Pollinators need more habitats

How to promote biological diversity using *land in hand*

Innovation Naturhaushalt

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1. *Land in hand* – a precious asset

The decline in animal and plant species is clearly noticeable. Blooming meadows, colourful butterflies and various types of birds have become rather scarce in many parts of our cultivated landscape. In summertime, beekeepers have to deal with less diversity of flowering forage than they were used to in the past.

A good solution: partially mowed strip alongside a road!

Motorway intersection surrounded by agricultural land

There are multiple reasons for this, including the intensification of farming, loss of natural habitats, expansion of transport infrastructure, and land consumption for residential purposes.

Preserving animal and plant habitats is vitally important, but habitat resources as part of the agricultural landscape are getting ever scarcer. While in the past agriculture was first and foremost about supplying food, today it also provides a significant contribution to energy supplies. In addition, farmers are increasingly required to meet nature conservation objectives. In Germany, every single day a piece of land of more than 100 football fields in size is sealed for building residential homes or transport infrastructure. This is why we have to carefully consider and specifically plan the use of existing land resources in the best possible way to protect and promote biological diversity. To do so without compromising our high level of productivity and quality we need the support of society as a whole. Such consideration will raise the importance of fallow land, residential areas and marginal land because only trying to preserve biodiversity in designated conservation areas would certainly be the wrong approach. A wide range of organisms provide "ecological services" such as soil fertility, pest control or pollination, and therefore play a key role not only in terms of nature conservation.

This study will present largely unexplored ways of how to promote biodiversity of insects and flowering plants, centring around the question whether it is possible to ecologically enhance specific existing areas, referred to as *land in hand*, to make them benefit animals and plants, in particular flowers and pollinating insects.

The answer is a clear yes; it is possible to do so without interfering with agricultural production or other forms of agricultural land use. This study will thus focus on areas that already exist in many places and can provide an essential contribution to promoting biological diversity of our cultivated landscape.

What do we mean by *land in hand*?

Land in hand refers to areas which are there anyway, but usually go largely unnoticed. In general, these are small-scale areas, not specifically used for agricultural or conservation purposes, which can be found everywhere: slopes, roadside verges, motorway or railway embankments, public areas in towns and villages, dams along water bodies – just to name a few examples.

Varying from one region to another, these areas account for a significant share of our agricultural landscape.

Depending on its properties, *land in hand* is home to a wide range of different animals and plants and offers various possibilities for ecological enhancement.

What are the characteristics of *land in hand* ?

- *Land in hand* is land influenced by humans.
- It consists of either compact small-scale areas (such as municipal grassland, green patches between roads) or narrow longitudinal strips (for example alongside transport routes).
- Compact small-scale areas are usually isolated; narrow longitudinal strips can serve as corridors.
- *Land in hand* can be a network of separate areas within an agricultural landscape.
- Due to its close proximity to agricultural land or residential areas, there is direct interaction with measures implemented in both areas.

Which resources does *land in hand* provide for pollinators, in particular for bees?

The drastic decline of pollinating insects, frequently referred to as a "pollinator crisis", can be attributed mainly to a lack of resources, in other words a lack of flowers and habitats. The situation is different for wild bees than it is for honeybees. Honeybees are managed by beekeepers, whereas wild bees are not; wild bees do not produce honey, but their pollination services are equally important for wild plants and crops with a view to nature conservation and agricultural aspects respectively.

What are the possibilities and what are the limitations of *land in hand* being used specifically for implementing measures to benefit flowering plants and pollinators? Habitats colonised by bees also benefit other pollinators. Abundant floral resources, diversity of the landscape and small structures are not only beneficial to bees, but also to butterflies and other insects. This is exactly what *land in hand* can provide.

Traffic island with a variety of flowers

Railroad embankment with abundant vegetation

Wild bee (apex-furrowed bee):
It looks different from honeybees and carries the pollen at different positions on its body.

2. Major groups of pollinating insects

Pollen grains stuck to a honeybee's branched hairs

Conifer tree pollen carried by the wind, without the need for insects

Pollination is one of the most successful symbioses ever crafted by evolution

It is a win-win situation for both groups of organisms involved: pollinators find food (nectar and pollen), and in return flowers profit from pollen being transferred from one flower to another. For the evolutionary much older form of pollination – which is wind pollination – it takes a lot more pollen grains for one of them to be placed on the ovary of a plant of the same species.

Nevertheless, wind pollination plays a significant role: grasses, ferns and mosses still use it, and some crops such as the various types of grains and maize are wind-pollinated as well. Whenever you see a beautiful flower, remember that its blaze of colours is not intended to delight people, but rather to send a message to insects telling them: "Come here to get your food!"

Honeybee with pollen stored in the "pollen basket" on its hind leg

Colourful bee beetle feeding on pollen; its larvae develop in bees' nests

Gossamer-winged butterfly covered with pollen

Red Admiral, to be found in many gardens

Striking bee chafer beetle visiting flowers

In Europe, only insects play an essential role in pollination, whereas in the tropics birds and even bats also have a role. In this context, the following groups of insects are worth taking a closer look at:

Beetles

A considerable number of beetles generally visit flowers to feed on pollen for their protein supply. Unlike bees they do not have special structures on their bodies to collect pollen and nectar and they do not travel from one flower to another that quickly. This is why beetles are in fact flower visitors, but the benefit usually lies with the insect (feeding on pollen), rather than with the plant (transfer of pollen from one flower to another).

Butterflies

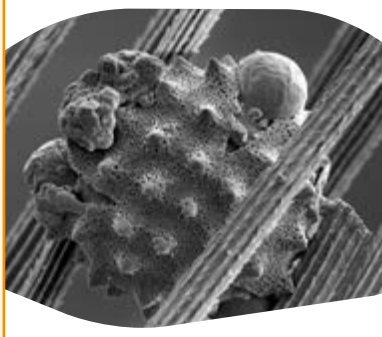
Butterflies mostly feed on nectar, while caterpillars feed on plants. While both stages of development rely on plants, butterflies and caterpillars usually live on and off different plant species.

It is quite common for many butterfly species to migrate over long distances. In Europe, there are so-called "transcontinental migrants", such as the Painted Lady (*Vanessa cardui*), which migrates from the Mediterranean all the way to Scandinavia before returning in the next generation. Other species (for example many gossamer-winged butterflies, *Lycaenidae family*) limit their habitat to a single meadow without showing any tendency to leave this area. *Land in hand* offers butterflies and other pollinators plants and flowers, and can therefore provide vital resources to caterpillars and adult butterflies alike. It can function as blooming "filling stations" for long-distance migrants during their migratory journey, as habitats for stationary species populations, or as corridors for species migrating short distances. This is also how butterflies carry pollen from one flower to another. There is clear evidence of the general decline of butterflies in cultivated landscapes. Some of them are synanthropic species, such as the peacock butterfly (*Inachis io*), the small tortoiseshell (*Vanessa urticae*) or the Red Admiral (*Vanessa atalanta*), whose caterpillars live on stinging nettles. *Land in hand* plays a key role when it comes to supplying forage for caterpillars.

Flies

A number of flies, for example various hoverflies, visit flowers mainly to pick up nectar, and sometimes also to feed on pollen. Pollinators primarily include members of the flower flies (*Anthomyiidae family*) and the hoverflies (*Syrphidae family*), but other groups of flies also perform pollination services.

Today, flies (green bottle flies, *Lucilia caesar*) are even commercially available as pollinators, which is an indicator of their relevance for pollination. Although flies may not be particularly popular, we should not underestimate their pollination services; they are in fact rich in species and individuals and they can quickly travel from one flower to another. Their larvae (maggots) live in different habitats, many of them feed on living or dead plants. Some hoverfly larvae eat aphids and are vital beneficial organisms in agriculture.

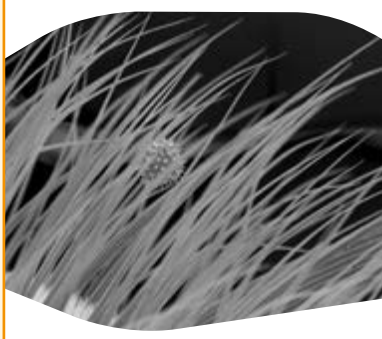


Pollen caught in the hairs of a butterfly's body

Flower flies are less noticeable as blossom visitors

Many hoverflies are similar to bees or wasps

Green bottle fly on an apple blossom



Pollen grains can also get caught by the smooth hairs of flies

Hymenoptera

The Hymenoptera order is very rich in species and includes a variety of groups such as ants, social wasps, ichneumon wasps and spider wasps. Amongst them, bees (*Apidae*) are particularly important for pollination services. There are approximately 20,000 to 30,000 bee species worldwide; about 2,100 in Europe and about 550 in Germany. Bees are dietary specialists – they feed on nectar and pollen, as do their larvae. Many of them are anatomically adapted to this mode of life: they have pollen-collecting apparatus on their legs, dense hair (referred to as scopa) for gathering pollen, or a honey stomach for storing nectar.

In the German language a distinction is made between honeybees ("bees" in general) and "wild bees", with the latter often being divided into "solitary bees" (living on their own or in small numbers), and "bumblebees" (having a plump, hairy body and establishing annual colonies). Although this distinction does not correspond to scientific classifications, it will be maintained for the purpose of this study to facilitate characterisation of the individual groups.

Honeybee

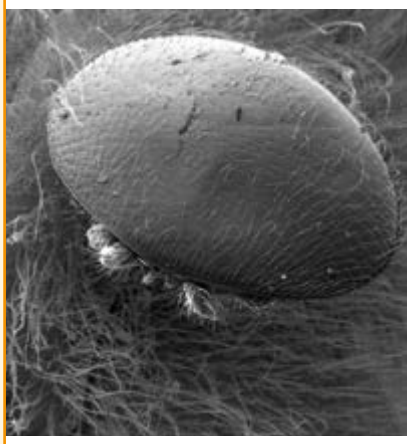
The bee colony is well taken care of by the beekeeper

Honeybees

The honeybee (*Apis mellifera*) is an insect that used to live in the wild in Europe. Today all honeybees are managed by beekeepers. "Wild" colonies and feral swarms are considered not very viable, primarily due to the parasitic mite *Varroa destructor*. Bee colonies are looked after by beekeepers, which sets them apart from all other pollinators. As a result, honeybee larvae do not depend on habitats in the wild.

Honeybees forage on a wide range of wild and cultivated plants. They are well-known for their skills such as their extraordinary ability to learn: once a honeybee realises that a certain type of flower – for instance dandelion – provides abundant food it will travel from one dandelion to the next and pretty much ignore daisies, which supports transfer of pollen between flowers of the same species. In doing so, they can adapt to the pollen and nectar sources of specific plant species without spending a lot of time on searching for the flower's honey glands ("flower constancy"). Honeybees are also famous for their outstanding communication abilities (dance language).

Honeybees establish perennial colonies with one female, the queen, which mates with several drones and can lay up to 1,500 eggs per day. In springtime, a honeybee colony consists of one queen, several hundred drones (reproductive males) and up to 40,000 workers (sterile females) performing different jobs throughout their lifetime: housekeeping, taking care of the brood, producing wax and foraging for nectar and pollen.



Honeybee's hair with a Varroa mite, greatly enlarged

Bumblebee collecting pollen

Comfrey is a typical "bumblebee flower"

The tawny mining bee likes visiting berry bushes

Bumblebees

In Germany, there are about 40 bumblebee species, living in annual colonies. Mated females overwinter and establish a new colony in the following year.

The pollination behaviour of bumblebees is somewhat special. They perform what is known as buzz pollination by vibrating their body to shake pollen loose from the flower. Some flowers, such as comfrey, have their honey glands hidden deeply in the calyx. It takes a bumblebee's long mandibles to reach these glands, which led to them being named "bumblebee flowers".

Solitary bees

Solitary bees either live on their own or in small numbers, but do not form true colonies with a proper division of labour. Sometimes, however, cooperation exists, for instance between several females building a nest. Usually, the pupae overwinter before the bees hatch in the following year. Low reproduction rates are typical of many solitary bees as they only lay a few eggs. What is characteristic of solitary bees is their selective choice of forage plants. In extreme cases, they will only visit one single plant species to gather pollen and nectar.

All three groups of Hymenoptera have one thing in common: foraging, nest-building and taking care of the brood are the sole responsibility of females; males do not participate in parental care.

SCHEMATIC OVERVIEW OF INSECT POLLINATION

	Beetles	Butterflies	Flies	Bees
Flowers required for adult insects	+	++	+	++
Living plants provide food for larvae	(+)	++	(+)	++
Relevance for nature conservation	(+)	++		++
Economic relevance for agriculture			(+)	++
Documented decline	+	++		++
Possible habitat protection measures on *land in hand*		+		++

What does this mean for the four groups of insects with a view to *land in hand*?

- The main focus is on bees due to their economic relevance and their strong dependence on habitats and flowering plants.
- *Land in hand* can supply nectar for butterfly caterpillars in the form of suitable forage plants or "butterfly flowers".
- Larvae of flower-visiting beetles and flies normally do not colonise *land in hand*. But, generally speaking, flowers visited by bees also provide a source of nectar and pollen for beetles and flies.

The focus of this study is therefore on bees because they are equally important for nature conservation, beekeeping and agriculture alike. This is why they are considered indicators for a substantial part of biological diversity. Butterflies and beetles would be worth a separate study.

SCHEMATIC OVERVIEW OF THE MAIN ECOLOGICAL CHARACTERISTICS OF BEES

	Mode of life	Numer of species in Germany	Economic relevance	Individuals per colony or population	Flight period	Special habitat requirements	Special forage plants
Honeybees	Perennial colonies with distinctive division of labour	1	Bee products (honey, wax); pollination of wild and cultivated plants; hobby	Up to 40,000 per colony in early spring	Throughout the year during the flowering period	Hardly selective, determined by the beekeeper	Hardly selective, determined by the beekeeper
Bumblebees	Annual colonies	about 40	Pollination of greenhouse crops; pollination of wild and cultivated plants	30–600 per colony	Throughout the year during the flowering period	Hardly selective, colonies usually underground (clearance cairns, mouse holes etc.)	Partially selective, "bumblebee flowers"
Solitary bees	Individually or in small numbers	about 550	Pollination of wild and cultivated plants	Often few individuals per population; colonies with > 100 individuals	Often only a few weeks a year	Sometimes very selective require-ments concerning soil profile and soil conditions	Varying; sometimes highly selective

3. Bee habitats on *land in hand*

Habitats on *land in hand* are attractive to bees for three main reasons: their need for flowers and nesting sites as well as the availability of structural elements in these areas.

Crocus – providing first forage for bees after winter

Need for flowers

The need for flowers does not only define the amount of floral resources required (nectar, pollen), but also the species and diversity of flowering plants and the seasonal distribution of flowering periods.

Amount of nectar and pollen needed

Bees feed their larvae on pollen and nectar. Compared to adult insects, young bees need a disproportionate amount of these resources. Adult bees mainly feed on nectar, which is known to be processed into and stored as honey, especially by honeybees. Bumblebees also build up honey stocks in the form of "honeypots", but they contain much less honey than do honeybee combs.

Wild bees' nutritional needs strongly depend on the size of the individual species. 85 per cent of 41 wild bee species analysed roughly need the entire pollen resources of approximately 30 flowers to produce one offspring. However, as there is competition for pollen amongst pollinators – meaning several bees collect pollen from the same flower – one plant must feed more than one bee. The number of flowers needed corresponds to the bee species' size. While it takes about 1,140 flowers to feed a leafcutter bee (*Megachile*) weighing 63mg, a scissor bee (*Chelostoma*) weighing only 2mg can manage with as little as about 7 flowers.

For wild bees in particular it is not only the amount of flowers that matters, but it is also essential to ensure long-term continuous availability. Species that visit only one or few types of flowers can lose their entire population when there is a shortage or even complete lack of host plants in a given year which interrupts the development of new adult bees.

As many solitary bees only fly during a limited period of the year – some of them just for a few weeks – the flying period has to match the flowering period of forage plants.

How does this compare to the nutritional requirements of honeybees? For them the situation is different than it is for many wild bees. First, honeybees visit a wide range of wild plants; they are "non-specific pollinators". Second, beekeepers extract honey and thus indirectly also nectar from the hive. Small flower stocks are referred to as "scattered melliferous plants" in beekeeping because they do not make a significant contribution to the honey yield.

This is why the main factor determining the amount of floral resources required for honeybees is not so much colony preservation, but rather honey yield. Colony collapse is less of a risk thanks to the beekeeper's care, even when there are not enough flowers of a specific species in a given year and region.

Large quantities of nectar are required for producing honey. To fill its honey stomach used for carrying nectar to the hive a worker bee must visit 1,000 flowers. For comparison: a thimble holds as much as sixty times the content of a honey stomach. A bee colony produces about 15 to 20kg of honey a year, and annual honey production in Germany amounts to 20,000 to 30,000 tons. Honey is based on nectar which undergoes biochemical processing (enzymes break up sugar) and then is concentrated into honey (the desired water content is 18 per cent). This is why a lot more nectar is necessary than there is honey that can be harvested. The figures clearly show that in beekeeping, it is quantity that matters – nectar for honey extraction and pollen for feeding the bees. As defined by nature, different standards apply to wild bees: they do not depend on mass forage; for them it is mainly about preserving the colony, which is possible for them with only few plants.

Species and diversity of flowering plants

Wild bees in particular strongly depend on the availability of specific forage plants as many of them specialise in a few, or maybe even one single type of host plant. In the German speaking countries, about 8 per cent of all wild bees rely on one specific plant genus and 28 per cent on a particular plant family. 30 per cent are considered non-specialised and another 25 per cent are brood parasites that do not collect nectar themselves. As a rough estimate, more than half of all native wild bees are food specialists.

What sort of plants do they need? These specialists feed on 17 different plant families, with the focus being on composites (*Asteraceae*), the Papilionaceae family (*Fabaceae*), crucifers (*Brassicaceae*) and the mint family (*Lamiaceae*).

Some species are even far more specialised as shown by the Bryonia sand bee (*Andrena florea*) that collects pollen and nectar exclusively from the bryony (*Bryonia*). The loss or decline of flowers below the critical threshold of a plant community or plant species therefore leads to local extinction of many wild bee species.

Marguerite daisy

Lupin

Cuckoo flower

Deadnettle

Bryonia sand bee *Andrena florea*

Rapeseed field

Orchard meadow

Black locust

Mowed roadside slope

Well-groomed municipal lawn

Yet again, the situation is different for honeybees. Beekeepers, for example, attach great importance to large-scale melliferous plants, not least because they can be used for producing single-variety honeys. They can be found in the form of large-scale flowering crops (such as rapeseed, fruit, black locust) which make for abundant honey yield.

Areas with different flower species, however, are also good foraging habitats for honeybees and support nutritional variety. Unlike many solitary bees, honeybees forage throughout the entire year and thus particularly depend on flowers that bridge the "summer gap" and still bloom once mass crops have ceased blossoming.

In this context, *land in hand* provides several options for accommodating the needs of honeybees and wild bees alike:

- Coordination of mowing times: *Land in hand*, too, requires proper maintenance; mowing is necessary as it may, for example, protect roadside slopes against erosion. But since mowing is not aimed at producing maximum yield of green mass as is the case for agricultural meadows, *land in hand* can be mowed partially or at longer intervals instead of being mowed as a whole at the same time.

- Nutrient-poor habitats: Although *land in hand* often benefits from nutrient input from adjacent agricultural areas, it is normally rather poor in nutrients, which is why insect-pollinated herbs usually find better conditions than wind-pollinated grasses.

- It is possible to specifically sow flower-rich plant species. Seed mixtures of native plants are available commercially and play a vital role, in particular for wild bees that have specialised on native plants.

- Another option would be the setting up of flower strips (annual or perennial) by sowing colourful non-native plant species.

- Shrubs or trees that make for suitable forage plants can be grown in residential areas or alongside transport routes.

Colourful flowering plants lining a road

Poppy and cornflower

Flowering camomile next to a farm road

Area sown with non-native flowering plants

Unfortunately, the measures described are not a silver bullet; in fact, there are a number of limitations to be taken into account:

Plant communities growing near farmland must be maintained to prevent problematic weeds from spreading from *land in hand* to adjacent fields. Cultivated flower strips or patches are usually welcome in terms of their contribution to beekeeping, but not very much appreciated by conservationists. As they contain a lot of non-native plants (for example *Phacelia*, marigold) they are only of limited support to wild bees, which frequently rely on native plants. Plant species typically to be found alongside transport routes can spark beekeepers' criticism, when pollen contains toxic substances. Amongst them are the viper's bugloss and the ragwort, which has been widely distributed for a few years now. In addition, invasive plants (neophytes) – recently introduced from other parts of the world – such as the Himalayan balsam or the Canadian goldenrod play an important role with regard to *land in hand*.

These species, in particular, blossom in late summer and thus provide vital forage during critical seasons. But some conservationists are still sceptical about them crowding out native plant communities.

Himalayan balsam

Need for nesting sites

"Wild" colonies and feral swarms are considered not very viable, primarily due to the parasitic mite *Varroa destructor*. Honeybee colonies are looked after by beekeepers, which sets them apart from all other pollinators. As a result, honeybee larvae do not depend on habitats in the wild.

Unfortunately, wild bees' nesting sites are not particularly attractive to people and are often perceived as "untidy". While we enjoy looking at flowering meadows, colourful flower strips or blooming hedges, clearance cairns, rotten wood or old undergrowth hardly manage to generate positive interest. Bees, however, depend on these habitats; this is why implementing habitat protection measures often takes a lot of persuading.

About 50 per cent of wild bees native to German speaking countries nest in the ground digging tunnels in the soil, 3 per cent burrow into wood or plant stems; 19 per cent nest in pre-existing cavities, 1 per cent use resin or hardened secretion to build free-standing nests. 25 per cent are parasites which do not build nests of their own, but use other wild bees' nests ("cuckoo bees").

Canadian goldenrod

Yellow flowering ragwort

WILD BEES' NESTING SITES

Habitat	Number of species	in %
Tunnels dug in the soil	369	50
Pre-existing cavities	143	19
Tunnels burrowed into deadwood or plant stems	23	3
Free-standing nests	7	1
»Cuckoo bees«, parasites in other wild bees' nests	184	24
Unassigned	23	3

Taking a closer look at these nesting sites it becomes clear why habitat conditions in Germany's agricultural and cultivated landscape are not particularly favourable to many species.

Old fruit tree in an agricultural landscape

Wasp beetle larvae boring tunnels into wood

Carpenter bee

Beetle larvaes' burrows

Raw soil habitats

Species digging tunnels themselves sometimes do so in meadows or in thick vegetation, but they actually prefer sites without or with only sparse vegetation. In the past, these "raw soil habitats" often developed as a result of floods; undercut banks were formed and eroded anew every year. Hollow roads or non-vegetated waysides and other elements of landscapes that were shaped by traditional agriculture turned into man-made "secondary habitats", most of which have by now been lost. Today sand and gravel pits or quarries provide essential habitats for these species, but they, too, often get lost due to their use no longer being profitable or as part of "landscape restoration projects". Many times it only takes small-scale areas, such as the verge of an unsurfaced path, to provide a home to a bee colony.

Raw soil habitats, in particular, have some typical characteristics besides the mere availability of non-vegetated land. What is important is soil consistency: it must be soft enough to allow for digging nesting tunnels and at the same time sufficiently stable to prevent the tunnel system from collapsing. Many species prefer loess soil, others sandy or loamy soil. Some species prefer flat surfaces, while others tend to nest on vertical (such as the sides of hollow roads), sloping or rain-protected surfaces.

Snag and deadwood habitat

In the past, when Germany was not yet cultivated by humankind and mostly covered by virgin forest, there was an abundance of snags and deadwood. This is no longer the case in cultivated forests; timber is being harvested and fallen rotten trees have become very rare. But partially rotten isolated trees are home to a variety of insects that have colonised these natural habitats – bees being amongst them. Honeybees used to establish colonies in hollow trees – a form of habitat we can maintain and enhance in both residential areas and agricultural landscapes. Two ecological groups of wild bees take up residence in these habitats: species that nest in holes left by other insects, predominantly by beetles nesting in wood, and species that burrow into wood themselves to build nests. The latter include the large striking carpenter bees of the genus *Xylocopa* with their shining blue/black coloration, to be mainly found in warmer areas.

Sand bee

Raw soil at a roadside slope

Slope

Sandpit

Flowering strip in late autumn

Riparian vegetation

Green patch between roads

Ecological enhancement
of traffic islands with flowering plants

Other habitats

Wild bees use various cavities for building their nests: crevices in soil, rocks and walls as well as empty snail shells. Many bumblebee species prefer abandoned mouse holes, only some of them hide under leaves, in vegetation or in plant galls. A lot of species nest in the hollow stems of dead plants.

Residential areas

Residential areas usually offer very good conditions for wild bees. They feature gardens full of flowers, sunny walls and a greater diversity of structures than can be found in many agricultural landscapes. This is true of rural areas as well as of big cities. Residential areas often provide all the resources required (nesting and flowers) within close distance, which is what distinguishes them from several agricultural landscapes.

Specifically man-made nesting sites

In many areas wild bees enjoy particular protection living in specifically built "wild bee hotels". They consist of blocks of different materials (such as brick, wood, clay) drilled with holes, used as breeding habitat by solitary bees. Wild bee hotels, however, can never fully replace the bees' natural habitats.

Turning gabions into breeding sites for wild bees is actually a creative idea supported by the "Stiftung Rheinische Kulturlandschaft", a regional foundation for nature conservation. Gabions have lots of holes and gaps to be inhabited by wild bees. Moreover, gabion walls can be complemented by additional elements with drilled holes. Apart from this, it is essential to have sources of forage available preferably nearby, which brings us back to *land in hand*.

By their nature, bees can also attract negative attention, for example in rural areas where they sometimes build their nests in loose walls of half-timbered buildings.

Foraging distances

Foraging distances give an indication on the maximum acceptable distance between foraging and nesting sites for the bee populations to be preserved. These distances differ from one species to another.

As a general rule, larger species travel longer distances than smaller species.

Dimensions of distances covered by solitary bees between breeding and foraging habitats:

- Small species: about 100 to 300m
- Larger species: about 600 to 1,200m
- Honeybees: 3 to 7km

Some individuals travel longer distances and are therefore able to colonise new habitats.

Wild bee hotel in winter

Gabions provide lots of holes and gaps

Stone wall built for wild bees, in winter

4. Specific requirements of bees

Combined habitats

In some respects honeybees and wild bees have common requirements concerning their habitat, but in many aspects they differ. Wild bees, in particular, need "combined habitat": forage plants and nesting sites must be available in close proximity. Many species are sun lovers.

As regards wild bee habitats, three fundamental criteria must be fulfilled:

- Suitable microclimatic conditions, especially warm temperatures, low humidity, and sunlight
- Suitable forage plants
- Suitable nesting sites

Only the combination of all three factors within a certain distance equal to the bees' flight radius allows for maintaining stable populations.

Variety of flowers growing on raw soil

Flight radius

For wild bees, the maximum distance between nesting and foraging sites depends on the individual species. The foraging distance is a good indication, but we must consider that some bees can also travel longer distances and therefore can colonise newly developed and more distant habitats.

The situation is different for honeybees. While the presence of a wild bee species is closely linked to the combination of different habitat conditions, the main focus for honeybees is on melliferous plants, as beekeepers are able to move their colonies practising migratory beekeeping. Moreover, honeybees are assumed to have a significantly wider flight radius, the maximum radius reportedly being 5 to even 10km. Generally, it is between 1 and 3km and thus clearly larger than for wild bees, even with non-migratory beekeeping.

Bees in road traffic

Roadside vegetation accounts for a major share of *land in hand*, as a result of which bees are exposed to traffic risks. Normally, bees fly over roads and streets just as they fly over buildings, but there will nevertheless be a certain risk of bees becoming victims of traffic. But we may admittedly question the relevance of this factor.

- When foraging, honeybees usually fly at a height of approximately 5m (oral information by Prof. Dr. Jürgen Tautz, BEEgroup Würzburg University) and are thus well protected against road traffic. But it goes without saying that they may also fly at lower heights when visiting flowers along the road or searching for new sources of food.

- The increasing presence of both honeybees ("urban beekeeping") and wild bees in urban areas with heavy traffic is an indicator of bees showing considerable tolerance of road traffic.

WILD BEE SPECIES IN GERMAN CITIES

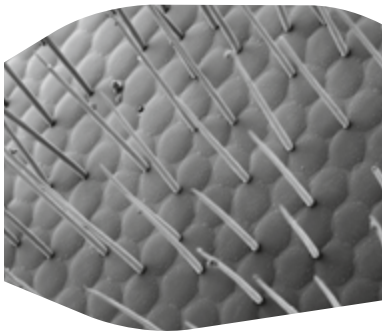
City	Area	Number of wild bee species
Berlin	892km^2	261
Stuttgart	207km^2	195
Köln	405km^2	157

- The sensory organs of bees, which are absolutely essential during foraging, are designed to detect obstacles and avoid them. Although evolution did not foresee modern road traffic, bees are naturally capable of adapting to complex three-dimensional habitats and to dynamic factors such as wind, as demonstrated by experimental studies with bees in a wind tunnel simulating an extremely dynamic environment.

Traffic risks associated with *land in hand* in residential areas or alongside roads can be mitigated by planting flowering trees (chestnut trees, lime trees etc.), as these will encourage foraging bees to leave the critical height of road traffic.

Birdsfoot trefoil and sage growing at the roadside

Honeybee's head with antennae with vital sensory organs



Surface of a honeybee's eye

Horse chestnut tree

Dog rose

Snag habitat

Coexistence of wild bees and honeybees?

In many agricultural landscapes the shortage of floral resources in summer leads to competition between various pollinators. Honeybees, though, are among the most competitive species, which puts them in an advantageous position:

- Honeybees exist in large numbers. Based on the conservative assumption that there are around 90,000 beekeepers in Germany, each of them managing 8 colonies with 40,000 individuals each in summertime, billions of honeybees are to be found in Germany every year.
- The honeybee is very much of a food generalist: it feeds on a wide range of flowering plants – mass crops as well as small-scale flower stocks.
- Honeybees are rather large, capable of displacing smaller wild bees from a flower.
- Honeybees tend to forage earlier in the day than many wild bees and can thus collect nectar before other bees visit the same flower.

To promote coexistence of honeybees and wild bees, these factors should be taken into account when planning specific habitat protection measures for wild bees, primarily on local small-scale areas.

How much space do bees need?

Honeybees have different requirements as to the size of their habitat compared to wild bees.

- With honeybees, the main focus is on the amount of melliferous plants available for producing honey. This can be in the form of large-scale flower stocks, but it can also be three-dimensional structures growing in a small-scale area, which is especially true of *land in hand*. Blooming trees or shrubs with a large number and density of flowers on a relatively small area, such as the horse chestnut tree or the dog rose, make for excellent forage.
- Several wild bee species are well-known for coping with small nesting sites. These can be found in weather-protected building façades in residential areas (sometimes bees would nest in the small joints between the stones), on waysides, roadside slopes or in old tree stumps. For a population to be preserved, a continuous habitat and host plant availability over a period of several years is often more important than habitat size.
- Large-scale areas are perfect habitats for flowering melliferous plants. This is where honeybees can get nectar from, considering that they need significantly larger quantities than wild bees. Small habitats with three-dimensionally structured sources of forage, such as trees or shrubs, provide a variety of food for honeybees, too; but they are particularly important and worth preserving as foraging and nesting habitat for wild bees.

5. Economic aspects

"About 80 per cent of the 2,000 to 3,000 native crops and wild plants rely on honeybees for pollination. The economic benefit of pollination services is 10 to 15 times higher than the value of honey production. In Germany, this amounts to 2 billion euros annually in total." These figures on the homepage of the German Beekeepers Association's (D.I.B.) demonstrate the importance of pollination services provided by honeybees and at the same time raise a number of questions.

Wild bee on an apple blossom

How do honeybees compare to other pollinators in terms of pollination services?

We often tend to point out the economic role of honeybees as pollinators, attributing pollination services to honeybees alone. Technically speaking, this is not correct as pollination services are performed by the entire ecological group of pollinators. However, there is hardly any reliable data on the actual percentage contributed by honeybees, wild bees and other pollinators respectively. And if so, it could only show the distribution for a limited period of time in a given region. Several factors, however, suggest that the importance of honeybees is sometimes overestimated, whereas their wild relatives are often underestimated.

- Ecosystems do not necessarily depend on honeybees as manifested by America, where honeybees have only been introduced by European settlers following Columbus's expeditions.

- Pollinating insects not belonging to the genus *Apis* are successfully used for specific agricultural requirements:
  - bumblebees (*Bombus terrestris*) in greenhouses, sometimes also in open air,
  - flies (*Lucilia caesar*) for example in seed production companies,
  - solitary bees (for example *Osmia bicornis*) in fruit production.

- As illustrated by pollination in fruit production, there is a considerable difference between honeybees and wild bees in terms of pollination services. Economic relevance is determined by a number of factors such as the type of fruit or local climate.

DIFFERENCES BETWEEN HONEYBEES AND WILD BEES IN TERMS OF POLLINATION SERVICES

Honeybees	Wild bees
One species with a large number of individuals	Many species with populations of few individuals
Relatively large foraging radius (about 3–5km)	Relatively small foraging radius (often only a few 100m)
Managed by beekeepers	Not specifically managed by humans
Pollination of various plant species	Often dependent on a few plant species

Various groups of pollinators clearly perform different "ecological services". But the individual services of honeybees and wild bees can well complement each another.

This immediately brings up the question of the economic value of *land in hand* for the protection of wild bees. It is understood that *land in hand* makes a substantial contribution to preserving wild bee populations, even more so when it undergoes specific ecological enhancement. If such areas are situated nearby orchards or other crops requiring pollination, we should certainly not underestimate their additional economic relevance. Given that wild bees account for a considerable share of pollination services, their nesting sites, or *land in hand*, also constitute vital economic resources.

Honeybee on an apple blossom

Pollination is a cooperative effort

Green bottle fly on an apple blossom

Additional forage

Once mass crops such as rapeseed or fruit have ceased blossoming, in many regions honeybees must fill the so-called "summer-gap", as it is often referred to by beekeepers. It would be unrealistic to expect the good old times to return on a broad scale, with flower-rich meadows characterised by large-scale extensive grassland management with long mowing intervals and little fertilizer input. But *land in hand* can effectively help compensate for this, providing habitats for a number of melliferous plants that can bridge the foraging gap:

a) trees and shrubs: willow, barberry, hawthorn, fruit trees, field maple, dog rose,

b) trailing and climbing plants, bushes: blackberry, bryony, grape ivy,

c) field flowers: speedwell, knapweed, bellflower, birdsfoot trefoil, marguerite daisy, white clover, sage, yarrow, widow flower.

This is associated with at least two positive aspects for beekeeping:

- increase of honey yield,
- improved bee health thanks to nutritional diversity.

Beautiful landscapes and biological diversity

Pollinators need flowers – and flowers are beautiful. Walking or cycling alongside blooming dog rose or sage meadows is certainly more pleasant than passing by a maize field flanked by a neatly mowed strip of grass. Pollinators are indicative of landscape diversity, which again not only benefits insects, but also satisfies the human desire for varied landscapes. Moreover, such landscapes are home to a variety of other animals. They are appreciated by insects, spiders and birds as well as by species useful in agriculture, such as lady beetles, lacewings or ichneumon wasps that control harmful organisms.

The coexistence of a wide variety of pollinator species is an integral element of biodiversity, which is not only relevant to conservationists or dedicated experts. Biodiversity is also about economic aspects.
In this context *land in hand* can play an essential role because it can:

- provide additional forage for honeybees and thus support beekeeping,
- enhance the landscape ecologically and aesthetically,
- promote other "ecological services", for example through beneficial organisms.

Attractive agricultural landscape

Bryony

Blossoming blackberry bush

Sage growing by the wayside

Hawthorn

Narrow-leaved ragwort often found alongside motorways

6. Possibilities and limitations of *land in hand* in promoting pollinators

Land in hand typically consists of small-scale landscape elements in agricultural landscapes, including residential areas in the form of small towns and villages. By definition, these areas do not have any specific purpose in terms of agriculture or nature conservation. They can be longitudinal, that is alongside transport routes or dams for instance.

Some are compact, such as green patches between roads, terraces or municipal green spaces; some are small-scaled and isolated from one another. Based on this short characterisation, we will now broadly define the possibilities and limitations of using *land in hand* to support pollinators.

Perennial flower strip between farm road and field

Snag

Possibilities of effective land use

Land for flowers

- No mowing during critical seasons: to bridge the "summer gap" in forage supply, mowing times can be scheduled early or late in the year.
- Coordination of mowing times: mowing times can be coordinated to guarantee flowering continuity throughout the whole year; in other words, alternating mowing of small patches at a time instead of large-scale mowing to always allow some flowers to remain.
- Sowing: sowing and care of perennial plant communities typical of the region is a key element of cultivating *land in hand*.
- Sowing "exotic" flowers: though not always appreciated by conservationists, this is also one of the relevant measures.
- Growing flower-rich woody plants: trees, shrubs and hedges can be selected based on whether they blossom at any time during the year or during critical seasons when forage is scarce.

Land for wild bees' nesting sites

- Raw soil habitats (non-vegetated areas), often small-scaled, can be established or maintained.
- Terraces with different degrees of slope inclination provide habitats to specifically adapted species.
- Snag and deadwood habitat, such as old and partially rotten fruit trees, can be preserved.
- Microhabitats rich in structure, such as clearance cairns, can be maintained.
- Artificial nesting sites ("wild bee hotels") can be set up.
- Overwintering habitats, such as unmowed vegetation, can be maintained.

Integrating the elements of an agricultural landscape

- The proximity required between nesting site and forage plants must be taken into account.
- Flight paths, for example along little used roads, can be specifically planned.
- Valuable options include a combination of both compact and longitudinal habitats on *land in hand*, but also a combination of designated conservation areas – which by definition are not l*and in hand* – and longitudinal *land in hand*.

Residential areas

- The relatively high density of bees must be maintained.
- Areas rich in structure are to be equally promoted as flowering gardens, public green spaces and vegetation alongside transport routes.

Plenty of space for flowers

A good solution: partially mowed strip alongside a road

Colourful flowers, including non-native species

Traffic island with raw soil

Even rooftops can provide valuable habitat

Land in hand as part of the overall agricultural landscape

In this study, we specifically looked at *land in hand* in terms of its benefit to pollinators, and to bees in particular. But in fact *land in hand* contributes to the use and development of agricultural landscapes in various complex ways. Unfortunately, *land in hand* does not yet get the attention in society and politics it actually deserves given the increasingly scarce land resources – at the global, national and often also regional level – in as much as land in hand is closely linked to other topics, too.

- Nature conservation: *land in hand* cannot only be home to pollinators, but also to other organisms and biocenoses.
- "Ecological services": apart from pollinators, a large variety of beneficial organisms can be found on *land in hand*.
- *Land in hand* can help increase agricultural biodiversity, for instance by growing regional fruit tree species alongside roads.
- *Land in hand* enhances agricultural landscapes and improves the overall appearance of towns and villages. Municipal green spaces promote citizens' quality of life; they are a key element of tourism and impact the value of real estate. Hence, ecological advantages go hand in hand with positive economic effects.

Forms of cooperation

Maintaining and managing *land in hand* must be considered a joint responsibility. In reality, of course, motivation greatly varies from one place to another. Success often depends to a large extent on the commitment of individuals, such as land owners or mayors. But together, we can make it happen.

Organisations as, for example, beekeepers' associations or nature conservation organisations can also make a big difference. And last but not least, political support is absolutely essential; this can be through funding measures or by integrating *land in hand* in existing or future land use plans.

We have outlined measures for ecologically enhancing *land in hand* to promote flowers and pollinators, but detailed planning and adaptation to specific local conditions can only be done in practice on the ground:

- Which areas are available and what would be an appropriate way of managing them?
- What sort of flower mix matches the regional soil conditions?
- Which are the native insects and how can measures be adapted to best suit their requirements?

To work towards achieving this goal in the most efficient way we recommend a gradual, systematic approach. The main factor of success, however, are the available resources: funding, committed staff, and expertise. When we manage to involve beekeepers' associations or experts on wild bees that are able to assess the local situation based on their knowledge and experience, the project will stand much better chances of success.

Limitations

Land in hand in agricultural landscapes constitutes a key resource for pollinators. But it does not offer the ultimate one-size-fits-all solution as there are a few limitations that cannot be ignored:

- Due to its proximity to agricultural areas, *land in hand* is subject to agricultural inputs, an example of this being fertilizer input, which usually benefits wind-pollinated grasses.
- Although *land in hand* can cover large areas in terms of total size, for instance when lining transport routes, it is mostly small-scaled or narrow. It is because of these structures that it cannot provide a suitable alternative to large-scale flowering meadows, which are preferred by beekeepers.
- Implementation of habitat protection measures can be more difficult on small-scale areas.
- Due to its close proximity to agricultural land many farmers are afraid of *land in hand* being a reservoir for problem weeds and possibly pests or plant diseases.
- *Land in hand* belongs to and is managed by a variety of owners, such as municipalities, private citizens or public institutions (railway companies, road construction authorities etc.), which poses logistical challenges when it comes to taking concerted measures.
- Resources are required for maintaining these areas. "Doing nothing" is actually not a desirable alternative because it can quickly lead to succession resulting in shrub encroachment. To prevent this from happening it takes adequate funding, expert advice and stakeholder commitment.

Townhall – together we can make a difference

Flower fly

Lady beetle

Well-groomed grass – not very attractive to pollinators

It is the mix of flowers that matters

Eh da-Flächen
für mehr Artenvielfalt

Summary

Agricultural landscapes do not consist of a uniform piece of land, but feature characteristic structures based on region, cultivation and population. Even with intensive agricultural management, there will always be areas that are neither cultivated nor designated conservation areas. They can be found in open landscapes, residential areas, surrounding buildings and farmhouses, and alongside transport routes or dams. Usually, these are small-scale areas, but they can be a vital resource for flowers and flower-visiting pollinators, in particular for bees. Ecological enhancement of *land in hand*, however, does not happen "by itself"; specific measures are required to realise the potential offered.

Bees – both honeybees and wild bees – can be considered indicators of a landscape's flower abundance and structural diversity. This is why it is worth looking at these organisms in more detail to define if and how an area can be ecologically enhanced. But this should never be an isolated approach in terms of the land available and the stakeholders involved. Land owners, municipalities and their citizens, farmers and political decision-makers must act in concert. Given the increasingly scarce land resources it goes without saying that we have to use the existing resources of an agricultural landscape in the most effective way to promote biodiversity in harmony with sustainable agricultural production.

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