SHOWCASE

LivingFields

A technical guide to managing vineyards and olive groves for bird and bat conservation in Europe

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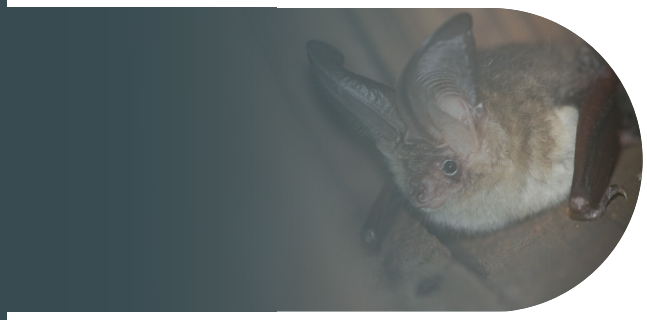

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Glosary of Terms

Technical terms used throughout the technical guide are defined here for easy reference.

Biodiversity-friendly practices: strategies that integrate conservation into productive landscapes, ensuring that ecosystems, species, and ecological processes can thrive alongside human activities.

Biodiversity: the diversity of genes, species and ecosystems.

Conservation concern: level of attention, priority, or action required to safeguard a species, habitat, or ecosystem that is threatened by decline, degradation, or extinction risk.

Ecosystem functions: specific ecological roles and processes through which a species contributes to the flow of energy, cycling of nutrients, and maintenance of ecosystem structure and stability.

Ecosystem services: the benefits that humans derive from nature, from economic benefits to spiritual benefits.

Global change: the combination of a series of rapid changes in social-ecological systems around the world, including both biophysical and social aspects of change.

Habitat: the natural environment in which a species or community of organisms lives, providing the resources and conditions necessary for survival, growth, and reproduction.

Landscape connectivity is the degree to which the landscape facilitates the movement of organisms, genes, and ecological processes between habitat patches, enabling species to access resources, disperse, and maintain viable populations.

Life-history traits: biological characteristics of organisms that shape their schedule of growth, reproduction, and survival across their lifetime.

Resilience: the ability of a system to absorb shocks, while maintaining essential functions.

Sustainable farming practices: agricultural approaches designed to produce food, fiber, and other resources in ways that maintain or improve ecosystem health, protect natural resources, and support long-term economic and social well-being.

Summary

Enhancing Biodiversity in Agricultural Landscapes: A Guide for olive groves and vineyards

Landscape modification for agriculture is widely recognized as a major global threat to biodiversity. In parallel to the expansion of farmlands, native vegetation often disappears and farming practices become more intensive, leading production landscapes to lack essential resources for wildlife such as food sources and nesting and shelter sites.

In Europe, olive groves (*Olea europaea subsp. europaea*) and vineyards (*Vitis vinifera subsp. vinifera*) occupy a significant portion of agricultural land. Over recent decades, intensified production in these crops has driven biodiversity loss at an alarming rate. In particular, birds and bats have suffered, with their diversity and numbers sharply declining as farming intensifies. This is concerning because these species provide essential services, such as natural pest control, which benefits such crop yield and quality.

Despite their importance, the conservation of birds and bats in olive groves and vineyards remains largely overlooked, likely related to the communication gap between conservation biologists, who establish the ecological basis of sustainable farming strategies, and the farmers, who are responsible for their implementation.

Purpose of this Guide

This technical guide aims to bridge this gap by summarizing key ecological principles and best management practices for the conservation of birds and bats in olive groves and vineyards of Europe. It is expected to inspire and support farmers in adopting sustainable practices that benefit both biodiversity and agricultural productivity.

To maximize its impact, the guide also highlights effective incentives that encourage farmers to invest in bird and bat conservation. It demonstrates how these investments can lead to ecological and socio-economic benefits, making biodiversity management a viable and rewarding strategy for the current agricultural sector.

Structure of the Guide

The guide is divided into two main sections:

1. **The Role of Birds and Bats in olive groves and vineyards**
   - Explains the ecological and economic importance of conserving birds and bats.
   - Summarizes how agricultural intensification affects bird and bat communities and their ability to provide ecosystem services.

2. **Creating Wildlife-Friendly Landscapes**
   - Describes how birds and bats use landscapes for foraging, roosting, nesting and commuting.

- Identifies key landscape elements management practices that can support birds and bats populations and sustain the provision of their ecosystem services

Development of this Guide

This guide was developed as part of the project SHOWCASE - Showcasing synergies between agriculture, biodiversity, and ecosystem services to help farmers capitalize on native biodiversity, funded under the European Union's Horizon 2020 Research and Innovation Programme (grant agreement No. 862480). SHOWCASE explored the synergies between agriculture, biodiversity, and ecosystem services. In addition to contributions from SHOWCASE researchers, it incorporates insights from world-leading experts, ensuring its relevance and applicability to olive and vineyard production systems across Europe.

By implementing the strategies outlined in this guide, farmers can actively contribute to reversing biodiversity decline, improving farm resilience, and aligning with EU goals for sustainable agriculture.

Bird and bat conservation in olive groves and vineyards

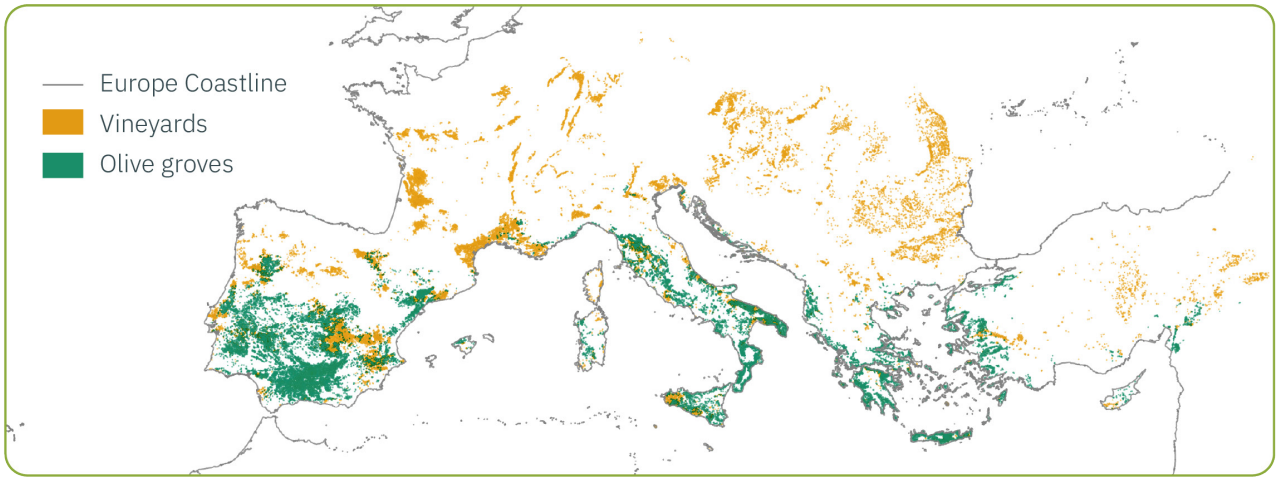
Olive groves and vineyards are critical for the conservation of birds and bats across Europe. Let's see why

1.1 Why olive groves and vineyards?

Olive groves and vineyards are two of Europe's most important crops, with olive and grape-based products being recognized as primary elements in the agricultural economy of Europe. Olive groves and vineyards indeed cover vast agricultural landscapes across many countries, making them key players in conserving European biodiversity, including not only species facing extinction threats but also common species.

Traditionally, these two crops were managed using low-impact farming practices, carrying deep cultural, socio-economic, and environmental significance. In recent decades, large-scale intensification has significantly promoted to increase crop efficiency and profitability, leading to changes in farming practices and altering such landscapes, often at the expense of biodiversity.

Fortunately, research and greener management techniques and policies over the past decade has shown that sustainable management of olive groves and vineyards can enhance biodiversity while improving essential ecosystem services. By integrating biodiversity-friendly practices and the maintenance of key landscape elements, farmers can benefit from increased yields and income, making biodiversity conservation in olive groves and vineyards a practical and rewarding investment.



Economic Importance of the Olive Industry in Europe

Aspect	Details
Cultivated area	Over 5 million hectares
Farms involved	Over 1 million olive farms
Market value	Over €11.5 billion annually, making Europe the world leader in olive oil and table olive production
Global share	Over 60% of the world's olive oil
Extra-EU Exports	Over €1.2 billions, the world's largest olive oil exporter

Economic Importance of the Grapevine Industry in Europe

Aspect	Details
Cultivated area	Over 3.2 million hectares
Farms involved	Over 2.2 million vineyard holdings
Market value	Over €60–70 billion annually, making Europe the world leader in wine production
Global share	Over 64% of global wine production
Extra-EU Exports	Over €17.9 billion, the world's largest wine exporter

1.2 Why birds and bats?

Europe is home to over 900 bird species and 45 bat species. The realized and potential distribution of many birds and bats currently overlap landscapes dominated by olive groves and vineyards, conditioning their conservation to the sustainable management of these two crops.

Monitoring programs reveal that many of Europe's bird and bat species are undergoing significant population declines, most of which use both olive groves and vineyards for foraging, nesting-roosting and commuting purposes. Both agroecosystems, for example, provide suitable habitats to millions of frugivorous songbirds wintering in the Mediterranean region, potentially affecting their populations at the continental scale. Remarkably, a range of bird and bat species that use olive groves and vineyards as suitable areas are of conservation concern being included into the International Union for **Conservation of Nature's (IUCN) Red List of Threatened Species**.

Common and abundant Europe's bird and bat species are also undergoing unprecedented population declines. While most of these species use olive groves and vineyards as suitable habitats, they are known to be negatively affected by agricultural intensification. This is troubling because, although they may constitute a small proportion of the local communities, common and abundant species are important in the delivery of ecosystem goods and services, some of which ensure crop yield and quality.

Some birds and bats that use olive groves and vineyards are legally protected

Conservation Status: *Miniopterus schreibersii*

Global IUCN Red List:

- **Near Threatened (NT)** (as of latest assessment)
- Justification: Declining populations across parts of its range, especially in Europe.

EU & National Status:

- Listed under the **EU Habitats Directive (Annex IV)** – requiring strict protection.
- Considered **Vulnerable** or **Endangered** in several European countries (e.g., France, Italy, Spain) due to local population declines.
- Included in **Appendix II** of the **Convention on the Conservation of Migratory Species (CMS)** and the **EUROBATS Agreement**.

Conservation Status: *Chersophilus duponti*

Present only in **Spain**; extinct or absent from **Portugal**.

Considered a Species of European Conservation Concern (SPEC 1).

- Listed in **Annex I of the EU Birds Directive**, requiring special conservation measures.
- **Endangered** or **Critically Endangered** at national level in Spain.

Population Trend:

- Rapid **decline in population size** and **range contraction** in Spain over the last few decades.
- Some local populations have gone **extinct**, particularly in marginal or isolated areas.
- North African populations are poorly monitored but may also be under threat from habitat degradation.

2 The importance of birds and bats in olive groves and vineyards

Birds and bats matter ecologically and economically

2.1 The ecological importance of birds and bats

Birds and bats posses a variety of life-history traits making them particularly important for the integrity and functioning of olive groves and vineyards. For example, their high trophic generalism (this is, their ability to consume a high variety of food resources), is well-recognized to have an impact on the population abundance of a range of arthropods, including olive and grape pests. Their high movement ability also enables birds and bats to actively track spatio-temporal changes in the population dynamics of arthropods, strengthening the role of insectivorous bird and bat species as natural enemies in olive groves and vineyards. Long-distance dispersal events of frugivorous species connect remnants of native vegetation transporting viable seeds over long distances in short time periods, facilitating gene flow and ecological connectivity between these landscape remnants at local and regional spatial scales. Noteworthy, even small landscape remnants of native vegetation are recognized as pivotal for the conservation of biodiversity and its ecosystem functions within both olive groves and vineyards.

The ecological importance of birds and bats in olive groves and vineyards is in any case strongly related to the role they play as ecosystem service providers. Ecosystem services are the benefits that humans derive from healthy ecosystems, supporting our survival and well-being. Birds and bats are indeed widely recognized as being key contributors to all four categories of ecosystem services defined in the Millennium Ecosystem Assessment:

Ecosystem services

Provisioning

Essential products we obtain from nature. Birds provide food, while bats contribute high-quality organic fertilizer through *guano*.

Cultural

Non-material benefits from nature, such as education, inspiration, and recreation. Birdwatching is a key example, widely enjoyed across Europe and globally.

Supporting

Essential ecosystem functions that sustain biodiversity and resilience. Frugivorous birds and bats help by dispersing seeds, aiding the regeneration of natural and semi-natural vegetation.

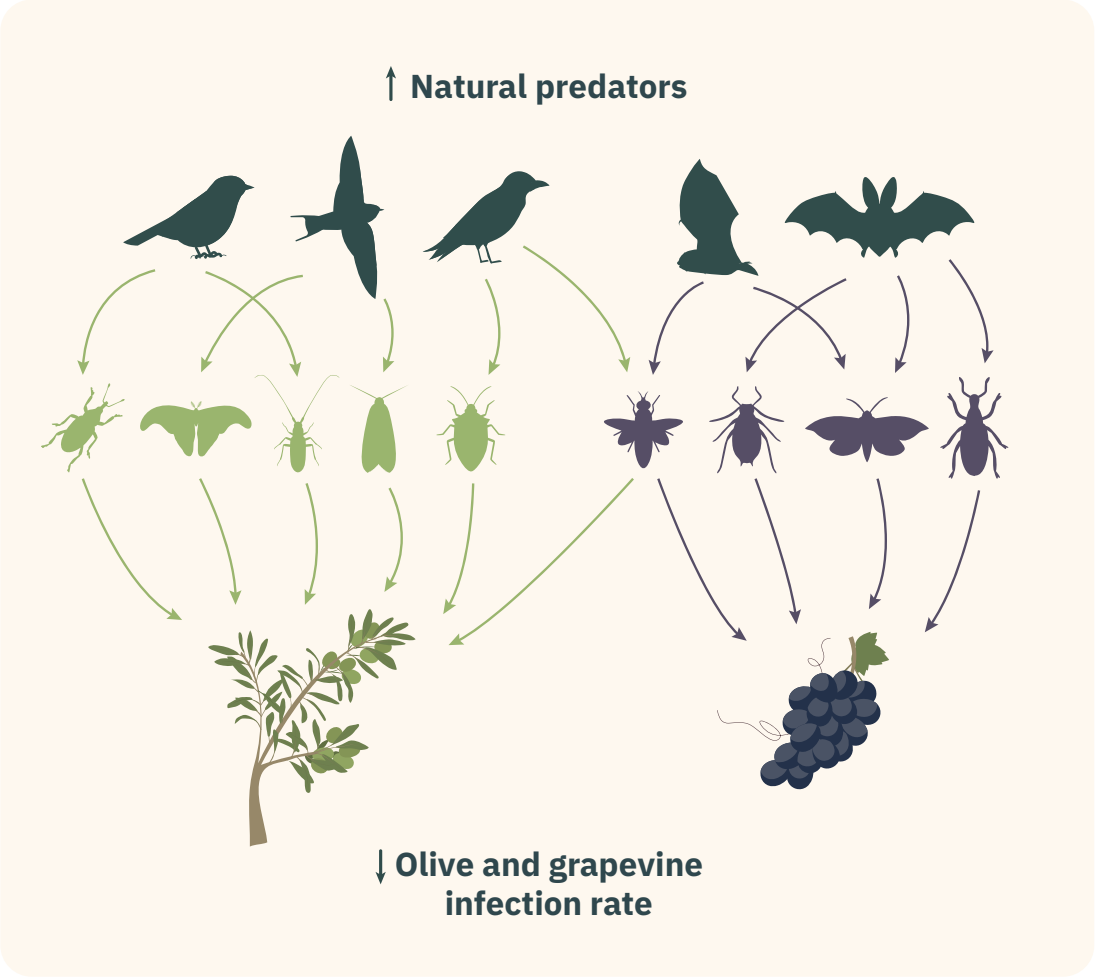
Regulating

Benefits from natural processes that control ecosystem balance. Insectivorous birds and bats help regulate pest populations, boosting crop yield and quality.

2.2 The economic importance of birds and bats

The economic importance of birds and bats is mostly related to their role as effective providersof ecosystem services. Olive groves and vineyards are able to harbor a range of insectivorous bird and bat species. Most of these species are known to prey on a diverse array of insects, including major olive pests such as the olive fruit fly (*Bactrocera oleae*) and olive fruit moth (*Prays oleae*) as well as major grapevine pests such as the European grapevine moth (*Lobesia botrana*). Remarkably, these insect pests significantly impact the agricultural industry by reducing yields and increasing production costs for farmers. Birds and bats are also known to prey on diverse leafhopper species, which are widely recognized as being primary vectors of *Xylella fastidiosa*, the major quarantine pathogen identified by the European Union. Far from being trivial, this pathogen cause annual production losses of €5.5 billion annually. Moreover, regionally-implemented plans to contain *X. fastidiosa* have so far proven not only inefficient in reducing production loss, but also highly detrimental to protected wildlife, including natural predators of *X. fastidiosa* insect vectors. Natural pest control services provided by birds and bats are especially valuable in integrated pest management strategies, where minimizing chemical inputs is both an economic and environmental priority. Indeed, they are suggested to be key to achieve the ambitious aim of the Farm to Fork Strategy from the European Commission to reduce by 50% the use and risk of chemical pesticides by 2030.

Olive groves and vineyards provide also suitable habitats to millions of frugivorous wintering birds, a good portion of which correspond to game species, thereby significantly contributing to the hunting and shooting industry. Particularly remarkable is the case of thrushes, which are recognized as



some of the most iconic small-game birds by European hunters. Notably, the economic value of the birdgame hunting industry in Europe is roughly estimated at €5.0 thousand million. Furthermore, ehe economic value of European bird watching-related tourism is estimated at approximately €23.1 billion annually, representing about 35% of the global market. Notably, many target species, including species of conservation concern, typically use olive groves and vineyards as suitable habitats.

Their delicate conservation status turn birds and bats into good ecological indicators of sustainable land management, being therefore useful for eco-labelling and for supporting the implementation of agri-environmental subsidy schemes. For instance, farms that support species-rich bird and bat communities are more likely to meet criteria for organic or sustainable certifications and commercial brands, which can lead to premium prices of olive and grape-based products.

The **Olivares Vivos+** project is a European initiative that promotes biodiversity-friendly olive farming through a scientifically validated certification scheme. The **Olivares Vivos** label guarantees that olive oils come from farms where concrete measures have restored wildlife and improved ecosystem services, linking biodiversity recovery directly to market value. The project scales up the impact of this certification across Spain, Portugal, Italy and Greece, aligning sustainable agriculture with profitability. Visit https://www.olivaresvivos.com/life-olivares-plus/ to learn more.

3 Legislation, policy and regulations

Preserving and restoring biodiversity is an unquestionable priority for the EU. Let's check how its legislative framework protects birds, bats and their habitats

3.1 Bird conservation

Bird conservation in Europe is guided by one of the most comprehensive legal frameworks in the world. The cornerstone is the EU Birds Directive (2009/147/EC), which aims to protect all wild bird species naturally occurring in the EU, along with their habitats. This directive mandates the designation of Special Protection Areas (SPAs) for species listed in Annex I and for regularly occurring migratory species, forming part of the Natura 2000 network, the largest coordinated network of protected areas globally. The Birds Directive also prohibits the deliberate killing, capture, disturbance, or destruction of nests and eggs of protected birds. At the international level, bird conservation is reinforced by the Convention on the Conservation of Migratory Species (CMS), the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), and the Bern Convention on the Conservation of European Wildlife and Natural Habitats. These legal instruments are supported by national laws and conservation policies in each member state, ensuring coordinated efforts to monitor populations, prevent illegal killing, and integrate bird protection into agriculture, forestry, and spatial planning.

3.2 Bat conservation

Bats are strictly protected across Europe under a robust legal framework that includes international, European Union, and national legislation. All European bat species are listed under the EU Habitats Directive (92/43/EEC), particularly in Annex IV, which mandates strict protection of species and their roosts, as well as Annex II for some species requiring the designation of Special Areas of Conservation (SACs). Additionally, all bat species are covered by the Agreement on the Conservation of Populations of European Bats (EUROBATS), a binding international treaty under the Convention on the Conservation of Migratory Species of Wild Animals (CMS). EUROBATS promotes coordinated action among European countries to protect bats and their habitats, monitor populations, and raise public awareness. Furthermore, many countries have specific national laws that prohibit the killing, disturbance, or destruction of bat roosts. This legal framework makes bat conservation a shared responsibility among EU member states, ensuring the integration of bat protection into land-use planning, forestry, agriculture, and infrastructure development.

3.3 Habitat conservation

The conservation of natural habitats in Europe is primarily governed by the EU Habitats Directive (92/43/EEC), which, together with the Birds Directive, forms the legal backbone of biodiversity protection in the European Union. The Habitats Directive aims to safeguard Europe's most valuable and threatened habitats and species by establishing the Natura 2000 network of protected sites. It requires EU Member States to designate SACs for habitats listed in Annex I of the directive and to implement management measures to maintain or restore them to a favorable conservation status.

The directive also imposes strict protection on species listed in Annex IV, including their breeding and resting places. This legal framework is complemented by other international agreements such as the Bern Convention, the Ramsar Convention on Wetlands, and the Pan-European Biological and Landscape Diversity Strategy. At the national level, countries are required to transpose these directives into domestic law, enforce protection measures, and integrate habitat conservation into sectors like agriculture, forestry, and land-use planning. Together, these policies aim to halt biodiversity loss and ensure the long-term resilience of Europe's natural landscapes.

While protected areas remain essential for safeguarding species and ecosystems, they are widely recognized as insufficient on their own. As a consequence, despite biodiversity conservation is firmly embedded in both national and international legislation and regulatory frameworks, farmland biodiversity is steeply declining globally. This undoubtedly requires to change the paradigm that views agricultural landscapes as ecological voids, to recognize them as suitable and appropriate scenarios for biodiversity conservation. To achieve this, it is however essential to identify effective incentives for farmers to invest in biodiversity and provide the evidence these incentives result in benefits for the agriculture industry

How crop production intensification impacts birds and bats

How crop production intensification impacts birds and bats

4.1 Farm-level impacts

At the farm level, intensification of management practices in olive groves and vineyards has significant negative impacts on bird and bat communities. Intensification typically involves the increased use of agrochemicals, the simplification of vegetation structure, and the removal of non-crop elements such as hedgerows, scattered trees, and ground cover. These changes reduce the availability of key resources such as insect prey, nesting cavities, and shelter, thereby

decreasing the suitability of the habitat for many bird and bat species. Insectivorous species are particularly affected, as the overuse of pesticides diminishes arthropod populations, while herbicide application eliminates flowering plants that support insect diversity. This trophic disruption can lead to declines in both the abundance and diversity of aerial insectivores that depend on a rich and varied prey base.

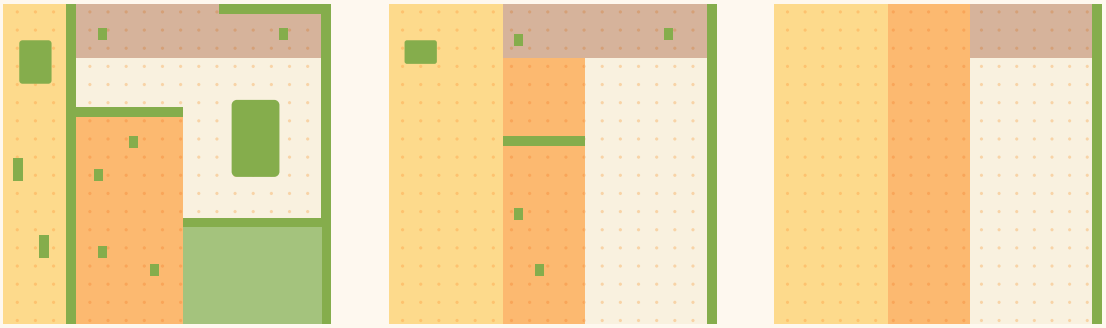
Structural simplification of the landscape further compounds these effects. Uniform planting densities, reduced tree age heterogeneity, and the removal of vertical and horizontal vegetation layers result in a more homogeneous environment with fewer niches (e.g. less availability of natural cavities typical of older trees) and less spatial heterogeneity. For birds, this often means fewer nesting and perching sites, while for bats, it translates into a loss of roosting options and reduced connectivity between roosting and foraging areas. The removal of inter-row herbaceous vegetation and woody elements like hedgerows and isolated trees also disrupts commuting pathways and impairs orientation during foraging. Collectively, these changes not only lower the carrying capacity of the landscape for birds and bats but also undermine their ecological functions, including natural pest control and seed dispersal.

4.2 Landscape-level impacts

At the landscape level, the intensification of olive grove and vineyard management leads to habitat homogenization, fragmentation, and the degradation of ecological connectivity, all of which have far-reaching negative consequences for bird and bat populations. As traditional, heterogeneous landscapes are increasingly replaced by large, uniformly managed monocultures, the diversity and abundance of key structural elements, including patches of natural vegetation, riparian corridors, and mosaic-like habitat configurations, decline sharply. This loss of landscape complexity reduces the availability of complementary resources across space and time, disrupting the ability of birds and bats to move efficiently between roosting, nesting, and foraging sites. Species that rely on a mix of habitat types, or those with large home ranges, are particularly vulnerable to these changes.

Moreover, landscape-scale intensification often results in the spatial isolation of suitable habitat patches, further limiting the dispersal and colonization opportunities for many species. For birds, this can lead to the breakdown of individual movements between populations, where isolated populations become more susceptible to local extinctions. For bats, especially species dependent on tree cover or linear features for navigation and foraging, fragmentation can severely impair movement and reduce foraging efficiency. The cumulative effect of these landscape alterations is a decline in species richness, shifts in community composition toward more generalist and disturbance-tolerant species, and a weakening of key ecological functions such as insect predation and seed dispersal.

Agricultural Intensification



Mosaic-like landscape. Low crop density (dot density). Abundant natural vegetation (green lines and polygons) and high diversity of land-cover types (color polygons).

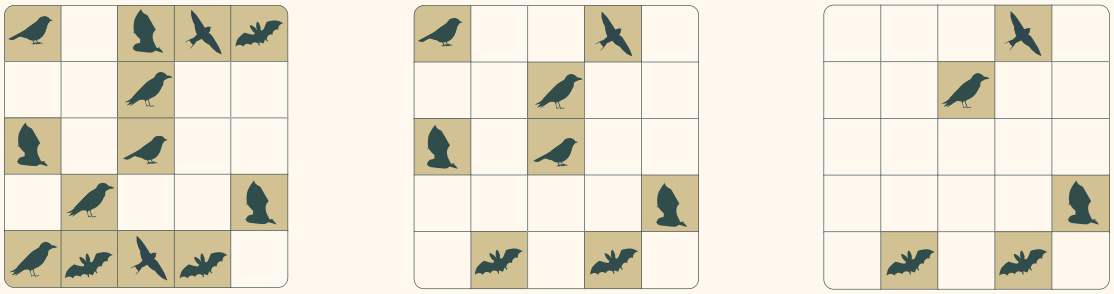
High diversity of species

Intensification of agriculture. High crop density. Low abundance of natural vegetation and diversity of land-cover types.

Gradual decline of species diversity

Intensive agriculture. Super high-density crop systems. Extremely low abundance of natural vegetation and diversity of land-cover types.

Significant decline of species diversity



Managing vineyards and olive groves for bird and bat conservation

5.1. Foraging

Creating and enhancing habitats that provide food and shelter for birds and bats

5.2. Nesting - Roosting

Sheltered places where birds and bats rest, sleep, or perform breeding activities

5.3. Commuting

Linking habitats, enabling wildlife movement and supporting birds and bats


Commuting
Foraging
Nesting - Roosting

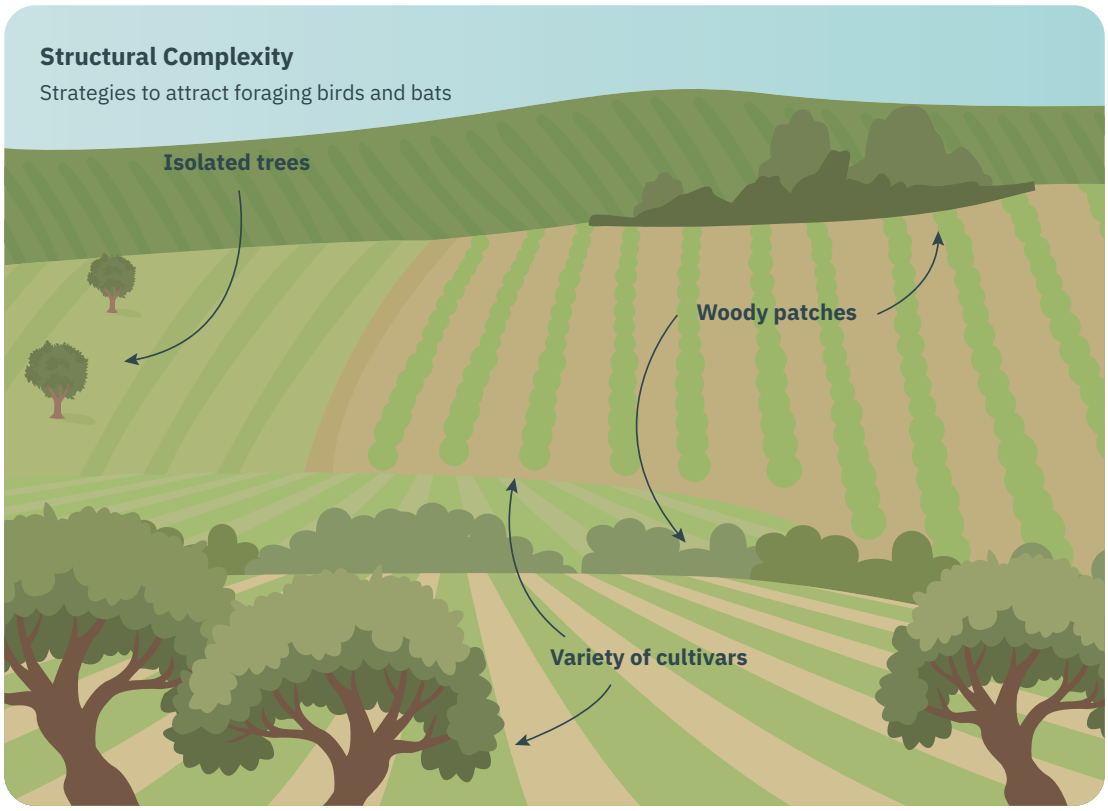
This technical guide approaches landscape design from the bat and bird ecology perspective by grouping biodiversity features into three primary needs addressed at the landscape level: foraging, nesting-roosting and commuting. All interventions aimed to increase the availability and suitability of foraging, nesting-roosting and commuting sites will benefit birds and bats, thereby enhancing their ability to effectively supply ecosystem services.

5.1 Foraging

Providing and enhancing foraging habitats is probably the most important intervention that can be done to improve the suitability of olive groves and vineyards for birds and bats. All European bird and bat species directly or indirectly rely to some extent on vegetation. Thus, interventions that increase vegetation availability, diversity and suitability (i.e., crop and non-crop vegetation) will benefit birds and bats

5.1.1 Structural complexity

Enhancing the structural complexity of olive groves and vineyards, both at the local and landscape scales, is crucial for the conservation of birds and bats. Farms with more diverse and layered vegetation structures provide a richer array of habitats and resources, supporting a greater variety of species. This, in turn, leads to increased foraging activity and enhances the delivery of key ecosystem services, such as natural pest control. Structural complexity makes also olive groves and vineyards more attractive to birds and bats, increasing the chances that these species will frequent and forage within the agricultural area.



Best practices for enhancing structural complexity to support foraging birds and bats:

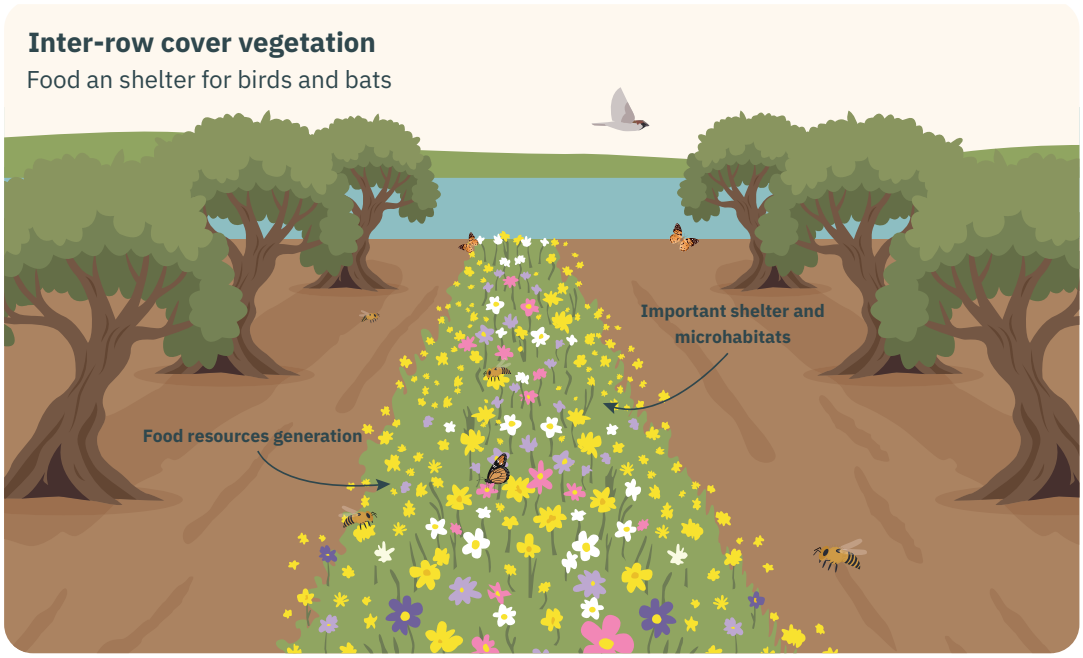
- ✓ Increase the distance and spatial variability between crop plants, both within and between rows
- ✓ Maintain a higher proportion of mature and old-growth crop plants
- ✓ Apply varied pruning patterns across different areas and over time
- ✓ Promote crop diversity by incorporating mixed cropping systems and a variety of cultivars
- ✓ Maintain and increase the occurrence and abundance of hedgerows between farms

5.1.2 Inter-row ground cover vegetation

Ground cover vegetation plays a vital role in supporting birds and bats by providing essential resources such as food and shelter. Farms with well-maintained ground cover generally host higher insect richness and abundance compared to bare or intensively managed fields. This increased insect availability offers a critical food source for many insectivorous birds and bats, while also supporting complementary ecosystem services such as pollination, pest control, and nutrient cycling.

Maintaining an alternation of taller and shorter ground cover often increases profitability for ground-dwelling birds, and frequently also the availability of flowers for pollinators. Areas with taller sward 'produce' food resources that become easily detectable in short-sward parts, where they are collected by birds.

Beyond food resources, ground cover also offers important shelter and microhabitats, enhancing habitat quality, especially for ground-dwelling and low-foraging species. By fostering diverse and well-managed ground vegetation, farms can become significantly more attractive to these ecologically important groups, helping to sustain their populations and the services they provide.



Best practices for managing ground cover vegetation to support foraging birds and bats:

- ✓ Maintain intermediate ground cover (40–60%) with moderate vegetation height (under 20 cm)
- ✓ Create structural variation by mowing herbaceous cover at different heights and intervals
- ✓ Encourage species-rich plant communities with diverse flower colors, fragrances, shapes, nectar supplies, and staggered flowering times to provide resources throughout the year
- ✓ Increase the diversity and abundance of pale-colored flowers, including white and cream hues, which attract dusk-active insects and are especially beneficial for foraging bats
- ✓ Delay mowing until plants have set seed to support natural regeneration and seed-eating birds
- ✓ Reduce agrochemical use through integrated or organic farm management (IFM/OFM) strategies
- ✓ Mow certain grassy areas only every other year to allow insects to complete their entire biological cycle on the plot or its surroundings
- ✓ Allow spontaneous grass to grow wherever possible near the plots and where it does not interfere with the crops

5.1.3 Woody vegetation

Woody vegetation provides highly valuable foraging habitat for both birds and bats, even for species that are not forest specialists. Increasing and maintaining woody vegetation within olive groves and vineyards significantly enhances habitat quality, supports biodiversity, and promotes key ecosystem services.

Native remnant trees offer a rich variety of food resources, including insects for insectivorous species and seeds or fruits for granivorous and frugivorous birds and bats. These trees also play an essential role in navigation: bats use them as orientation landmarks during flight via echolocation, while birds often use them as stopover or perching sites. From elevated perches above the olive tree or vine canopy, birds can scan the landscape for predators or prey, increasing their foraging efficiency.

Although they may occupy only a small portion of the land, native trees function as *keystone structures* in agricultural landscapes. Their ecological importance lies in their ability to support a wide range of species and promote the functional diversity of foraging birds and bats.

Woody patches such as small forest fragments, hedgerows, and riparian corridors are vital foraging sites within vineyard and olive grove landscapes. These areas combine multiple habitat layers, offering food, shelter, and protection for species that rely on woodland environments. They are particularly important for higher trophic-level predators, like insectivorous bats and birds of prey, which may struggle to find adequate resources in simplified agricultural settings. In addition, by providing important alternative feeding resources for insectivorous birds and bats, woody patches contribute to maintaining these species (and their potential pest-control services) close to agricultural areas, even when crop-related insects (including crop pests) are less available.

These patches also serve critical landscape functions. Linear elements like hedgerows act as corridors, while isolated patches serve as stepping stones that enable birds and bats to move through the landscape. This mobility maintains functional connectivity across fragmented habitats and supports ecosystem services, including seed dispersal, pollination, and pest regulation.

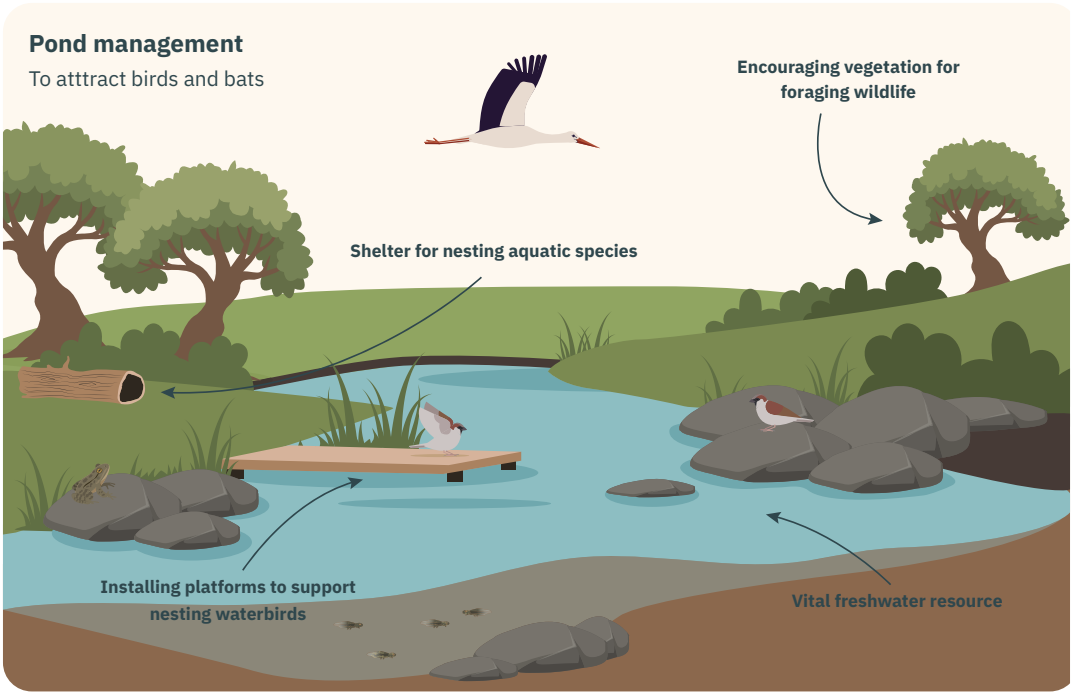
Woody vegetation
Keystone structures in agricultural landscapes

Best practices for managing native woody vegetation to support foraging birds and bats:

- ✓ Retain as much native woody vegetation as possible, aiming for at least 20% coverage across the landscape
- ✓ Maintain structural diversity, from isolated trees to larger, denser woodland patches
- ✓ Leave some patches unmanaged, with a dense understory (≥50% cover), to support a wide range of species
- ✓ Preserve and enhance spatial arrangements of woody patches to promote movement and functional connectivity
- ✓ Use hedgerows to divide fields and define property boundaries, improving habitat continuity
- ✓ Restore and maintain riparian habitats along watercourses to support diverse ecosystems
- ✓ Reduce trimming intensity and frequency at most as possible
- ✓ Conserve standing and fallen deadwood, which provides nesting cavities for birds (e.g., woodpeckers, rollers, owls, passerines) and roosting sites for bats, as well as habitat for insect prey
- ✓ Favour a high variety of plant species to diversify suitable plant resources; including fleshy-fruited species like fig and apple-trees, and dry-fruited species like nuts (like almonds, cashews, walnuts), legumes (like beans and lentils), and achenes (like those found in sunflowers).

5.1.4 Ponds

Freshwater is vital for all bird and bat species, particularly in water-scarce Mediterranean ecosystems. These animals rely on open water sources not only for drinking but also for feeding—many species forage on aquatic insects, especially those with water-based larval stages. Ponds with well-developed vegetation further enhance food availability and offer important shelter for foraging wildlife. Establishing and properly managing ponds can significantly increase bird and bat activity, boosting both visitation rates and foraging behavior. However, to maximize their ecological value, key features such as pond location, design, and management must be carefully considered.



Best practices for managing ponds to support foraging birds and bats:

- ✓ Place ponds within 50 meters of important landscape features that birds and bats use for commuting or foraging, such as riparian corridors, woody patches, or hedgerows
- ✓ Create ponds as large as possible —ideally 50 m² or more— to accommodate a greater diversity of species
- ✓ Encourage a mix of native plant species along pond edges to provide both food and shelter
- ✓ Develop pond complexes with varied sizes and depths to support a range of species with different habitat preferences
- ✓ Foster conditions that support the growth of native wetland plants
- ✓ Prevent pollution and nutrient runoff to maintain clean, healthy water

- Modify existing irrigation ponds to make them safer and more attractive to birds and mammals. Consider installing platforms to support nesting waterbirds

- Create gentle slopes on the banks to allow animals to exit easily and create different depth levels to provide resources for a greater diversity of species

5.1.5 Insect hotels

Insect hotels are artificial structures designed to provide shelter for beneficial insects, especially pollinators like solitary wild bees. Typically built from untreated wood and other natural materials, they come in various shapes and sizes and offer safe spaces for nesting and overwintering. By supporting insect populations, these structures help sustain a reliable food source for insectivorous birds and bats, contributing to greater biodiversity and improved foraging opportunities in agricultural landscapes.

Some insect hotels can also be adapted to support a wider range of wildlife by including nesting materials for birds or roosting cavities for bats, making them versatile tools for biodiversity conservation.

Best practices for optimizing insect hotels to support foraging birds and bats:

- Install multiple insect hotels with diverse designs to attract a wider range of insect species

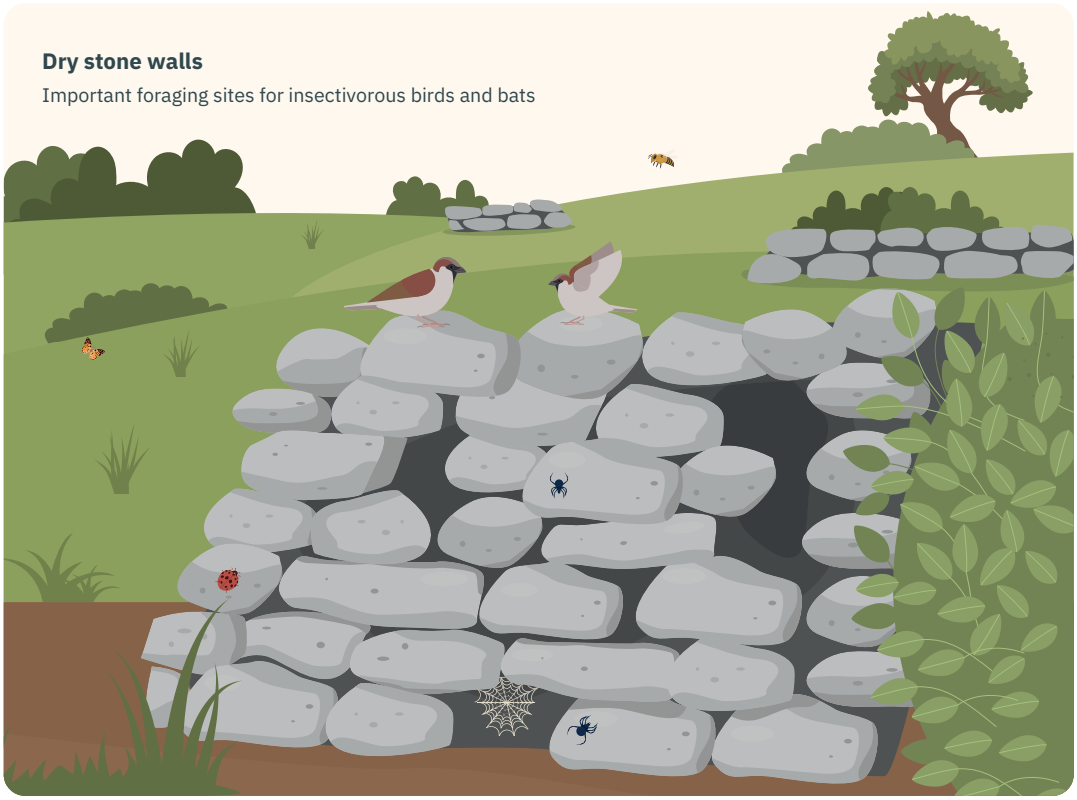
- Select or customize hotels to support insect species that are key prey for local bird and bat populations, maximizing ecological benefit

- Set up piles of deadwood and/or stones which can act as insect hotels

5.1.6 Dry stone walls

Dry stone walls, traditionally used to mark field boundaries, also function as valuable microhabitats for a wide range of insects and spiders. These groups, in turn, attract insectivorous birds and bats, making the walls important foraging sites. The numerous crevices and cavities within the walls also offer excellent roosting and nesting spots for both groups, enhancing their ecological significance.

To further increase their value as habitat, dry stone walls can be transformed into green walls by planting climbing vegetation. These plants provide additional food and shelter, especially for birds, making the walls even more supportive of local biodiversity.



Best practices for designing ecologically valuable dry stone walls to support foraging birds and bats:

- ✓ Build walls without mortar, using locally sourced natural stones to maintain ecological compatibility
- ✓ Ensure walls are at least 1 meter tall to maximize their use by wildlife
- ✓ Aim for longer and wider structures to expand foraging, roosting, and commuting opportunities
- ✓ Plant native climbing species —especially those that produce fleshy fruits and create dense canopies— to boost food availability and shelter for birds and bats
- ✓ Build cavities at different heights

Key Strategies to Boost Foraging Opportunities

- ✓ Increase spatial variability in planting patterns and crop structures to create diverse habitats.
- ✓ Favor mixed cropping systems over monocultures to support greater biodiversity.
- ✓ Maintain a high diversity of land cover and land-use types around farms.
- ✓ Conserve or establish species-rich vegetation between crop rows.
- ✓ Keep woody vegetation at different densities, ranging from isolated trees to small woodland patches.
- ✓ Retain unmanaged woodland patches with dense understory to provide shelter and food for wildlife.
- ✓ Preserve standing and fallen dead wood as important habitats for wild species.
- ✓ Use hedgerows to separate fields and define boundaries, enhancing landscape connectivity.
- ✓ Create and maintain freshwater sources like ponds and ditches for drinking and foraging.
- ✓ Protect and restore riparian habitats along streams and water bodies.
- ✓ Develop pond complexes with a variety of pond sizes and types to support diverse species.
- ✓ Install insect hotels to increase prey availability for insectivorous birds and bats.
- ✓ Build dry stone walls to mark field boundaries while providing valuable habitat and shelter.

5.2. Nesting-Roosting

Roosts are the resting or sheltering spots that birds and bats use throughout the year. Both species groups require a variety of nesting-roosting locations and will often select different types depending on the time of year and their specific ecological needs.

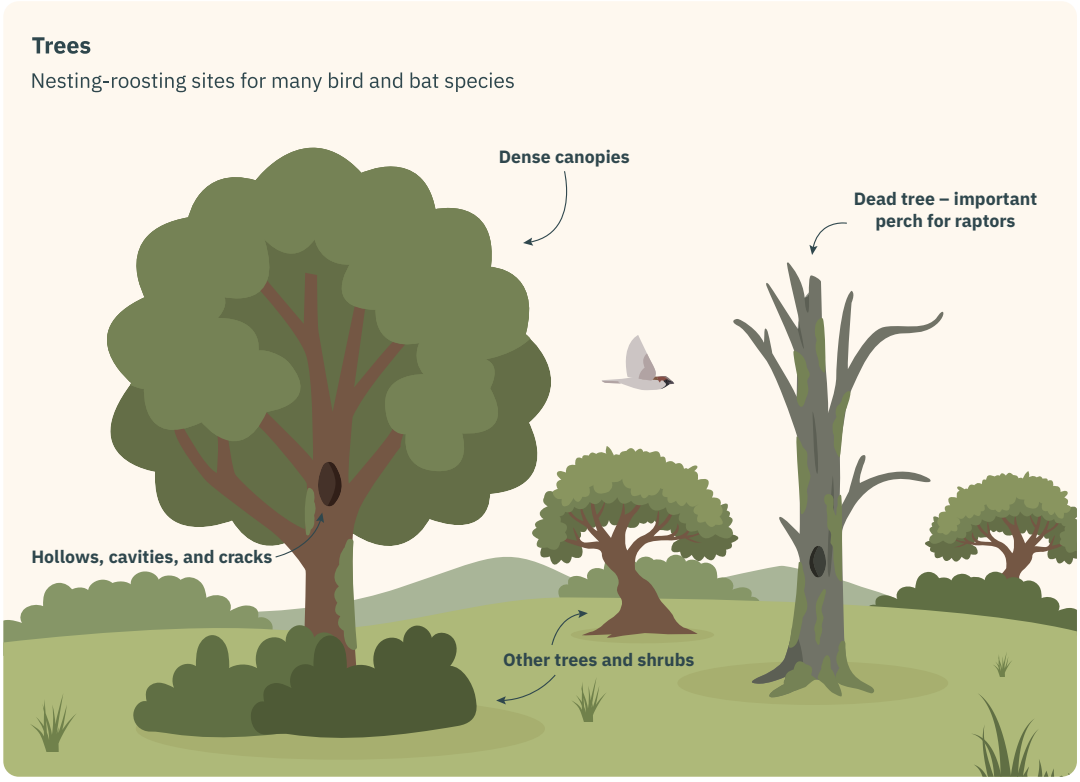
5.2.1 Trees

Trees are especially important roosting sites for many bird and bat species. However, the exact roosting requirements vary between species. Key features that make trees ideal include dense canopies, hollows, cavities, and cracks or splits in branches. Mature native trees — commonly found in woodland patches or hedgerows— are particularly valuable for providing these features. Even isolated remnant trees can serve as nests-roosts, as long as they have the necessary characteristics.

It's also important that roost trees are surrounded by a buffer zone of other trees and shrubs. This vegetation helps maintain a stable microclimate around the roost and improves overall habitat quality. Research shows a strong link between the size and proximity of woodland patches and the presence of roosting birds and bats, with most roosts located within 500 meters of woodland areas, regardless of patch size.

Maintaining trees for roosting birds and bats:

- ✓ Identify and protect trees with high roosting potential, including dead trees, which can provide critical shelter
- ✓ Preserve a buffer zone of surrounding trees and understory plants to protect the microclimate of roost sites
- ✓ Increase the number of suitable roosts by planting trees known to offer good shelter and food resources. Recommended species include flowering cherry (*Prunus spp.*), rowan (*Sorbus spp.*), birch (*Betula spp.*), carob tree (*Ceratonia spp.*) and crab apple (*Malus spp.*). These species have dense canopies that protect against predators and produce flowers and fruits that attract insects, providing additional food for birds and bats
- ✓ No management intervention during nesting-roosting period



5.2.2 Buildings

Existing buildings in agricultural landscapes often provide excellent roosting sites for many bird and bat species. Over time, some species have adapted to using these structures and may even depend on them for survival. Older buildings like barns and abandoned houses are especially valuable because they offer plenty of cracks, gaps, and perches that birds and bats can use.

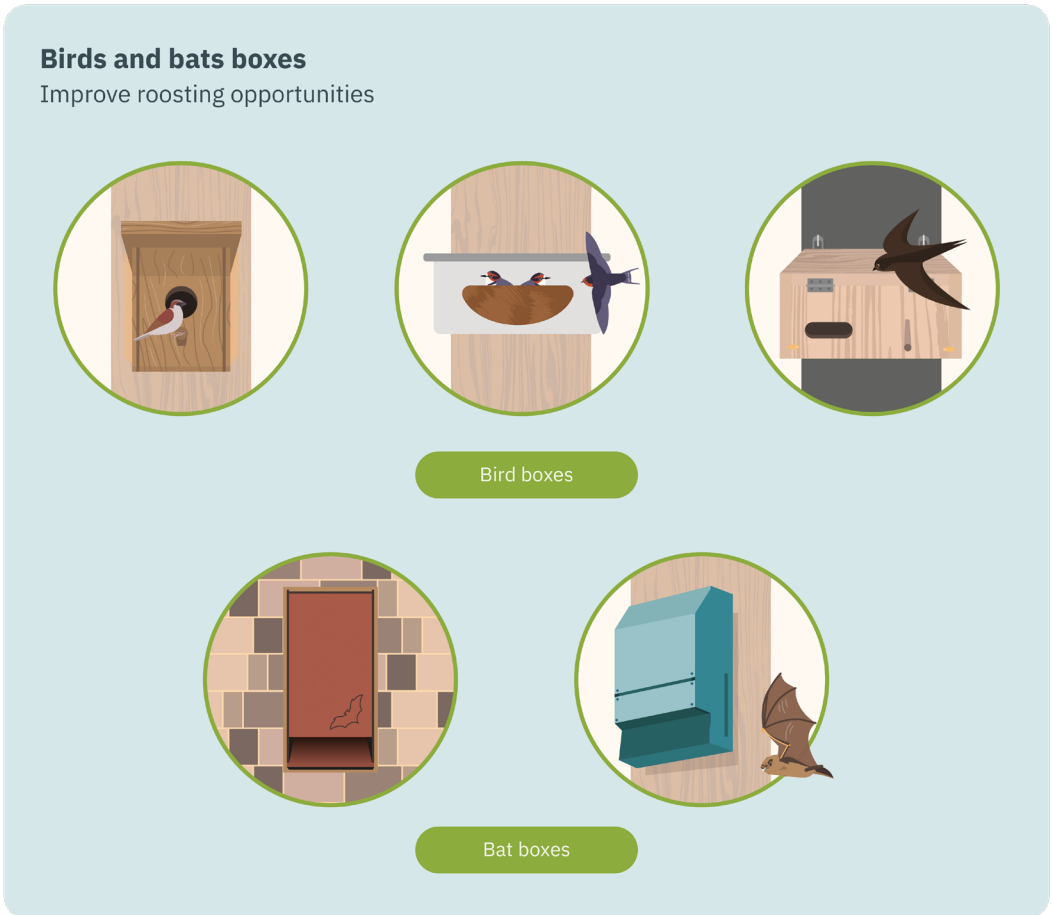
Newer buildings, on the other hand, tend to be more sealed and offer fewer natural roosting spots. This makes it important to intentionally include roosting features in the design of new structures —especially in recently established olive groves and vineyards— to support local wildlife.

Maintaining and creating nesting-roosting sites in buildings:

- ✓ Preserve existing buildings that provide or could provide roosting sites for birds and bats
- ✓ Avoid disturbing or altering buildings currently used by roosting birds or bats, even if the animals are not present at the moment
- ✓ Before repairing or sealing cracks, gaps, or openings, inspect buildings for signs of bird and bat use
- ✓ If building changes may impact roosting, follow proper licensing procedures and consult a qualified ecologist
- ✓ When designing new buildings, include dedicated roosting spaces and access points to support wildlife

5.2.3 Purpose-built roosts

Installing bird and bat boxes can greatly improve roosting opportunities, especially in landscapes where natural roosts are limited. The microclimate inside these artificial shelters is crucial for their success. To be effective, boxes should be draft-proof and made from materials with good thermal stability, such as untreated wood or woodcrete. For bats, integrated roosts built into the structure of buildings tend to be more permanent and less likely to be disturbed compared to external boxes.



Placement and design tips for bird and bat boxes:

- The entry size, internal space, and placement height vary by species. Always check the specific needs of your target species before installation
- Using acoustic lures (like playing social or foraging calls of the species) and olfactory cues (such as applying excrement) can increase the chances of occupancy
- Bat boxes should receive full or partial sunlight and be installed at least 2 meters above ground—preferably over 4 meters. Varying the orientation can provide different roosting conditions
- Bird boxes should ideally face between north and east. They can be placed between 3-5 meters to improve occupancy roosting conditions
- Place boxes near suitable vegetation like hedges or tree lines to make them more attractive
- The number of boxes depends on habitat size. A general guideline is about 20–25 bird boxes and 2–4 bat boxes per hectare. For specialist birds like owls and hawks, use fewer boxes because they need large hunting territories
- Predation by rodents and small carnivores can reduce bird occupancy and fledging success. For passerines, especially in olive groves, nest entrances may need special designs to reduce predation risk. For larger birds like owls, kestrels, and European rollers, mounting poles should be cemented into the ground rather than buried directly to prevent rot and damage. Adding smooth or slippery materials to the pole can help keep predators from climbing
- Examine bird and bat boxes periodically (ideally yearly) to monitor their effectiveness

Key Strategies to Boost Nesting-Roosting Opportunities

- Birds and bats use a variety of roosting sites, including crevices, cracks in old buildings, and holes in trees.
- Protect all bird and bat roosts from damage or disturbance, even when they appear unoccupied.
- Old and dead trees often have valuable features that make them ideal roosting spots; conserving these trees should be a priority.
- Properly managed modern buildings can also provide important roosting sites for birds and bats.
- Surround roosting trees or potential roost trees with a buffer of trees and dense understory to improve the microclimate and roosting conditions.
- Even small gaps (15-20 mm) are important for bats and should be protected.
- Installing bird and bat boxes can increase roosting opportunities. Place these boxes in warm spots, with varied orientations, at least 2 meters above the ground, and away from disturbances.
- Design boxes to fit the specific needs of the target bird or bat species.
- Position boxes near natural habitats -ideally within 450 meters- to make them more attractive and effective.
- To prevent predation by rodents and small carnivores, take measures to block their access, such as making climbing difficult and protecting box entrances.

5.3 Commuting

Connectivity is crucial for preserving biodiversity in agricultural landscapes. It helps shape where species live and how well they survive by providing pathways or “stepping stones” for their daily movements or occasional dispersal. This movement between roosting and foraging sites is called commuting. While both birds and bats commute, bats especially rely on specific routes—known as commuting corridors, flight paths, or flyways—due to their larger spatial needs. These routes often follow tree-lined features like isolated trees, treelines along waterways, and hedgerows, which act as important links across the landscape. Creating and maintaining these corridors is essential to support both birds and bats in olive groves and vineyards.

5.3.1 Remnant Trees and Small Woodland Patches

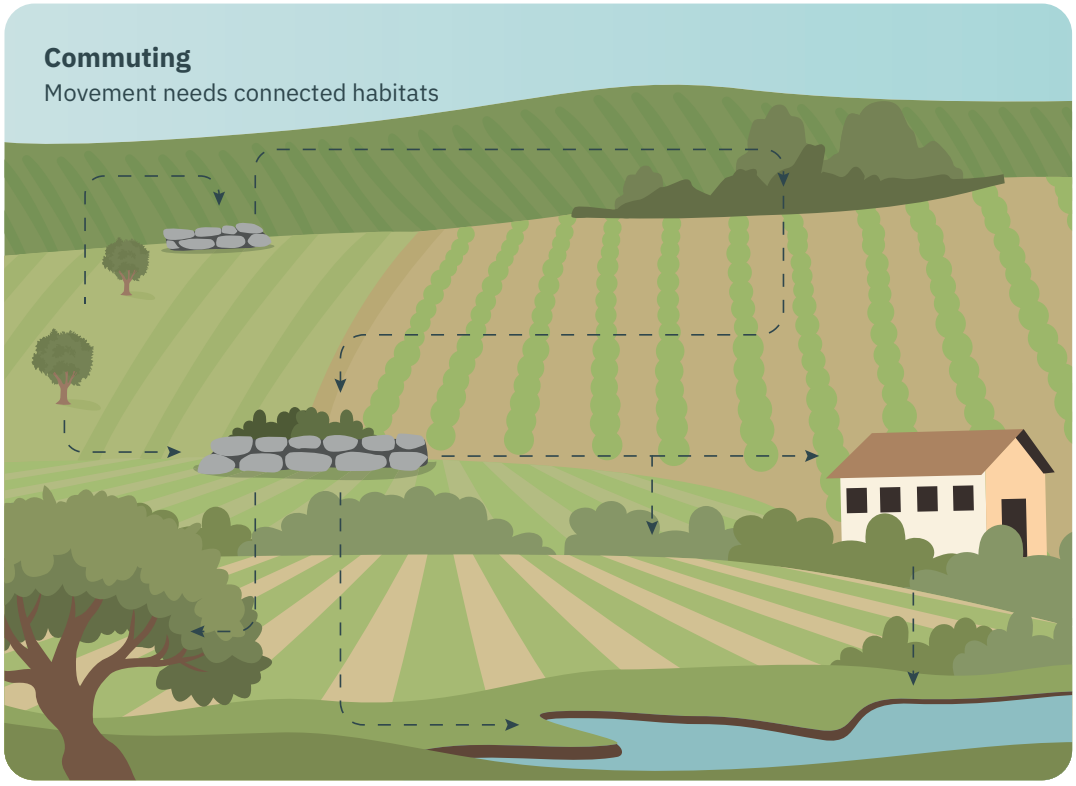
Remnant trees and small woodland patches are common in many production landscapes, including European olive groves and vineyards. Besides providing important food resources and nesting/roosting places, these patches help birds and bats move through the landscape safely. They also support other species, like fruit-eating birds, by acting as stepping stones for seed dispersal. This process helps new plants and young trees grow under the shelter of existing tree canopies, aiding the conservation and health of natural habitat patches.

5.3.2 Riparian Areas and Stream Buffers

Riparian zones and stream buffers serve as valuable corridors that boost connectivity, especially for birds and bats. These areas offer rich habitats that often support higher populations of wildlife, which can then spread offspring to other, less fertile parts of the landscape. Riparian zones also support frugivorous species—fruit-eating animals—that play a key role in dispersing seeds and helping plant communities thrive.

5.3.3 Hedgerows

Hedgerows are vital features in agricultural landscapes, providing habitat, food, and connectivity for both birds and bats. They offer nesting spots, shelter from predators, and abundant food such as insects, berries, and seeds. For bats, hedgerows act as safe corridors for foraging and navigating through fragmented areas. They also support insect-eating species, which helps control pests, boosts biodiversity, and strengthens ecosystem resilience.



Managing hedgerows for commuting birds and bats:

- ✓ Plant a variety of species to provide food year-round
- ✓ Keep hedgerows thick and dense for shelter
- ✓ Avoid cutting hedgerows during bird breeding season unless necessary for safety
- ✓ Don't cut hedgerows too often or too tightly; annual cutting should be avoided unless required for access
- ✓ Use rotational cutting, so only part of the hedgerow is trimmed each year, protecting overwintering insects
- ✓ Include tree-like species to add structural complexity and habitat diversity
- ✓ Avoid the use of herbicides

Key Strategies to Boost Commuting Opportunities

- Commuting between roosting and foraging areas is essential for birds and bats. Wherever possible, all known commuting routes should be protected and improved.
- These routes usually follow important landscape features such as remnant trees, riparian zones, stream buffers, and hedgerows. It's important not only to preserve these features but also to increase their presence throughout the landscape.
- Commuting routes connect fragmented habitats, turning small patches into larger, continuous areas that boost biodiversity.
- To maintain connectivity, avoid gaps longer than 10 meters along these linear features.
- Promote the growth of flowers and grasses at the base and edges of these features to support foraging.
- Linear features should be at least 2.5 meters tall, made up of native plants, and have diverse species to provide food and shelter year-round.
- Adding standard trees within hedgerows (called hedgerow trees) increases the value of these corridors for commuting birds and bats.

6 Design Process

Managing vineyards and olive groves to support bird and bat conservation is a straightforward but multi-step process.

Step 1: Environmental Characterization

Bird and bat species are distributed through space and time based on the spatial and temporal signature of suitable resources and conditions, including sources of food and shelter. Thus, any conservation management strategy has to start by thoroughly characterizing target farms at both the local and the landscape-scale.

To characterize target farms at the local-scale preemptively use:

- **Parcel size (ha):** Area of the target farm
- **Planting density:** Number of trees/vines per hectare.
- **Row spacing and canopy structure:** Affects light, temperature, and microhabitats.
- **Tree/vine height and age:** Indicates structural maturity.
- **Canopy cover (%):** Extent of foliage cover, influencing habitat suitability.
- **Ground cover:** Type and cover of herbaceous vegetation or bare soil.
- **Presence of suitable habitat structures for birds and bats:**
  - Stone walls, terraces
  - Hedgerows, isolated trees
- **Farming system:** Organic, integrated, conventional, or biodynamic.
- **Pesticide use:** Type, frequency, and intensity of chemical applications.
- **Fertilizer use:** Organic vs. synthetic, quantity applied.
- **Soil management:** Tillage practices, mulching, ground cover management.
- **Irrigation:** Rain-fed or irrigated system.
- **Pruning regime:** Frequency and type of pruning.
- **Harvesting method:** Manual or mechanical.

To characterize target farms at the landscape-scale preemptively use:

- **The amount and spatial configuration of land-cover and land-use types within buffers from of 250 m to 1 km, including:**
  - Semi-natural habitats (forest, shrubland)
  - Other crops (arable, orchards, urban areas, roads, grasslands, pastures)

This step serves two main purposes:

1. To identify all those potential environmental correlates underlying the local community structure of birds and bats (i.e., number of species and species-specific relative abundance).
2. To assess the conservation actions needed to support their three primary needs —foraging, roosting/nesting, and commuting.

Step 2: Ecological Survey

Qualified ecologists should conduct farm-level detailed surveys of the bird and bat communities. Bird and bat communities can be characterized and monitored through a combination of standardized field methods tailored to capture species diversity, abundance, and activity patterns in target farms. For birds, common approaches include point counts and transect surveys conducted during key periods such as the breeding season or migration, which record species presence, numbers, and behaviors like foraging or nesting. Bat communities are often monitored using passive acoustic detectors that record echolocation calls throughout the night, allowing identification of species and quantification of activity levels. Complementary methods such as mist-netting for bats or nest box monitoring for birds can provide additional information on species presence and reproductive success. Surveys in surrounding land-cover and land-use types should be ideally also performed. The data collected will reveal community composition and help assess conservation status by comparing the observed species richness and abundance to expectations based on regional species pools. Additional information about potential species can be gathered from literature reviews or species distribution models. Surveys should be performed during a complete year to account for seasonal-dependent variations in the structure of bird and bat communities.

Step 3: Implementing Management Actions

The nature of management actions will depend on the conservation target. If the conservation target is a single species, for example, a bird or bat species of conservation concern, then management actions will be focused on increasing habitat suitability for such a species. This includes its species-species foraging, nesting/roosting and commuting opportunities. For community-level approaches, conservation management should recognize that no single measure benefits all species due to their differing ecological needs. Priority should be given to maintaining and enhancing landscape features that support multiple species simultaneously. Before adding new habitat features, existing valuable habitats should be preserved and improved, with efforts made to connect them to adjacent areas.

Leveraging biodiversity-mediated ecosystem services requires a thorough understanding of natural history, including:

1. **Species contributions to ecosystem functions:**
   Understanding which species contribute to specific services is essential for biodiversity management. Conservation efforts should target all species involved in providing these benefits or, at a minimum, those that contribute the most and/or make it in a different, complementary way (functional complementarity).
2. **Spatial and temporal variability of ecosystem services:**
   Since the community composition of ecosystem service provides changes over time, conservation strategies aimed to benefit for biodiversity-mediated ecosystem services should adapt accordingly.
3. **Ecological factors influencing ecosystem services**:
   Identifying the environmental factors that influence the presence and activity of service-providing species is crucial for designing effective biodiversity conservation strategies. Without understanding these ecological mechanisms, efforts to enhance biodiversity and ecosystem services risk become ineffective.

Management actions (rows) and their benefits for biodiversity (foraging, roosting and commuting)

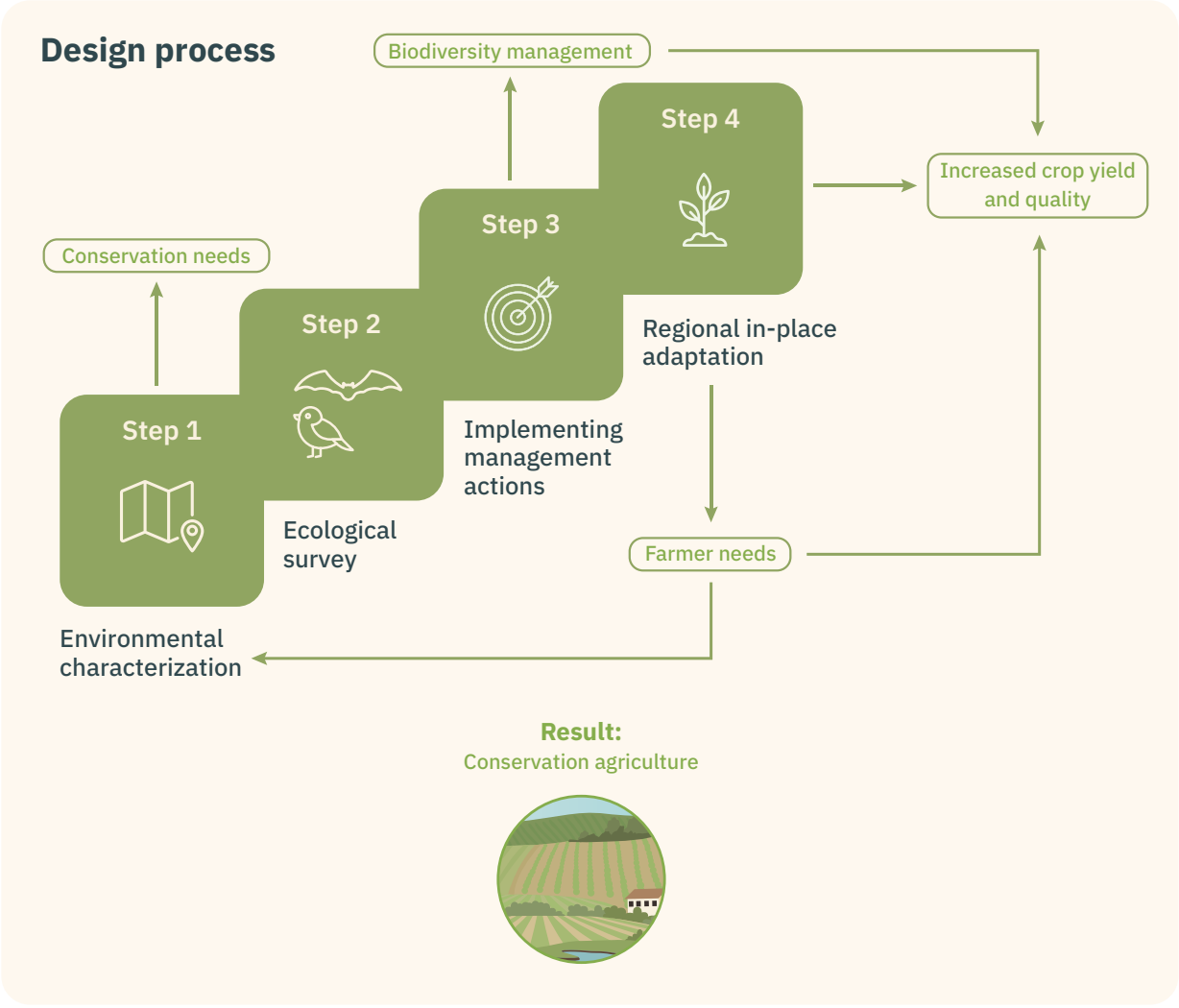
	Foraging	Nesting/Roosting	Commuting
Farm-level structural complexity			
Landscape-level structural complexity			
Inter-row vegetation			
Woody vegetation			
Ponds			
Insect hotels			
Dry stone walls			
Buildings			
Artificial refugee			
Riparian vegetation			
Hedgerows			

**Each pairwise interaction is represented with a colour that reflects its relative importance (darker blue, more importance).*

Step 4: Regional Adaptation

Adapting biodiversity conservation management actions across regions is essential because ecological conditions, species compositions, and threats to biodiversity vary significantly across different landscapes. A one-size-fits-all approach is unlikely to address the unique environmental, social, and economic contexts that influence conservation outcomes in each region. Local variations in climate, land-use patterns, habitat types, and community needs mean that effective conservation must be context-specific, aligning strategies with regional ecological realities and stakeholder priorities. By tailoring actions to local conditions, conservation efforts can more effectively support the persistence of native species, maintain ecosystem functions, and enhance the delivery of biodiversity-mediated services across diverse geographic settings.

In this fourth step, it would be valuable to emphasize that the work of ecological experts helps to define a “robot portrait”—an idealized model—of the landscape features most favorable to birds and bats. However, this vision must then be discussed and refined in consultation with farmers to ensure that any proposed actions also take into account their technical, agronomic, and land-use constraints. Effective implementation depends on this dialogue: only through consultation can we ensure that conservation measures are both ecologically sound and practically feasible. It is also worth noting that initial efforts should ideally focus on non-productive areas of the farm such as herbaceous strips, hedgerows, or ditches where ecological interventions are often more easily integrated into existing farm operations.


Design process
Biodiversity management
Step 4
Increased crop yield and quality
Step 3
Conservation needs
Step 2
Regional in-place adaptation
Step 1
Implementing management actions
Ecological survey
Farmer needs
Environmental characterization
Result:
Conservation agriculture

7 Acknowledgements

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SHOWCASE

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