens Alfken, 1924	2	
Megachile (Xanthosarus) willughbiella (Kirby, 1802)	1	
Trachusa (Archianthidium) laticeps (Morawitz,1874)	1	
Trachusa (Paraanthidium) interrupta (Fabricius, 1781)		1
Anthidium (Anthidium) florentinum (Fabricius, 1775)	1	
Icteranthidium laterale (Latreille, 1809)		1
Chelostoma (Chelostoma) florisomme (Linnaeus, 1758)	1	
Heriades (Heriades) crenulatus Nylander, 1856	1	2
Hoplitis (anthocopa) sp. Lepeletier & Serville, 1825	4	
Hoplitis (Anthocopa) sp. N2 Lepeletier & Serville, 1825	1	
Osmia (Hoplosmia) anceyi Pérez, 1879	3	
Osmia (hoplosmia) sp. Thompson, 1872	1	
Protosmia (Chelostomopsis) capitata (Schletterer, 1889)	1	
MELITTIDAE		
Dasypoda argentata Panzer, 1809	10	