PSDR DYNAMIQUES -Dynamics of biodiversity and ecosystem services during peri-urban development

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Abstract

The DYNAMIQUES project is a multidisciplinary research programme that studies the consequences of peri-urban development both on biodiversity and the services it provides to humans. The project is being carried out on the Saclay Plateau, an area located in the junction zone between the Paris conurbation and the great plains surrounding it, with the dual characteristic of being in the process of urbanization following the development of the great Paris Saclay science and technology cluster, and of integrating more than 2,000 hectares of some of the most fertile agricultural land of France. The general objective of the project is to produce knowledge to promote sustainable coexistence on the same territory between agriculture, the city and biodiversity, in conjunction with urban and agricultural development partners. One of the major characteristics of peri-urban spaces is the coexistence of two types of spaces that are highly modified by human presence, agricultural spaces and urbanized spaces. It is already known that this strong modification has negative consequences for biodiversity, and that agricultural and urbanised spaces contain on average much lower biodiversity than natural spaces. The simultaneous presence of agricultural and urban areas on a territory could therefore seem particularly problematic for biodiversity, but it is also possible that these two types of highly modified areas complement each other and that their association is on the contrary relatively beneficial for biodiversity. The project has shown that in some cases there is a positive synergy between agricultural and urban spaces. Insect pollinators seem to benefit from the simultaneous presence of these two types of spaces, while in other cases the synergy is negative: peri-urban ponds suffer from double contamination when they are located in the agricultural and urban interfaces.

Keywords: Urban ecology, Agriculture, Urbanization, Pollination service, Organic matter recycling service, Contaminants

1. Introduction

1.1 Issues and problems

We are currently in a period of rapid destruction of the natural world. The work of biologists indicates that the current rate of species extinction is at least a hundred times greater than the ordinary extinction rate, constituting what has been called the "6th mass extinction" in the history of our planet (Ceballos et al., 2015). What's more, many previously common species are seeing major declines in their populations, reducing their ability to provide ecosystem services to humans (Ceballos et al., 2017). More than 15,000 scientists have just signed an article warning against the rapid destruction of biodiversity and the danger

of humanity pushing "ecosystems beyond their capacity to sustain the web of life", and suggesting that it is necessary to fundamentally rethink the relationship between humans and nature (Ripple et al., 2017).

A major cause of this decline in biodiversity is the simultaneous increase in the human population and the natural resources consumed per capita (Crist et al., 2017). This increase in the human population is associated with an increase in the number and surface area of urbanised areas and an increase in the proportion of the population living in this type of space. In France, as in most other European countries, almost 80% of the population live in cities, with this proportion exceeding 95% in the Ile-de-France region. Although urban development has slowed considerably since the end of the 1960s, the proportion of the population living in peri-urban areas, mainly in detached housing, continues to increase significantly.

Over the last few decades, the evolution of peri-urban areas on the fringes of metropolitan areas has been characterised by the extent to which agricultural and natural spaces have been transformed into urbanised areas. In just fifty years, these areas have undergone considerable change, and the boundaries between built-up areas and agricultural land have become blurred, creating complex interfaces between urbanised areas and open farmland (Cusin et al., 2016). Urban development generally has a significant negative impact on biodiversity (McKinney, 2008), although this varies according to taxonomic groups and their ecological characteristics. However, the juxtaposition in a peri-urban environment of urbanised and agricultural areas, each associated with different types of anthropogenic pressure, can potentially constitute either a threat if these pressures act synergistically, or on the contrary a mitigating factor, if urban and agricultural areas have a complementary role for biodiversity. This hypothesis has been proposed, for example, for pollinating insects, which could potentially benefit from the greater diversity of habitats present at the interface between agricultural and urban areas. The PSDR4 DYNAMIQUES project aims to link biodiversity, two important ecosystem services for agriculture - pollination (Winfree et al., 2011) and the recycling of soil organic matter (Pelosi et al., 2021) - and the presence of contaminants (Grimm et al., 2008) to the presence of agricultural and urban areas, with the Saclay plateau as the study area.

1.2 Presentation of the study area

The selected study area is the Saclay plateau (Figure 1), located at the junction between the Paris conurbation and the great plains that surround it. It is bounded by the Yvette valley to the south and east, the Mérantaise valley to the west and the Bièvres valley to the east. Until very recently, the Saclay area was mainly used for agricultural purposes, but the ongoing development of the major scientific and technological hub of the Université Paris Saclay is considerably increasing the area's urban footprint. At the same time, a natural, agricultural and forestry protection zone (ZNPAF) covering more than 4,000 hectares has been created, ensuring that the plateau's agricultural land remains in permanent use. The Saclay plateau was chosen as the experimental area for the project because it presents major challenges in terms of the coexistence of urban and agricultural areas and biodiversity in a context of urbanisation, and reflects on a smaller scale a significant proportion of the problems facing the Ile-de-France region. Another criterion was the growing interest in biodiversity conservation among local stakeholders.

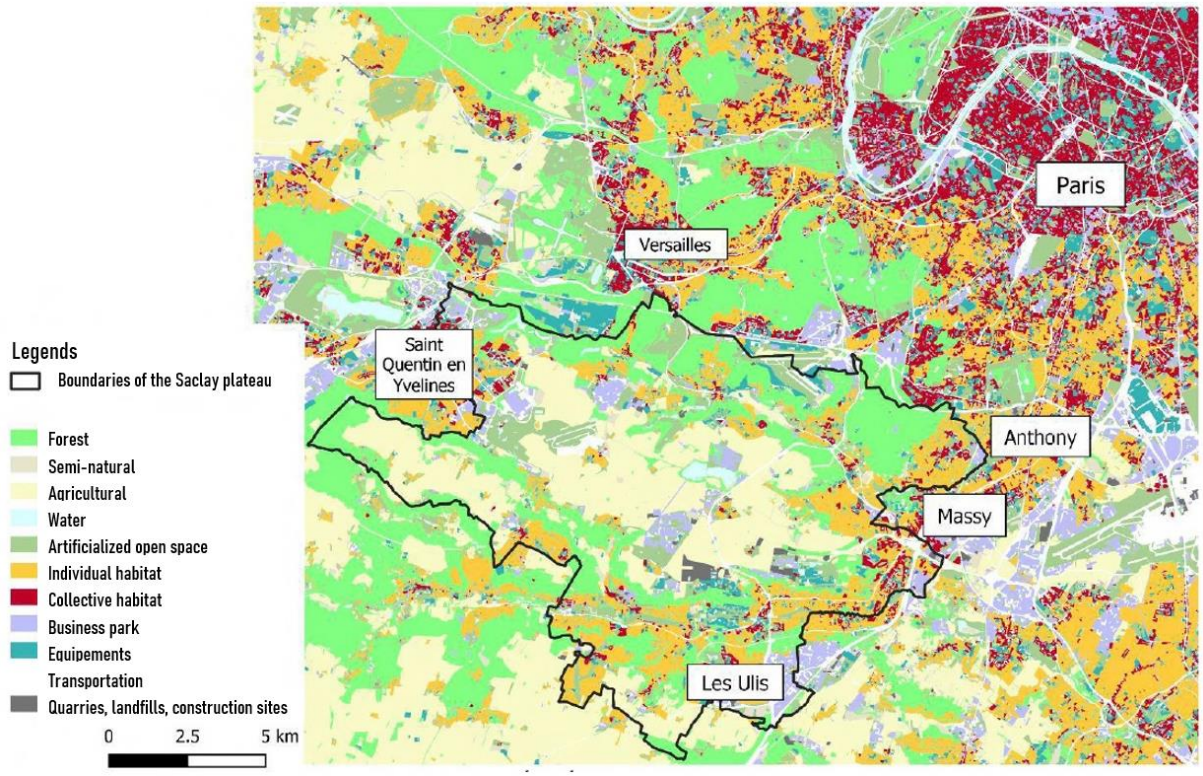

Figure 1: Land use mapping and context of the study area (Sources: MOS 2017 and Openstreet Map). Credit: Claire Lamarre.

Within this area, sampling points for terrestrial environments and ponds for aquatic environments were chosen to maximise coverage of the different landscape contexts in the study area: agricultural, urbanised and semi-natural contexts.

1.3 Project partnership

To understand how interactions between agricultural and urban spaces influence biodiversity and ecosystem services in peri-urban environments, the project has brought together partners working in several disciplines:

ECOSYS, Unité Mixte de Recherche en écologie fonctionnelle et écotoxicologie des agroécosystèmes. This partner led the ecotoxicology studies as well as the soil compartment studies, and led both the measurements of the accumulation and effects of contaminants linked to urban and agricultural activities in the various environmental compartments (water, sediments and soil) and the biodiversity measurements carried out on the soil macrofauna and terrestrial invertebrates.

EGCE, Evolution, Genomes, Behaviour and Ecology, Joint Research Unit on the Evolution and Dynamics of Biodiversity. This partner led the biodiversity inventories carried out in aquatic environments using molecular metabarcoding methods.

ESE, Écologie, Systématique et Évolution, Unité Mixte de Recherche en écologie et évolution. This partner led the biodiversity inventories carried out in aquatic and terrestrial environments, as well as the measurements of ecosystem services. It also coordinated the project.

Terre et Cité, an association working across the Plateau de Saclay and its valleys to preserve, promote and develop quality agriculture and enhance the associated heritage. The Terre et Cité association participated in the project thanks to its in-depth knowledge of the players on the Saclay plateau. In particular, it facilitated exchanges between ecologists, farmers and local decision-makers.

2. Main results obtained

2.1 Impact of agricultural and urban landscapes on contamination of water and sediments in ponds

Ponds are particularly rich in biodiversity and provide important ecosystem services such as water regulation and decontamination, and organic carbon sequestration. In peri-urban environments, they are potentially exposed to both contaminants of urban origin, such as trace metals and polycyclic aromatic hydrocarbons (PAHs), and those of agricultural origin, such as excess nutrients and pesticides. We carried out numerous measurements on the water and sediments of 12 ponds located in various landscape contexts within the study area (Nélieu et al., 2020). We have shown that the ponds present very varied contamination profiles, which are mainly correlated with agricultural use for the water compartment (Figure 2) and mainly correlated with urban use for the sediments, the latter presenting in some cases an accumulation of potentially toxic PAHs.

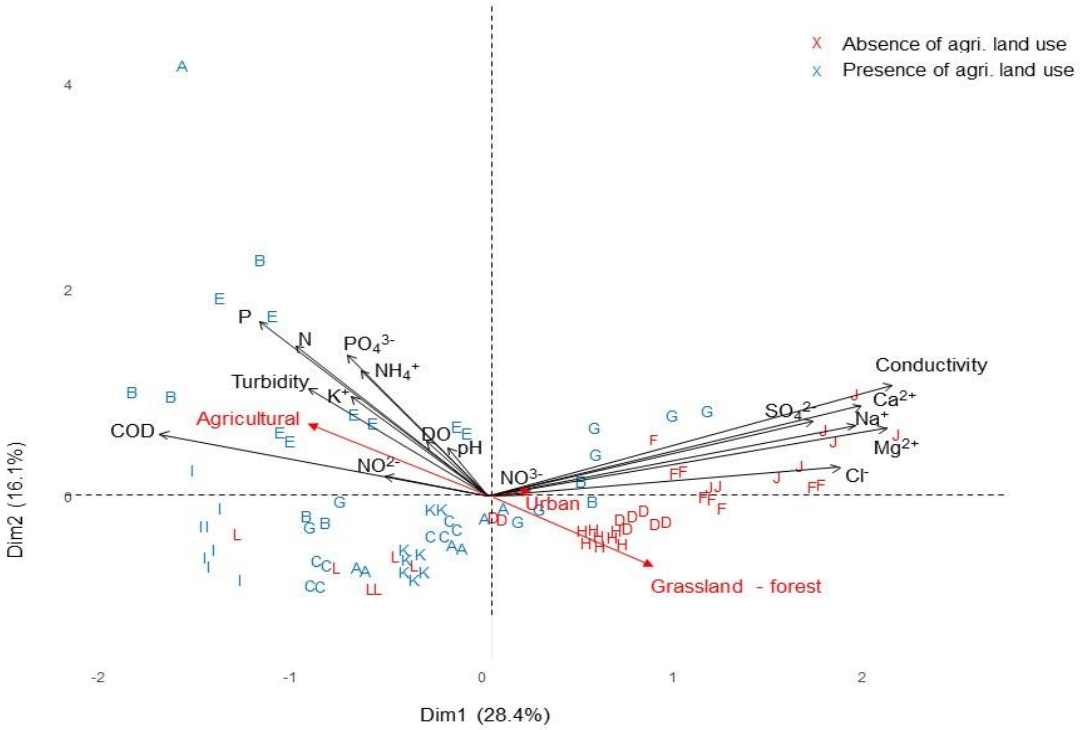

Figure 2: Principal component analysis of the physico-chemical properties of the water in 12 peri-urban ponds, showing the relationship between land use (red arrows) and the physico-chemical properties of the water. The letters indicate the identity of the pond studied. Figure adapted from Nélieu et al (2020).

2.2 Within Ile-de-France, domestic gardens have a positive influence on the diversity of pollinating insects

Urban sprawl is generally unfavourable for biodiversity, but the green spaces included in the urban fabric, and in particular the domestic gardens that often make up the majority of these spaces, can have a compensatory effect. Using data produced by the French citizen science programme SPIPOLL, Suivi Photographique des Insectes Pollinisateurs, we studied the relationship between land use and the diversity of pollinating insects (Levé et al., 2019). We have shown that domestic gardens constitute locally favourable habitats, integrated into a landscape in which urban impermeable surfaces represent unfavourable areas (Figure 3). We highlight the interconnection between the local scale and the landscape scale, as well as the potentially important role of domestic garden plots in residential areas.

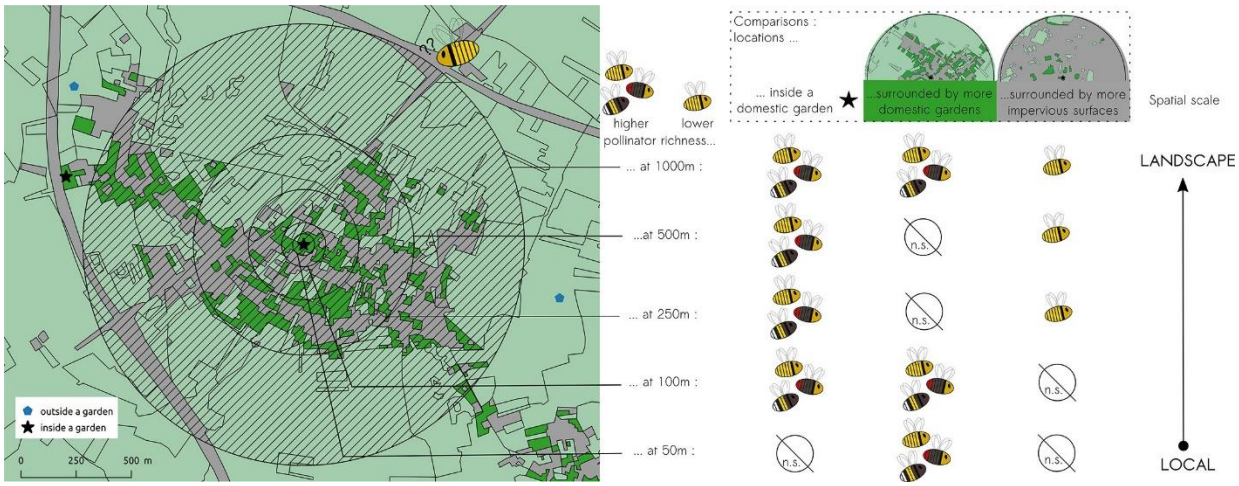

Figure 3: Summary of the relationship between the presence of gardens and pollinator diversity at different spatial scales. Figure taken from Levé et al. (2019). Credit Marine Levé.

Methodological result: participatory science data can be used to reconstruct plant-pollinator interaction networks. Ecologists are increasingly interested in plant-pollinator networks, which synthesise in a single object the species and interactions that link them in their ecological context (Figure 4). To reconstruct these networks, it would be interesting to be able to use the data produced by participatory science programmes, which generally have a relatively low taxonomic resolution. Indeed, the participatory science programmes that study pollinating insects are carried out by non-scientist-professionals, who are often unable to identify the species of insects observed, but rather their genus or, in some cases, their family. We have shown that it is possible to significantly estimate the properties of plant-pollinator interaction networks with a taxonomic resolution below the species level, and therefore to use data from participatory science programmes for this purpose (Renaud et al., 2021).

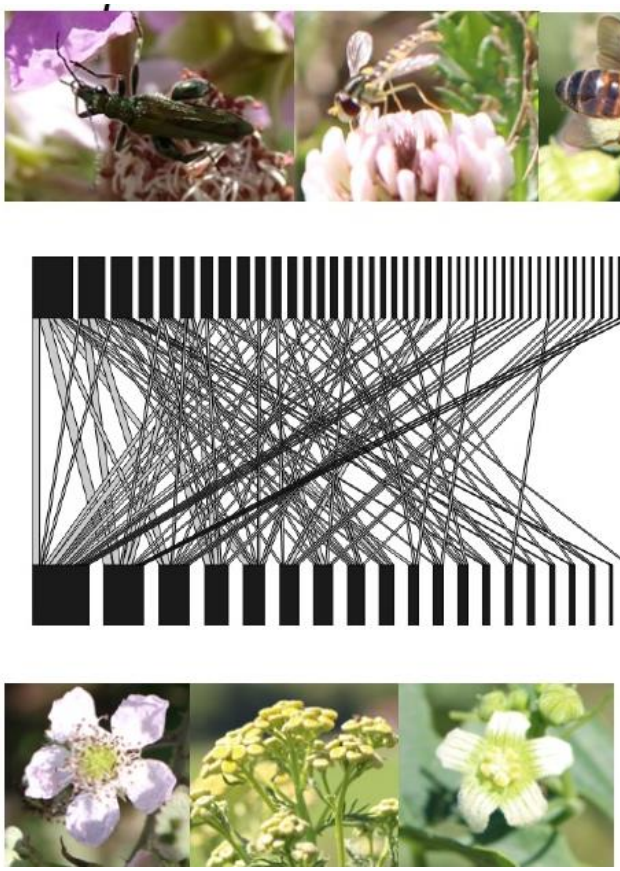

Figure 4: Example of a plant-pollinator interaction network at one of the sampling points in the study area. Credit: Estelle Renaud. The black bands at the top each correspond to an insect taxon, the width of the band indicating the abundance of the taxon in question, and those at the bottom correspond to flowering plants. The lines connecting them indicate the interactions between plants and pollinators that have been observed.

2.3 In the peri-urban environment, the pollination service is more effective in areas where urban and agricultural surfaces are intermingled than in purely urban or agricultural areas.

Many species of wild and cultivated plants depend for their reproduction on what is known as the pollination service, i.e. the transport of pollen by pollinating insects. Using an experimental measurement based on birdsfoot trefoil flowers (Figure 5), we have shown that the pollination service is more effective in environments containing both agricultural and urban surfaces than in those that are purely urban or agricultural, indicating that these two types of surface are complementary for pollinating insects. Agricultural areas are rich in food resources but poor in nesting sites. Cities, on the other hand, offer fewer food resources, but certain areas such as low walls and alleys can be good nesting sites.

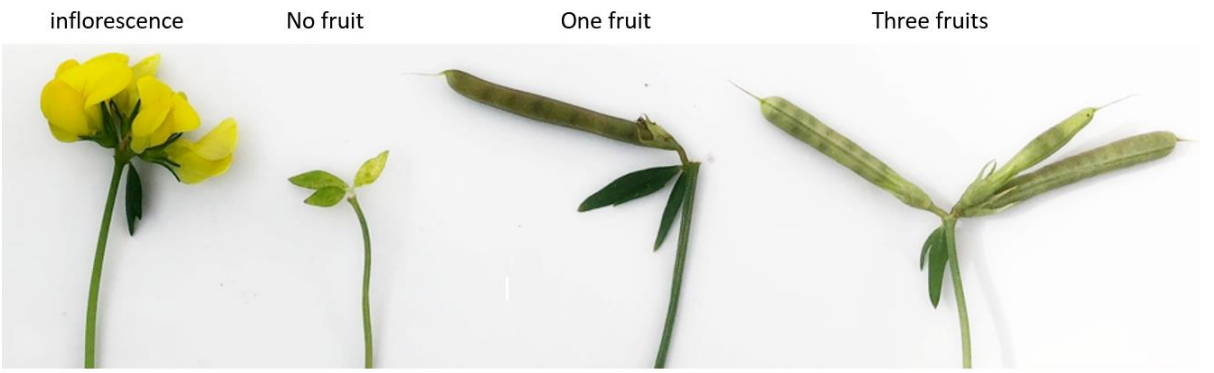

Figure 5: Bird's-foot trefoil inflorescence in flower and bearing 0, 1 or 3 fruit(s) Since birdsfoot trefoil must be pollinated by insects in order to produce fruit, each fruit bears witness to the passage of a pollinating insect. Credit Virginie Héraudet.

Methodological result: electricity is a relevant method for analysing earthworm diversity in urbanised or agricultural soils. We compared the effectiveness of two methods, one using a chemical irritant and the other electricity, for assessing earthworm populations in agricultural and urban landscapes. We have shown that both methods provide a similar description of the diversity of species present (Figure 6), and that in urbanised environments where, due to social and health and safety considerations, it is not always possible to use chemicals and disturb the soil by digging pits, the electrical method is a useful tool for sampling earthworms (Pelosi et al., 2021).

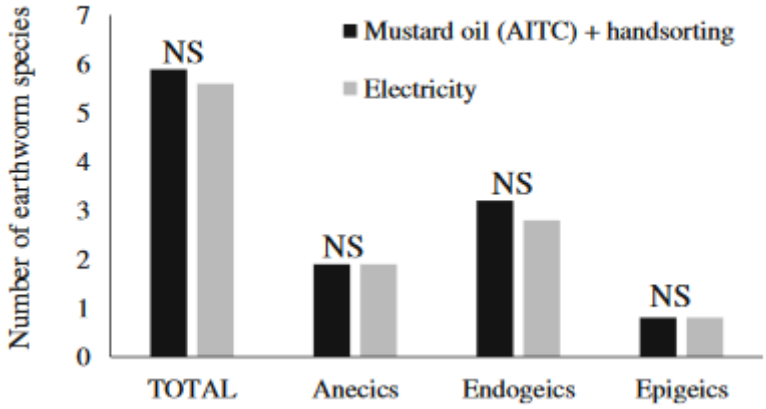

Figure 6: Diversity of earthworm species recorded at sampling points in the study area using the electrical method or the method using an irritant (mustard oil). Figure taken from Pelosi et al (2021).

3. Contribution to regional development

The main aim of the PSDR 4 DYNAMIQUES project is to produce knowledge and tools that can be used to ensure the most harmonious possible cohabitation between biodiversity, the peri-urban environment and agricultural activities. This theme corresponds to the challenges facing the Île-de-France region, which has a high level of agricultural activity, with around half of the region's land used for agriculture, but is also the most urbanised region in France, with a steadily increasing proportion of its land classified as urban or peri-urban. This increase in urban and peri-urban land is mainly at the expense of agricultural land, threatening the region's production potential at a time when demand for local agricultural produce is rising sharply. At a regional level, the tensions between agricultural activities, urbanisation and biodiversity are particularly acute due to the construction of Paris Saclay, combined with the existence of a ZPNAF aimed at safeguarding agricultural activities and a high level of interest in biodiversity on the part of local stakeholders.

As part of this project, large datasets were developed on the biodiversity of the study area, which were integrated into the Ile de France naturalist database CETTIA, as well as into the SPIPOLL participatory science database on pollinating insects, These databases provide information on the region's biodiversity issues, help to raise awareness of the Ile-de-France's natural heritage at regional level, and contribute to knowledge at national and global level, since the data is sent to the National Inventory of Natural Heritage (INPN) and the Global Biodiversity Information Facility (GBIF). At a regional level, this data has been used

in a number of ways, aimed at the general public through a variety of outreach activities (nature walks, participatory conferences, a serious game with SCube, posters, events, teaching units, etc.), at farmers through the use of the data and at the general public.Finally, it is targeting local decision-makers, through meetings with local players organised by Terre et Cité, through interactions such as those with EPAPS (Etablissement d'Aménagement Paris Saclay) to help integrate biodiversity into planning decisions, and through participation in the Assises Nationales de la Biodiversité.

The results of the project will also be able to be used as input for discussions on regional planning and the practices of local stakeholders. The project has shown that the ponds located in the area, which have a particularly important ecological role, have very varied contamination profiles, mainly correlated with agricultural use for the water compartment and mainly correlated with urban use for the sediments, the latter in some cases showing an accumulation of hydrocarbons that are potentially toxic for biodiversity. These results provide food for thought both in terms of the use of plant protection products and possible measures to reduce airborne pollution. The project has also shown that in urban areas on the outskirts of towns, private gardens represent a particularly favourable type of space for pollinating insects, leading to a positive interaction between agricultural and urban areas for the pollination service. At the same time, the project showed that there is a deficit in the pollination service in the entirely agricultural areas of the region, a deficit that is potentially damaging to the yields of crops requiring pollination, such as oilseed rape and sunflower for field crops, or market gardening and arboriculture. The results of the project suggest that this deficit could be at least partially compensated for in the border areas between agricultural and urban areas.

Ethics
The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models
The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.
The authors used artificial intelligence for the English translation.

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Authors' contributions
All authors contributed to the production of data for the article. E. Baudry wrote the first draft of the paper. C. Barraud, E. Baudry, C. Bessa-Gomes, C. Capdevielle-Dulac, O. Crouzet, C. Hanot, M. Harry, V Héraudet, F. Hulot, S. Karolak, I. lamy, S. Nélieu and E. Renaud contributed to data analyses and interpretation, and final editing of the manuscript.

Declaration of interest
The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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All publications relating to the 33 projects in the PSDR4 programme can be consulted at: https://www.psdr.fr/

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Link to the 4-page summary of the project: http://www.psdr.fr/archives/INS1528PDFN1.pdf

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