BOOSTING BIODIVERSITY IN OLIVE ORCHARDS: THE BENEFITS OF ORGANIC FARMING AND GREEN INFRASTRUCTURE

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Intensive management of agricultural lands, along with the production intensification of farming systems and monocultures and combined with climate change, has degraded agroecosystems' functionality and impacted food quality and quantity (Cramer et al., 2018). The establishment of green infrastructures (GIs) or ecological infrastructure in olive orchards and other perennial crops has been suggested as a promising strategy to improve orchard biodiversity and functionality by enhancing the provision of agroecosystem services to achieve sustainability in food production (Kabourakis, 1999; MAES et al., 2018). Organic farming plays a key role in protecting the environment by promoting biodiversity and supporting green infrastructures.

WHAT IS ORGANIC FARMING AND HOW DOES IT SUPPORT BIODIVERSITY?

Unlike conventional management, organic farming prohibits the use of synthetic chemicals and promotes the application of farming methods that sustain agroecosystems by conserving/protecting agroecosystem biodiversity and enhancing biodiversity-related biological processes and agroecosystem services. By providing habitats and subsequently fostering a variety of plants, animals and microorganisms, organic farms create balanced habitats that enhance biodiversity and soil health, leading to pest control and increased pollination. GI (including hedgerows, stone and water refugia and cover crops) further support biodiversity while managing water and soil resources. Together, these practices build resilient farming systems that not only produce high-quality food but also contribute to mitigating the negative effects of climate change, facilitating crop adaptation and long-term sustainability. Organic farms often have more diverse plant species, which attract a variety of insects, birds and other wildlife (Solomou and Sfougaris, 2021). The absence of harmful synthetic chemicals also means fewer threats to beneficial organisms, such as soil microbial flora and fauna, pollinators and predators and parasitoids of olive tree pests. Examples of increased biodiversity include multiple crop varieties (not just monocultures); pollinators such as bees and butterflies; predators, parasitoids and decomposers such as ladybugs (natural pest control), and ants, birds and small mammals in hedgerows and grassy strips.

WHY DOES BIODIVERSITY MATTER IN FARMING, AND HOW CAN IT BE ENHANCED?

Greater biodiversity makes olive orchards more resilient to pests, diseases and climate change. It reduces the need for synthetic chemical inputs and helps maintain long-term productivity and agroecosystem health. Farming practices that enhance biodiversity include the use of:

- crop rotation,
- mixed cropping and intercropping,
- native vegetation biotopes, hedgerows spontaneous flora field margins and flowering plant strips,
- minimal tillage,
- proper tree canopy and pruning residue management,
- optimal irrigation and plant protection management,
- ecological nutrient and fertiliser management.

WHAT IS FUNCTIONAL BIODIVERSITY IN AN OLIVE ORCHARD?

Functional biodiversity is biodiversity that offers several benefits to humans and the environment, including several flora and fauna species related to the provision of agroecosystem services. Examples of fauna species are arthropods of several taxa. Important examples are Hymenoptera species that are parasitoids (*Psytallia concolor*) or predators (ants and lacewings) of the olive fruit fly (*Bactrocera oleae*), the main pest of olive trees in the Mediterranean area (Figure 1).

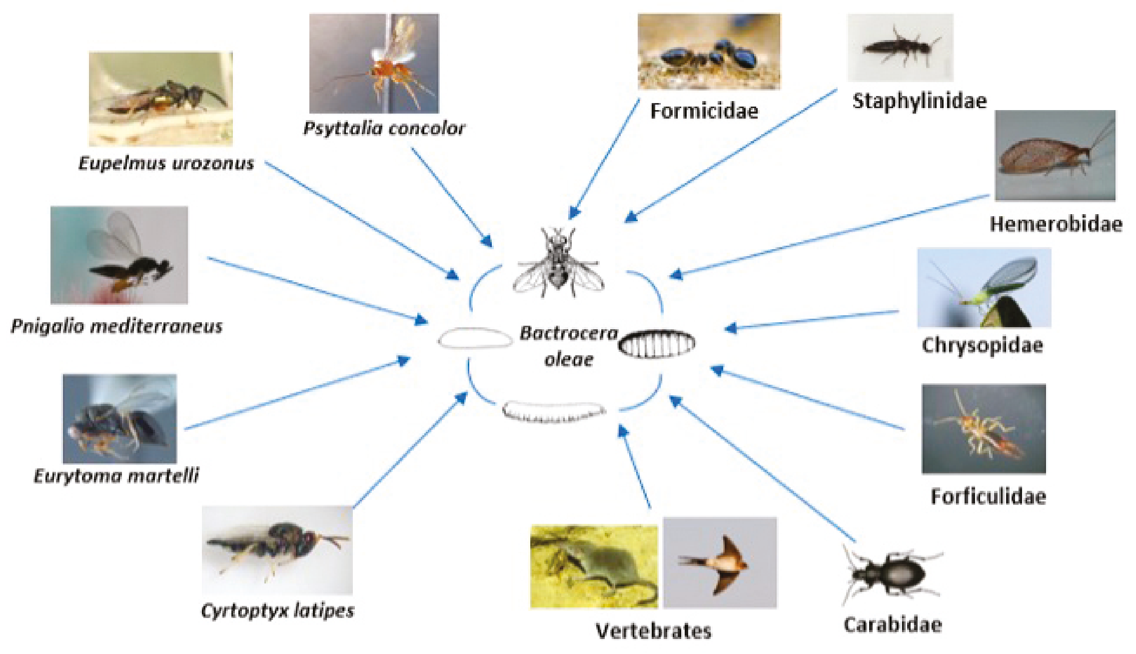
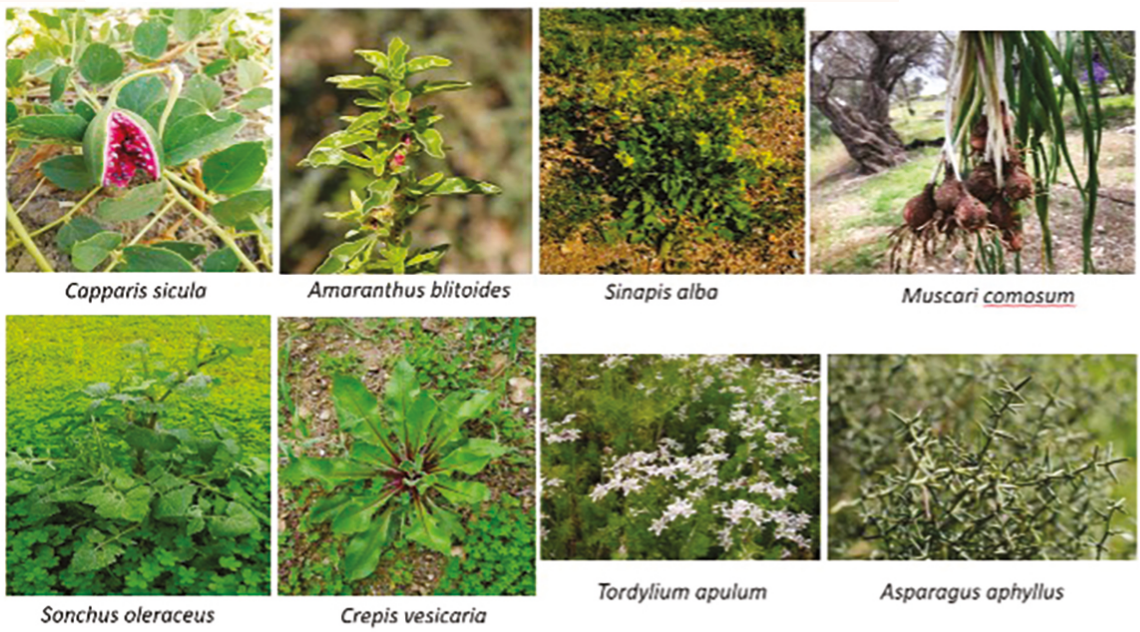


Figure 1. Predators and parasitoids of the olive fruit fly supported by green infrastructure (source: LOVAPS lab – HMU).

Other arthropods, such as Coleoptera (beetles), also serve several important biological processes, such as predation and decomposition. Butterflies (Lepidoptera) serve the important service of pollination. Other fauna species, such as birds, reptiles and mammals, can be important regulators of agroecosystem functions as well as facilitators of biological pests and disease control by predating on several enemies of the olive tree. Examples of mammals that have been found in the LIFE IGIC project are several species of shrews, badger and hedgehog. Several species of legumes (family: Fabaceae) grow natively in olive orchards in the project; they can significantly improve soil fertility. There are also plant species that attract large numbers of pollinator species (families: Apiaceae, Asteraceae) and species related to soil structure improvement (Families: Poaceae, Fabaceae). Moreover, species related to food provision (edible species) are important for providing agroecosystem services.

HOW DO GREEN INFRASTRUCTURES SUPPORT FUNCTIONAL BIODIVERSITY IN AGRICULTURAL SYSTEMS?

Green infrastructures (GIs) are defined as 'a strategically planned network of natural and semi-natural areas, with other environmental features, designed and managed to deliver a wide range of ecosystem services' (European Commission, 2013). In agricultural systems, particularly in olive orchards, GIs include elements such as hedgerows, ponds, stone and brush refuges, cover crops, agroforestry and buffer strips. These components help manage water, soil, and biodiversity (Figure 2, Figure 3) while supporting sustainable production.



(photo: LOVAPS lab – HMU)

Figure 2. Edible olive orchard flora

(photo: LOVAPS lab – HMU)

Figure 3. Fauna diversity supported by green infrastructure in olive orchards

(photo: E. Kabourakis, LOVAPS lab – HMU)

Figure 4. Green infrastructure elements

By enhancing functional biodiversity, GIs improve several agroecosystem services. They reduce erosion and runoff, improve soil fertility and structure, support pollination and promote natural pest control. Planting aromatic, medicinal and fruiting shrubs and trees provides food and shelter for beneficial insects, birds, reptiles and small mammals, many of which contribute to pest regulation, including predators of the olive fruit fly (*Bactrocera oleae*).

GIs also enhance belowground biodiversity, including soil invertebrates and microorganisms that drive key processes such as assimilation, nitrification and decomposition, essential for tree nutrition and long-term soil health. These improvements contribute to greater resilience to climate change and environmental stress.

Beyond ecological functions, GIs support the production of high-quality olives and additional resources such as wild herbs and contribute to rural development through landscape enhancement and agrotourism. When integrated with sustainable practices, they represent a multifunctional strategy to improve the environmental and economic sustainability of Mediterranean olive farming.

WHICH GREEN INFRASTRUCTURES CAN BE IMPLEMENTED IN PERENNIAL CROPS, AND WHAT ARE THEIR MAIN IMPACTS?

As mentioned above, GIs in agroecosystems can take the form of plantations of perennials, medicinals, aromatics and fruit-bearing shrubs and trees, brush piles (wooden branches), stone elements and artificial water ponds (Figure 4).

Among all these green infrastructures, some are particularly well suited to perennial crops:

- **Cover crops**: improve soil fertility, prevent erosion, suppress weeds and attract pollinators and beneficial insects. Examples include legumes (e.g., clover, vetch), grasses (e.g., rye, barley) and wildflowers.
- **Hedgerows and windbreaks**: provide habitats for birds/insects, reduce wind erosion and act as buffers. Examples include native shrubs, aromatic herbs (such as rosemary), or nitrogen-fixing trees (such as tree medick, carob or acacia).
- **Bioswales and infiltration trenches**: capture runoff, increase groundwater recharge and reduce erosion. One example is shallow vegetated ditches between rows or at field edges.
- **Pollinator strips/windflower borders**: support pollinators and beneficial insects. They should be placed along borders, paths or between rows or flat edges.
- **Agroforestry and intercropping**: serve the purpose of generating diversity and improving soil microclimate. Examples include lavender or thyme (inter)planted in olive orchards.
- **Insectary habitats/beetle banks**: encourage natural pest control agents such as ladybugs, lacewings and ground beetles, as well as hymenopteran parasitoids. In practice, they can be grassy or herbaceous plant strips between fields or specially built shelters for bees, bats and other species.
- **Tree islands or scattered native trees**: provide shade, promote biodiversity and wind protection. A recommendation is to use drought-tolerant natives such as cypress, holm oak or Mediterranean pine.

HOW SHOULD GREEN INFRASTRUCTURES BE ESTABLISHED IN OLIVE ORCHARDS?

Some technical details for establishing GIs in olive orchards are suggested below. It is important to consider that the technical details should be adjusted for each area and each olive orchard, as differences in climatic conditions and landscape morphology can impact the effectiveness of the established GIs. A Decision Support Tool (DST) support to evaluate green infrastructure in olive orchards, available at https://lovaps.hmu.gr/apps/green-report/index/, and a short demonstration video (https://www.youtube.com/watch?v=IvGDESfrsmI) have been created in the context of the LIFE IGIC project.

Regarding GI elements:

- Suggested number: 100–400 aromatics/ha or 30–100 trees/ha or a combination of both, 5 brush piles/ha, (minimum 2/ha), 5 stone elements/ha (minimum 2/ha), 2 water ponds/ha (minimum 1/ha)
- Location and construction: olive orchard margins, to avoid hindering farming processes. Stone elements should be meshed to avoid element destruction through human intervention. Water ponds should be close to irrigation systems for easier refilling and cleaning of the pond, and preferably under the canopy of olive trees to avoid water evaporation.

Regarding sustainable farming practices:

- Olive tree canopy management: shredding and incorporation of pruning residues.
- Soil, spontaneous vegetation and field margin management: mowing and minimal tillage, use of green manures, soil covers and cover crops, uncultivated hedge strips of spontaneous flora and GI plantations.
- Nutrient and fertiliser management: rational use and minimisation of synthetic chemical inputs. Use of organic fertilisers.
- Irrigation water management: efficient and economical irrigation methods according to the olive tree and soil requirements.

ADDITIONAL MATERIAL

- Green Infrastructure in olive orchards: www.lifeigic.eu, https://www.youtube.com/watch?v=IvGDESfrsmI, https://www.facebook.com/lifeigic/
- Decision Support Tool for assessing green infrastructure in olive orchards: https://lovaps.hmu.gr/apps/green-report/index/
- Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J., Iglesias, A., Lange, M. A., Lionello, P., Llasat, M. C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M. N., & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. Nature Climate Change, 8(11), 972–980. https://doi.org/10.1038/s41558-018-0299-
- EC, 2013. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Green Infrastructure (GI) — Enhancing Europe's Natural Capital /* COM/2013/0249 final */ Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52013DC0249
- Bogka G., N. Volakakis, D. Kollaros, B. A. Pannebakker, N. Fatouros, and E. Kabourakis. 2021. Comparing olive fruit fly (Bactrocera oleae) density, fruit damage levels and parasitism rates in organic and conventional olive orchards in Crete, Greece. IOBC-WPRS Bulletin Vol. 158, 2022 pp. 7-11
- Gkisakis, V. D., Volakakis, N., Kollaros, D., Bàrberi, P. & Kabourakis, E. M. 2016. Soil arthropod community in the olive agroecosystem: Determined by environment and farming practices in different management systems and agroecological zones. *Agriculture, Ecosystems and Environment*, 218: 178–189.
- Georgopoulou, E., Gkisakis, V., Kabourakis E. M. 2022. Local land snail assemblages of olive orchards in Crete, Greece. Diversity, 14(7), 565. https://doi.org/10.3390/d14070565.
- Kabourakis, E. 1999. Code of practices for ecological olive production systems. Olivae 77:46-55
- Solomou, A., Sfougaris, A. Comparing conventional and organic olive groves in central Greece: plant and bird diversity and abundance. Renewable Agriculture and Food Systems. 2011;26(4):297-316. doi:10.1017/S1742170511000111

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