The power of flowers in agricultural landscapes

Landscape simplification is undermining the valuable role that natural ecosystems can play. Insect physiologist Lucy Alford explains how we can use biodiversity to restore their attributes

Lucy Alford

EXAM LINKS

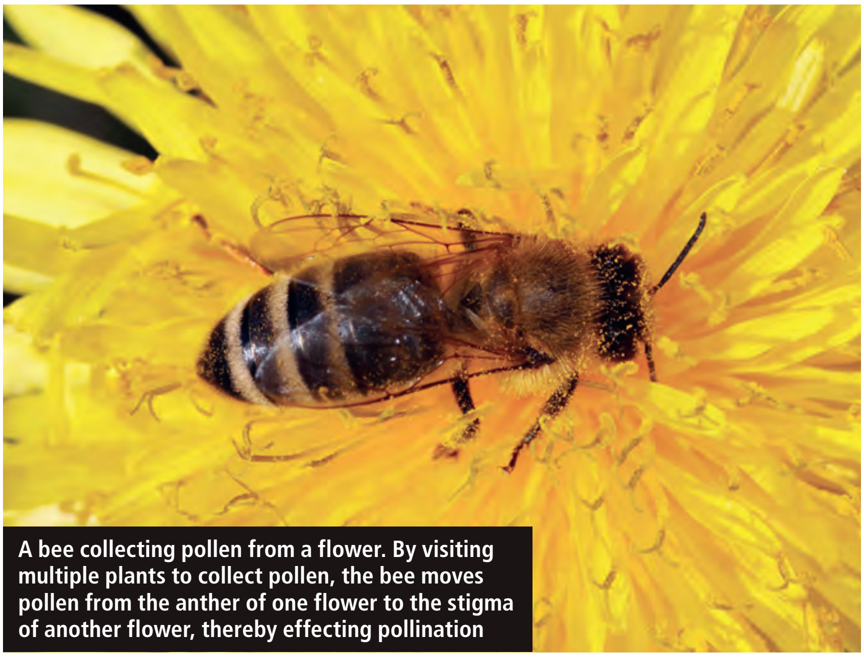
AQA Biodiversity within a community; Populations in ecosystems
OCR A Biodiversity; Populations and sustainability
OCR B Photosynthesis, food production and management of the environment
Pearson Edexcel A On the wild side
Pearson Edexcel B Biodiversity; Human effects on ecosystems
WJEC/Eduqas Human impact on the environment

Humans have been greatly simplifying ecosystems on a global scale for many centuries. Whether this involves clearing tropical rainforests for palm oil plantations or the removal of British woodlands in favour of cereal **monocultures**, humans have been changing landscapes for centuries. With a current world population of over 7.7 billion, including 67 million people in the UK alone, devoting land to agriculture is inevitable if we are to meet the ever-growing needs of humanity for food and fuel. However, **landscape simplification** removes biodiversity from ecosystems, undermining their complexity and stability, and the valuable services they provide.

What is an ecosystem service?

An **ecosystem service** is defined as any benefit that we can derive directly from the natural environment for free. These benefits come in many different forms, but are commonly categorised under four headings.

- **Provisioning services** comprise all the products that we can obtain directly from the ecosystem. These include food, raw materials such as wood, fresh water, medicinal resources and energy. It is relatively easy to assign monetary value to provisioning services as they normally have a market value.
- **Regulatory services** are the benefits obtained from the regulation of ecosystem processes, including climate regulation, purification of water and air, carbon sequestration, waste decomposition and detoxification, pollination, and pest and disease control.
- **Cultural services** are those that enrich human lives. These are mainly non-material benefits and include spiritual, historical, recreational, educational and therapeutic benefits.



A bee collecting pollen from a flower. By visiting multiple plants to collect pollen, the bee moves pollen from the anther of one flower to the stigma of another flower, thereby effecting pollination

- **Supporting services** are the processes essential for continued ecosystem functioning and the provisioning of ecosystem services. Examples include soil formation, nutrient cycling, primary production and habitat provision.

With so many ecosystem services being non-material, it is understandably difficult to assign a monetary value to their benefits to humans. However, in 1997, Professor Robert Costanza and colleagues estimated the value of ecosystem services to humans to be $33 trillion per year. That is the amount it would cost humans to replace the services if the ecosystems of our world were unable to perform these services.

Agricultural intensification and the loss of ecosystem services

Agriculture provides us with crops for food, fodder and bioenergy, as well as botanicals for cosmetic and medicinal purposes. Within the last century, agricultural intensification across Europe has increased agricultural productivity. Unfortunately, this intensification has also resulted in the simplification of the landscape, with increased field sizes, a preponderance of large monocultures, a reduction in semi-natural habitats, habitat fragmentation, and a loss of biodiversity. As the landscape becomes increasingly simplified, the ecosystem cannot function optimally and valuable ecosystem services become disrupted and degraded. These include nutrient and water cycling, soil formation, pollination and biological control (the natural reduction in a pest population by a predator, parasite or pathogen).

To compensate for this reduction in ecosystem services, chemical inputs such as fertilisers, insecticides and herbicides are required to fertilise the soil, or control crop pests. This leads to further disruption and degradation of the agricultural ecosystem and the result is intensive farming systems that are highly dependent on chemical inputs.

The importance of invertebrates

Invertebrates, including insects, provide many beneficial ecosystem services to agricultural systems, including pollination, soil aeration, waste decomposition and biological control. Insect pollinators are necessary for an estimated 35% of global food production. The pollination of agricultural crops by the honeybee alone is believed to be worth $117 billion per year globally. Insects are therefore critical to the success of our agricultural systems. Alarmingly, however, many insects are being lost from our agricultural systems. An estimated third of British wild bees are in decline, with some species having experienced population declines greater than 50% in the last 30 years.

A similar story is reported for butterflies. In English farmlands, butterflies are reported to have declined by 58% between 2000 and 2009, with agricultural intensification, habitat loss and use of chemical insecticides being primary causes. In response to mounting evidence on the dangers of chemical insecticides to beneficial invertebrates in 2018, the European Union put a ban on the outside use of one of the main classes of insecticides, the neonicotinoids (see Box 1).

Box 1 Neonicotinoid pesticides

Neonicotinoids are a class of insecticides that affect the central nervous system of insects. They bind to receptors in the nerve synapse (receptors for the neurotransmitter acetylcholine), disrupting excitation of the nerves and eventually leading to insect paralysis and death. These receptors are more sensitive in bees than in other insects, making bees particularly vulnerable to neonicotinoid insecticides.

Since their introduction in the 1990s, neonicotinoids initially gained popularity due to their believed low toxicity to birds and mammals, as well as to many beneficial insects such as bees. By 2009, the global neonicotinoid market was worth $2.63 billion and accounted for one-quarter of the global insecticide market. However, thanks to ecological research and species monitoring, neonicotinoids are now known to be a primary cause of the widespread decline of insects, aquatic invertebrates and insect-eating birds. In 2018, the European Union placed a total ban on neonicotinoid insecticide use with the exception of confined use within closed greenhouses.

TERMS EXPLAINED

Ecosystem service The benefits we obtain from ecosystems. There are four main categories: provisioning services, regulatory services, cultural services and supporting services.

Field margin The area of land surrounding a field – the space between the crop and the field boundary.

Granivore Animals that feed on grain/seeds.

Landscape simplification The reduction in diversity of land cover and increasing landscape patch size.

Monoculture An area of farmland where only one crop is grown or one species of animal is kept.

Trophic level A group of organisms that occupy the same level in the food chain. These levels include primary producers, primary consumers, secondary consumers, third level consumers and apex predators.

Restoring ecosystem services to agricultural systems

With recent declines in beneficial insects such as those reported for wild bees and butterflies, in conjunction with the 2018 ban on neonicotinoids, scientists are looking for ways to restore the valuable ecosystem services provided by insects and other invertebrates back into agricultural systems and ultimately ensure the sustainability of agriculture into the future.

One possible method involves maintaining a high level of plant diversity, since diverse plant communities are commonly associated with diversity at higher **trophic levels** and enhanced stability against environmental and human-induced stressors. This is because an increased variety of plant species (primary producers) can support a greater diversity and number of primary consumers (e.g. herbivorous and **granivorous** insects, rodents and birds). This in turn supports a greater diversity and number of secondary consumers (e.g. insectivorous birds, frogs and snakes), all the way to the apex predators at the top of the food chain.

Functional redundancy

When an ecosystem has high diversity throughout all levels of the food web, the ecosystem becomes increasingly stable. This is because similar taxonomic groups perform similar roles in the functioning of the ecosystem. In ecology, this is referred to as functional redundancy. We can essentially think of similar taxonomic groups as substitutes for each other. If one taxonomic group fails, another group takes over the role. Having high diversity and thus functional redundancy in the ecosystem therefore increases the stability of an ecosystem since it increases the likelihood of a particular function continuing in the event of a disaster.

Box 2 Insects for sale

Did you know that farmers can bulk-buy beneficial insects to release into their fields and greenhouses? This artificially boosts the beneficial ecosystem services provided by insects, particularly in agricultural systems where these services may have been degraded.

Companies such as Biobest are specialists in the mass-rearing of beneficial insects. Bumblebees, for example, are pollinators of many important crops, including tomatoes, peppers, aubergines and cucumbers. A farmer can purchase a box of bumblebees to release into their fields or greenhouses to help pollinate their crops. As well as pollinating insects, a farmer may also purchase insects to help with the biological control of pest insects. Ladybirds such as the two-spotted ladybird are natural predators of aphid pests, such as greenfly. Artificially releasing large numbers of ladybirds into fields and greenhouses helps to reduce aphid pests and protect the farmer's crop from aphid damage.

As an example, imagine a plant pollinated by only one species of bee. If the bee population is wiped out by a disease, the plant loses its pollinator, so cannot reproduce. This would have serious implications for the herbivorous animals that feed on this plant, and suddenly the entire ecosystem is in danger of collapse.

In contrast, now imagine an ecosystem where the same plant can be pollinated by several species of bees, hoverflies, butterflies, beetles, rodents and birds. If a disease wipes out only one species of bee, we will lose that species of bee from the ecosystem but not the function of pollination from the ecosystem. This is because the other species of bees, as well as the other pollinating species, continue to pollinate the plant, enabling the ecosystem to continue functioning in the absence of that one species of bee. Intensive farming (and any human activity that removes and/or simplifies natural habitats) removes functional redundancy from ecosystems.

Role of plants

Since increasing plant diversity can help to restore diversity and functional redundancy at higher trophic levels throughout the ecosystem, plants represent an important tool to help us reintroduce diversity and function back into degraded ecosystems and ultimately restore ecosystem services. Flowering plants are particularly important in agricultural ecosystems. This is because the

A flower strip, comprising poppies and cornflowers, sown alongside the farmer's crop field

Exam-style questions

Use information from this article and your own knowledge to answer the following questions.

1 (a) Neonicotinoids bind to acetylcholine receptors in synapses. Explain the effect of neonicotinoids on the neurones of bees. [4 marks]

(b) Explain why bees are particularly susceptible to neonicotinoids. [1 mark]

2 Explain why diverse plant communities are commonly associated with diversity at higher trophic levels. [3 marks]

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nectar of flowering plants provides a food source to many important insects, as well as providing insects with shelter, nesting and over-wintering sites.

Strips of land containing mixtures of flowering plants are commonly used in agricultural landscapes. They increase plant diversity using marginal land (**field margins**), thus providing minimal disruption to the farmer and harvest crop. Flowering plants may also be used to provide winter cover to bare fields following the harvest of the main crop. Examples of winter cover crops include radish, mustard, field beans, phacelia, clover and buckwheat. Here, the benefits are twofold: winter-cover crops offer shelter and a winter food source to insects in harsh winter months when food is otherwise scarce. They also help fertilise the soil and prevent erosion of what would otherwise be bare, exposed soil.

Supporting winter populations of insects through winter-cover crops also helps to boost spring populations of beneficial insects, such as predators that predate pest insects and naturally reduce pest population sizes. This is particularly beneficial in the spring, when crops are young seedlings and more vulnerable to pest attack. Ultimately, flowering plants can encourage and support the persistence of beneficial insects in agricultural landscapes, and with them, the beneficial ecosystem services these valuable insects provide. Increased insect biodiversity also has positive impacts on the wider ecosystem, providing a food source to carnivorous arthropods and insectivorous birds, further increasing the biodiversity (and functional redundancy) throughout the entire ecosystem.

Companies such as Biobest mass-rear beneficial insects. Here a farmer has purchased a box containing a bee hive, most probably *Bombus terrestris*, for release in their greenhouse to help pollinate their tomato crop

A ladybird eating aphids from a plant stem. It is estimated that an adult ladybird can eat up to 50 aphids per day

Points for discussion

- Farmers may sow flowering plants in their empty fields during winter. This is beneficial to many important insects because it provides a food source during the harsh winter months when food may otherwise be scarce. For what other reasons might it be beneficial to the farmer (and the ecosystem) to cover bare soil during winter?
- Farmers can buy beneficial insects to release into their fields and greenhouses (see Box 2). What factors do you think should be considered when artificially releasing an insect into an ecosystem?

KEY POINTS

- Ecosystem services are benefits that we obtain from ecosystems for free.
- Landscape simplification is removing biodiversity from ecosystems and undermining the valuable ecosystem services they provide.
- Insects, in particular, have declined in recent years as a consequence of agricultural intensification, habitat loss and the use of chemical insecticides. This in turn has had consequences for the valuable ecosystem services insects perform, including pollination and biological control.
- Using flowering plants to reinstate plant diversity in agricultural landscapes encourages beneficial insects and helps restore the valuable ecosystem services of pollination and biological control.

Dr Lucy Alford is a zoologist and insect physiologist from the Université de Rennes 1 in France. Lucy is particularly interested in identifying and developing greener and more environmentally friendly ways of controlling pest insect populations.