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Sown Wildflower Strips – A Strategy to Enhance Biodiversity and Amenity in Intensively Used Agricultural Areas

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1. Introduction

1.1 Agricultural changes and effects on biodiversity

Biodiversity in agricultural areas in Europe has been in constant decline (European Environment Agency [EEA], 2010). Agricultural land is a habitat for many species, both plants and animals, which have adapted to the special conditions of these human-influenced ecosystems. The decline in diversity is due to the intensification of agricultural production and the abandonment of marginalised agricultural areas that are no longer profitable. Intensive agricultural production involves increased application of herbicides, pesticides and fertiliser, which has a profound effect on many plant and animal communities (Stoate et al., 2001, 2009). Often emphasised examples are fertilisation or aerial deposition of nitrogen on semi-natural grassland, which leads to a decline in many herbal plants adapted to less nitrogenous conditions (e.g. Dupre et al., 2010). The application of insecticides has been shown to affect whole food webs, for example a decline in bird species due to the lack of insect prey (Vickery et al., 2009).

The intensification of agricultural production has not only changed the quality of habitats, but also their quantity, with areas of low production, for example semi-natural grasslands, being in dramatic decline. The removal of certain biotopes to enlarge arable field size and its consequences for biodiversity have been discussed for several decades, for example the removal of hedges and field margins (Robinson & Sutherland, 2002). These measures have caused profound changes to the landscape pattern of agricultural landscapes, resulting in fragmentation of semi-natural areas and homogenisation (Jongman, 2002).

The decline in many species groups with habitats on farmland has been widely acknowledged. Birds have been one of the most studied groups and loss of bird species is well documented (e.g. Chamberlain et al., 2000; Donald et al., 2001; Newton, 2004; Wretenberg et al., 2010). The decline in birds is related to agricultural intensification practices, such as increased in herbicide use, change in sowing regimes (from spring to autumn sowing), land drainage and changes in landscape pattern. Kragten et al. (2011) emphasise the importance of farming system (organic versus conventional) for the abundance of invertebrate prey for birds. Dramatic declines in species have also been recorded for insects, for example butterflies (Nilsson et al., 2008; van Swaay et al., 2006), bumblebees (Goulson et al., 2008) and bees (Biesmeijer et al., 2006). The picture is similar for beetles (Kotze & O'Hara, 2003) and bugs (Frank & Künzle, 2006). Again, the reasons cited for the decline are habitat loss and fragmentation, loss of foraging opportunities and the general homogenisation of the agricultural landscape (Benton et al., 2003; Diekotter et al., 2008; Tscharntke et al., 2005).

1.2 Sown wildflower strips

In order to decrease the negative effects of intensive farming and support extensive farming practices, agri-environmental schemes were introduced within the EU Common Agricultural Policy (CAP) in the late 1980s. Today, agri-environmental schemes are part of the Rural Development Programme (RDP), which is compulsory for all EU member states. However, the schemes can be designed differently by the member states within the given framework. Sown wildflower strips have been introduced in several European countries as a measure to enhance and support biodiversity especially in intensively farmed areas (Haaland et al., 2011, Noordijk et al., 2010). The overall goal with the establishment of wildflower strips is to enhance biodiversity and the abundance of certain species groups such as insects, birds and plants. This is especially important in areas with intensive agriculture. Such strips are often particularly intended to enhance the abundance of particular functional insect groups, such as pollinators and predators of pest species, through the provision of adult food resources, for example nectar-rich flowers. Such pollinators and pest predators are important in the context of agricultural production. Birds can also benefit from high insect numbers or seeds in the wildflower strips (Vickery et al., 2009). Some of the schemes are designed to support (rare) plant species that used to be common and typical for field margins prior to the introduction and wider application of fertilisers and herbicides (Marshall & Moonen, 2002)

Sown wildflower strips are usually established on arable land by sowing a seed mixture of wild flowers. Establishment and management are carried out by the farmer, who is compensated for the cost of seed mixtures, any management operations required and loss of income according to the regulations of the particular agri-environmental scheme. Sown wildflower strips vary regarding the seed mixture applied, size of strip, duration of the scheme and management. The seed mixture applied varies between countries and also between the different agri-environmental schemes within a country. Thus in some seed mixtures only a few wildflower species are present (1-5), while others can comprise up to 30 species (Nentwig, 2000). Two examples of seed mixtures are given in an appendix to this chapter. The agri-environmental schemes specify which seed mixture the farmers are allowed to use among the seed mixtures offered by commercial suppliers. One distinctive difference is whether seed mixtures contain grass species or not. The importance of using local provenance when establishing wildflower strips has been pointed out (Bischoff et al., 2010). Strip width can vary between from a few metres up to 24 metres, while certain schemes allow for areas instead of strips. Strips can be sown along field edges or within fields but a minimum size of total area sown is often required. Some schemes last only one or two years, while other run for up to five or seven years.

Management of wildflower strips also varies, a common feature being that the use of pesticides, herbicides and fertilisers is prohibited. However, in special cases the use of spot treatments with herbicides may be permitted when certain weed species become a problem. In some countries, for example Switzerland, wildflower strips are often not managed at all after their establishment and are left uncut over a period of up to seven years. Due to succession processes the plant composition of wildflower strips can change greatly during that time, for example due to the invasion of grasses, the passing of annuals and sometimes the increasing dominance of a single plant species in the seed mixture, for example *Dipsacus fullonum* (see also Noordijk et al, 2011, for an example from the Netherlands).

On the other hand uncut strips offer an excellent overwintering habitat for many insect species (Frank & Reichhart, 2004; Pfiffner & Luka, 2000). In other countries it is more common to cut wildflower strips once a year in autumn.

The potential of sown wildflower strips for amenity purposes in the countryside has only recently been discussed as a strategic option (see examples from Germany where wildflower strips are promoted as '*Blühende Landschaften*', flowering landscapes). Wildflower strips can be very attractive landscape features when flowering and thus appreciated by people visiting the agricultural landscape for recreational purposes (Junge et al., 2009; Lindemann-Matthies et al., 2010).

The combination of biodiversity goals and recreational goals makes wildflower strips a particularly interesting element in the context of intensively used agricultural landscapes, where available space for recreation and wildlife is equally scarce. This is particularly the case in peri-urban areas, where the need for recreation opportunities is high and the pressure on land is increased due to housing developments. In the following sections we illustrate some biodiversity benefits from wildflower strips for insects and then suggest some ways in which biodiversity goals and recreation interests can be combined in the same greenway system. By the term greenway, we refer to linear features that are established on arable land, covered by vegetation and suitable for walking and possibly other forms of recreation. Paved paths, gravel paths or walking paths are not included in the definition, although the large body of existing research on greenways (e.g. Ahern, 1995; Fabos & Ryan, 2006), also includes much broader definitions. We conclude by suggesting possible approaches for implementation.

2. Wildflower strips for biodiversity conservation

2.1 Abundances and species diversity in wildflower strips

Quite a number of studies have investigated the abundance and diversity of insects (Haaland et al., 2011) and spiders in sown wildflower strips. These studies have identified several factors that can affect abundance and species diversity in the strips: flower abundance (e.g. Pywell et al., 2006), plant diversity (e.g. Aviron et al., 2007) seed mixture (e.g. Marshall, 2007), vegetation structure (e.g. Woodcock et al., 2005), management (e.g. Woodcock et al., 2008), age (e.g. Noordijk et al., 2010) and landscape factors (e.g. Aviron et al., 2007). Species groups that have been studied include bees and bumblebees, butterflies, beetles, bugs, grasshoppers. Sown wildflower strips have proven capable of containing high numbers of bumblebees (Carvell et al., 2006, 2007; Haaland & Gyllin, 2010; Pywell et al., 2005, 2006), with strips sown with few plant species particularly rich in pollen and nectar attracting most bumblebees (e.g. Pywell et al., 2005). Nevertheless a greater variety of wildflower plant species has the advantage of providing food resources during a longer period of the year and might be able to support particular species (Carvell et al., 2007). Sown wildflower strips can attract more butterflies compared with other margin types or other habitats typical for the open agricultural landscape (Aviron et al., 2007; Feber et al., 1996; Haaland & Gyllin, 2010). Interestingly, Jacot et al. (2007) found higher butterfly diversity in strips sown with both grasses and wildflowers compared with strips sown with wildflower seeds only. This might be explained by the fact that several butterfly species have grasses as the food plant for their larvae. In sown wildflower strips often the more common butterfly species are found, but a relatively large percentage of a region's species pool can be observed within them (Haaland & Bersier, 2011).

Beetles are a well-studied insect taxa in sown wildflower strips. Studies have shown that wildflower strips have a greater diversity of beetles than other types of field margins or agricultural habitats (Aviron et al., 2007). However, beetle abundances are rather dependent on factors such as management and vegetation structure, and thus higher beetle abundances are not necessarily found in sown wildflower strips compared with other field margins (Woodcock et al., 2008). For grasshoppers, high species richness and abundances have been recorded in margins sown with both grass seeds and a wildflower mixture (Jacot et al., 2007, Marshall, 2007). Bugs can reach similar high abundances and diversity in wildflower strips as in meadows (Zurbrügg & Frank, 2006).

Spider densities can be significantly increased in fields adjacent to sown wildflower strips compared with other types of field margins (Schmidt-Entling & Döbeli, 2009). In addition, since wildflower strips can contain a larger number of insect species, they can act as a good food resource for birds (Vickery et al., 2009).

2.2 An example from Sweden

In the most southerly province of Sweden, Scania, we have studied butterfly and bumblebee diversities and abundances in two different types of green structures: sown wildflower strips and greenways established primarily for recreation purposes (Haaland & Gyllin, 2010). Until recently, there were no agri-environmental schemes for wildflower strips in Sweden, but the Swedish University of Agricultural at Alnarp (near Malmö) established wildflower strips in the vicinity of the university campus for various purposes such as demonstration, amenity, research projects (Figures 1 and 2). These wildflower strips were mostly sown with a seed mixture of grasses (5 species) and wildflowers (15-25 species). In two cases, wildflower strips were established using cut hay from a nearby meadow. In addition, three greenway systems were studied. These were established either on the initiative of a farmer (*n*=1, Tottarp, Figure 3) or the municipality of Lund on private land after negotiations with the concerned land-owners (*n*=2, Arendala and Lund, Figure 4). In all three cases the landowner is being paid compensation by the municipality.

Butterflies and bumblebees were recorded by visual observance along transects in both wildflower strips and greenways during one summer (2007). Each transect was divided into sections of varying length, with each section having more or less the same characteristics. The recorded transect length was 2.9 km in the wildflower strips at Alnarp and 6.8 km in the greenways at Tottar, Arendala and Lund (for more details see Haaland & Gyllin, 2010).

Fig. 1. Sown wildflower strip at Alnarp, Scania, Sweden. Photo: Mats Gyllin.

Fig. 2. Sown wildflower strip at Alnarp, Scania, Sweden. Photo: Christine Haaland.

Fig. 3. Greenway established by farmer primarily for recreation purposes (walking, horse riding) on arable land. Tottarp, Staffanstorp, Scania, Sweden. Photo: Christine Haaland.

Fig. 4. Greenway established primarily for recreation purposes by the municipality of Lund on arable land. Bushes and tree species were also used in order to meet biodiversity goals. Lund, Scania, Sweden. Photo: Christine Haaland.

1769 butterflies of 18 species (including one day flying moth) and 1216 foraging bumblebees (8 species) were recorded during the study. Although the greenways investigated were more than twice as long as the wildflower strips, nearly all butterflies (86%) and bumblebees (83%) were observed in the wildflower strips. The mean number of butterflies was about 20 times higher in the wildflower strips than in the greenways. Bumblebees were virtually absent from the grass sown greenways, but occurred in slightly higher numbers in the greenways with plantings and some flowering edge vegetation (greenways in Lund, Figure 4). Most butterfly and bumblebee species recorded are common species in southern Sweden. Species numbers were higher for both butterflies and bumblebees in the sown wildflower strips (Figure a, b). In terms of the flowers visited by butterflies and bumblebees, it was noted that a few plant species were visited very often (Figure 6). Thus two-thirds of all butterflies observed on a flower were seen on brown knapweed (*Centaurea jacea*) and greater knapweed (*C. scabiosa*) and field scabious (*Kanutia arvensis*) (Figure 6a). Three-quarters of all foraging bumblebees were observed on *Centaurea* ssp. and 14% on *Knautia arvensis* (Figure 6b). This shows that few plant species attract most individuals of these two species groups and that preferences differ between species groups. However, flower visit patterns change during the season as the availability of flowering plants changes with their flowering period.

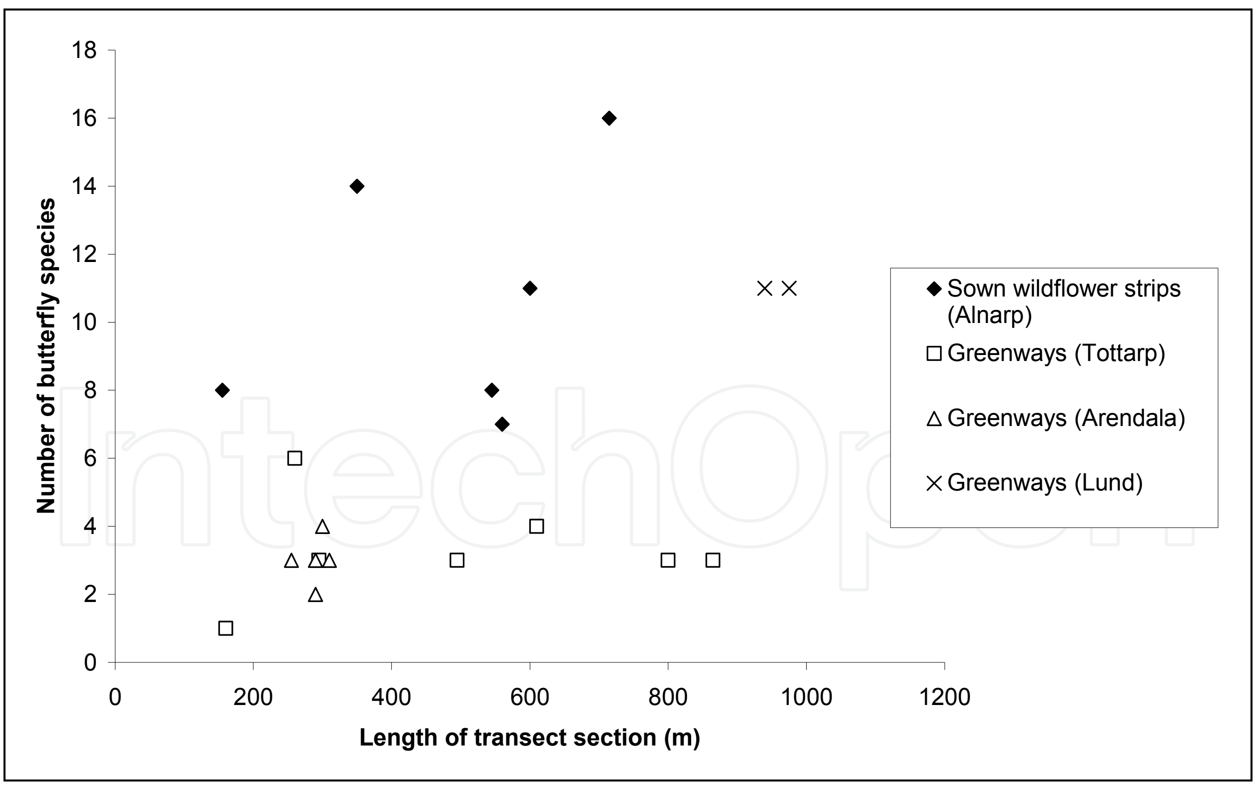


Fig. 5a. Butterfly species numbers in sown margins and greenways at the different study sites in relation to length of transect section, Scania, South Sweden.

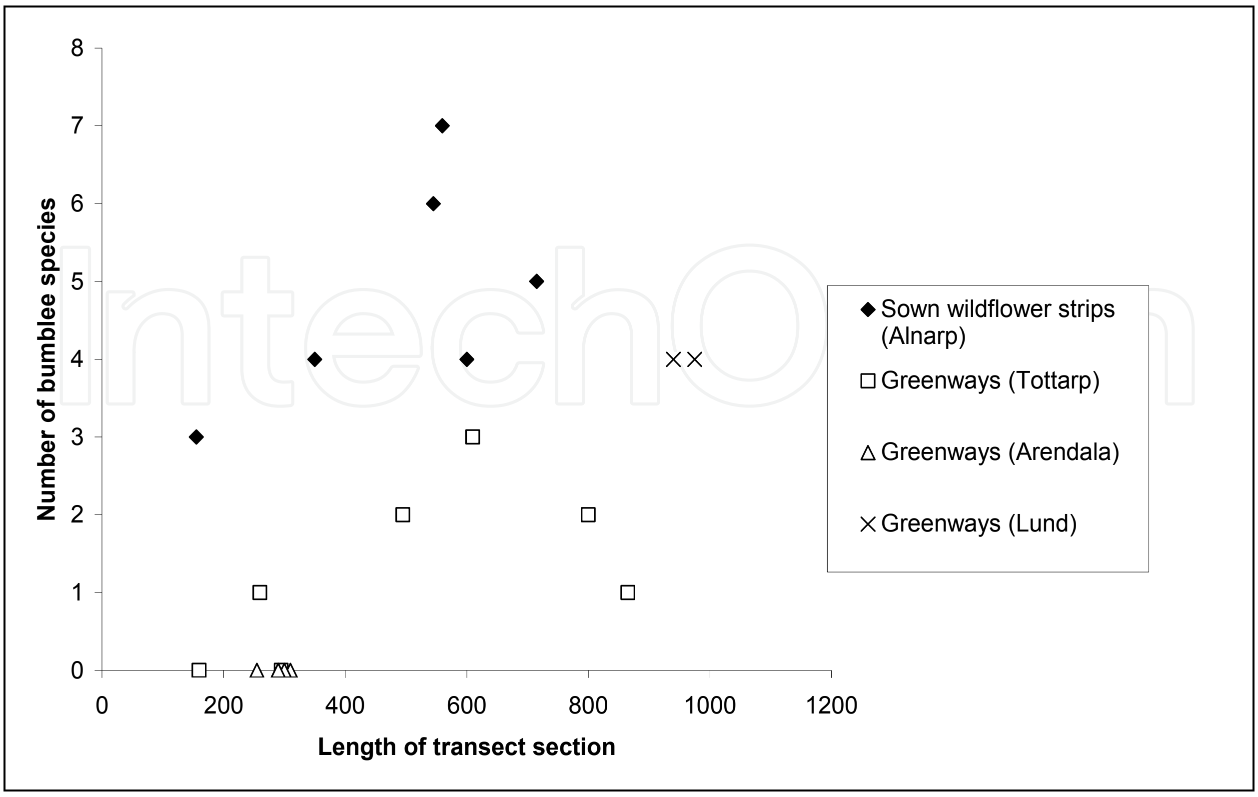


Fig. 5b. Bumblebee species numbers in sown margins and greenways at the different study sites in relation to length of transect section, Scania, South Sweden.

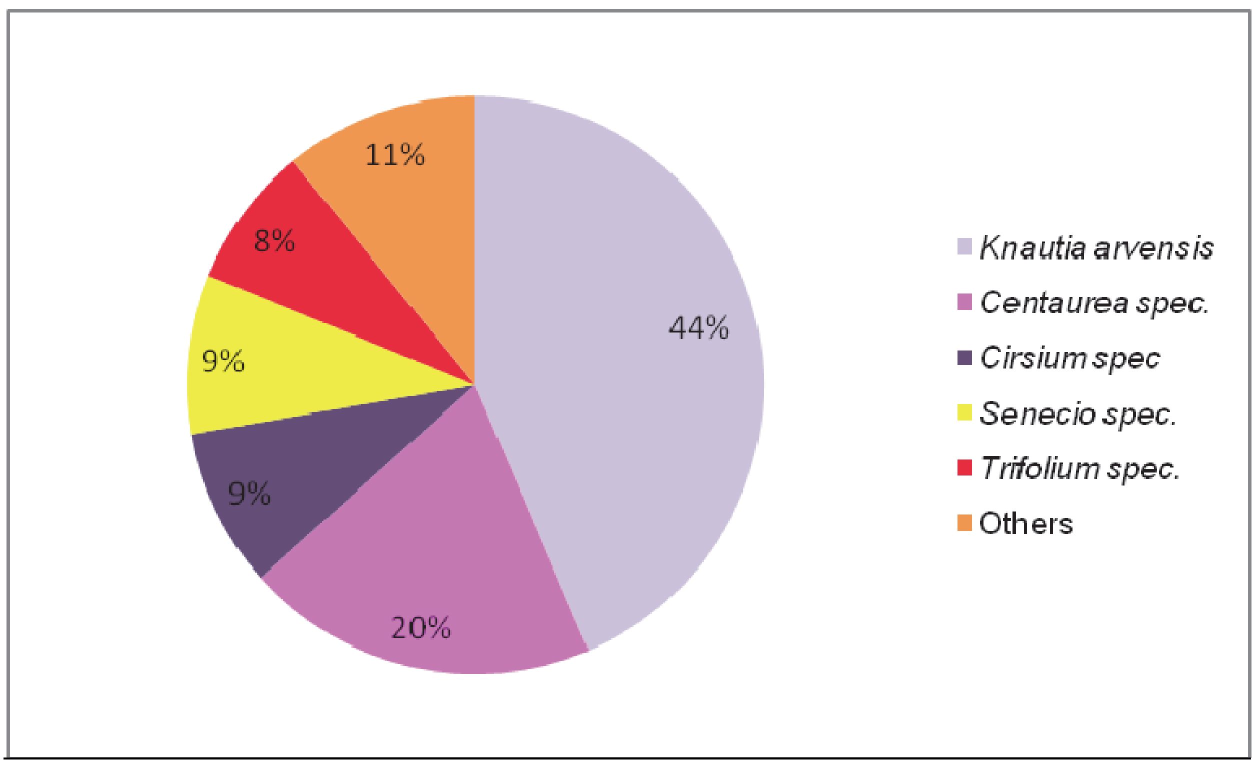


Fig. 6a. Flower visits by butterflies in wildflower strips and greenways, n=347 (Scania, Sweden).

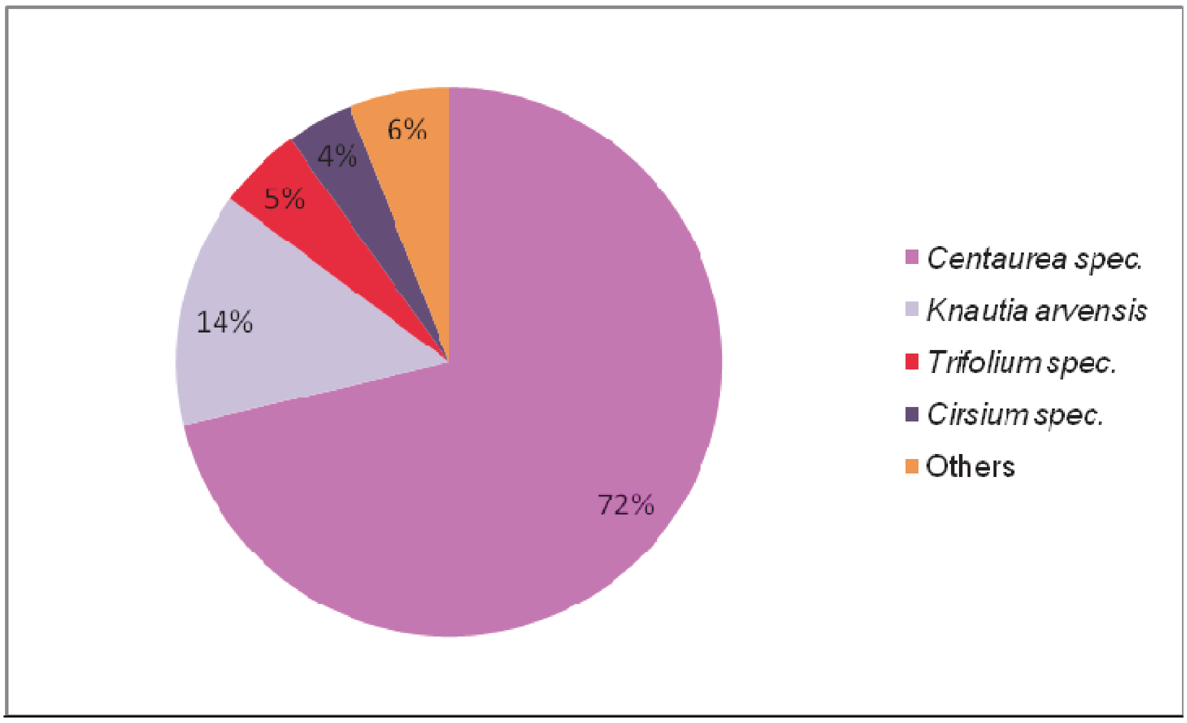


Fig. 6b. Flower visits by bumblebees in wildflower strips and greenways, *n*=1216 (Scania, Sweden).

3. Combining biodiversity and recreation goals

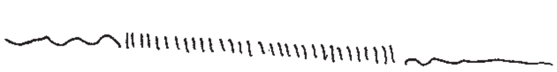
Sown wildflower strips can provide food and other resources for insects and thus also for other species groups such as birds. Potentially they are also suited to increase the amenity of intensively farmed agricultural landscapes. The types of greenways that have been typically established on arable land in the most Southern part of Sweden fulfil recreation goals in that they provide possibilities for walking and horse riding in a landscape that is otherwise rather inaccessible due to the removal of farm tracks and field boundaries to enlarge field size. However, these greenways do not contribute to biodiversity conservation or biodiversity enhancement, despite this being a goal that is often stated in policy documents in connection with their establishment. Even though the primary aim of greenway establishment is recreation, there is still the ambition that these green structures should positively contribute to biodiversity goals. In landscapes with intensive agriculture which are simultaneously under pressure from urban development, arable land for developing recreation opportunities or biodiversity goals is scarce. Thus it would be desirable to create green structures that optimally serve both needs. In our project 'Multifunctional Greenways' we are trying to find design solutions for greenways where recreation and biodiversity goals are better integrated than is currently common practice in southern Sweden. We suggest a combination of approaches partly originating in agri-environmental schemes and partly in the (European) greenway tradition (Fumagalli & Toccolini 2007).

There are several challenges in the design of such local networks. Within most agri-environmental schemes regarding sown wildflower strips, the farmer is relatively free where to establish the strips: on arable land at the edge or within the field. No network approach or connectivity of strips is needed. In addition, the strips are established on arable land and can be ploughed up again after the scheme has expired. Furthermore, the strips are only intended to meet biodiversity goals and thus farmers do not have to deal with an increased number of people moving across their farmland. Thus when creating multifunctional greenways that serve recreation and enhance species richness, a network approach is needed, continuity is desirable, but not necessary (as long as no bush and tree plantings are involved) and the farmer must be willing to allow public access on his farmland.

Regarding visitors, there are also different interests to take into account (Peterson et al., 2010). In southern Sweden, most greenways are used by both walkers and for horse riding. This can work well as long as the number of visitors is limited, but can become problematic when walkers are afraid of meeting horses on a rather narrow greenway or horses are disturbed by walkers. In wet weather it is often not suitable to use the greenways for horse riding because of damage to the vegetation. Mountain bikers are another group that might increasingly wish to use the greenways, and here similar problems can occur in wet weather conditions in terms of damage to vegetation.

Multifunctional greenways can be designed to suit different recreation purposes and at the same time be more beneficial to wildlife than simple grass sown greenways (Figure 7). Depending on available width, local conditions and local needs, different solutions can be chosen. When riders and walkers frequently use the same network, plantings or sown wildflower strips can be established in the middle of the greenway to separate these two visitor groups. The width of a mown path can also be adjusted to the kind of recreation experience intended or to the number or type of visitors. In this type of green structure, both recreation values and biodiversity can be enhanced. Plantings of bushes or trees are only sensible in networks that are intended to be continuous. Sown wildflower strips within agri-environmental schemes are regularly ploughed up, so an approach combining grass strips with wildflower strips can also function in a non-continuous network.

A. Greenways without tree and bush plantings



a) 'Classic' greenway, sown with grasses only, cut short (several times per year)

b) Greenway where grass areas are combined with sown wildflower strips at both edges

c) Greenway with sown wildflower strip along one edge

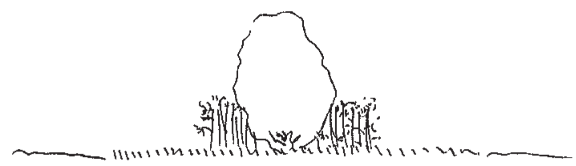
d) Greenway with sown wildflower strip in the middle

e) Sown wildflower strip with mown path in the middle

f) Sown wildflower strip with two mown paths

B. Greenways with bush plantings

a) Greenway with planted bushes and sown wildflower strips along one edge



b) Greenway with bush planting and two sown wildflower strips in the middle

c) Greenway with bush plantings along both edges, sown wildflower strips and mown path

Fig. 7. Possible design for multifunctional greenways. A) without bushes and B) with bush plantings. Illustration: Christine Haaland

4. Possible approaches for implementation

There are several ways to implement multifunctional greenways in which measures for biodiversity and recreation are combined on agricultural land. In Sweden we have idnetified three possible approaches for implementation (Haaland et al., 2010). Greenways have so far been established on the farmer's initiative, the initiative of the local authority (municipality) and private initiative, for example sporting organisations. In addition, agri-environmental schemes can be viewed as a framework for financing the establishment and management of greenways.

The first greenway network in Sweden on arable land was initiated by a farmer, but subsidised by the municipality (Figure 3). (However, farmers' reluctance to allow public access to farmland is an acknowledged problem, Ryan & Walker, 2004). There can be a pressing need to channel recreation on farmland, especially in peri-urban areas and particularly when horse riding is involved. Swedish law provides the right of public access to the countryside, but this right is difficult to exercise in areas of intensive agriculture with large fields, few farm tracks and field boundaries. Thus there may be a tendency for walkers and riders to access areas of the farmland where the farmer does not want them (small verges between fields, farm tracks near the farm) or along road verges of trafficked roads, which can be very unsafe. Farmers themselves can therefore have an interest in channelling visitors to parts of the farm where they disturb farm operations least. There are also farmers who welcome visitors, like to offer access for recreation on their farmland and are willing to prepare these – at least when they are compensated. An open question is how interested these farmers would be in combining access issues and biodiversity measures within the same green structure network.

Several greenway networks have been established by municipal authorities to provide recreation possibilities for the urban population in peri-urban areas. Here land is often leased by the municipality and farmers may be additional compensated for management. This approach allows for well-designed greenways for both recreation and biodiversity means, but is not fully exploited yet. There are examples where both aims are considered, for example choosing certain bush and tree species, which are intended to enhance biodiversity (in this case birds, Figure 4). Here, relatively easily sown wildflower strips or patches could be added.

In other cases private initiatives have been taken to establish greenways to improve accessibility, for example by equestrian organisations (Larsson et al., 2011). In these cases, where recreation and access issues have priority for the initiative takers, biodiversity issues are easily neglected (Larsson et al., 2011). This might especially be the case where organisations pay compensation to farmers. When municipalities are involved in paying compensation, it is easier to ask for biodiversity measures in addition.

Agri-environmental payments could potentially be used to finance the establishment and management of multifunctional greenways (Von Haaren & Reich, 2006). In Sweden, several greenways projects are financed at least partly through payments regulated in the Rural Development Programme, for example Leader projects. Another possibility would be to enhance the function of buffer strips along water courses to include recreation access. In some municipalities in Scania this is already common practice, but it may occasionally contravene the rules of the agri-environmental schemes. These buffer strips would also be suitable for part sowing with wildflowers (e.g. along the field edge) instead of grass mixtures only.

It can be assumed that the use of agri-environmental payments to increase access to intensively used agricultural areas can enhance the acceptance of such payments by the public – or at least among those interested in access to these areas.

5. Conclusions

Sown wildflower strips can support and enhance species richness in intensively farmed areas. The number of species in wildflower strips is dependent on the type of seed mixture sown, which affects other factors such as flower abundance, plant species diversity and vegetation structure. These factors are in turn influenced by the type of management. The age of the strips is relevant for species numbers, how is often depending on the type of management, which steers if and how fast successional processes take place. Where suitable, we advocate combining sown wildflower strips with recreation possibilities by creating multifunctional greenways. Multifunctional greenways enhance species richness and also increase access for visitors in areas with intensive agriculture. This can be particularly relevant in peri-urban areas. The most suitable design and management of greenways is dependent on the species groups they are intended to support and the visitor groups that will use them. The question of how long the greenways are supposed to exist is crucial for issues such as bush and tree plantings. Thus greenway design can be adapted to local conditions and needs. There are several possible approaches to implement multifunctional greenways, where farmers, organisations and municipalities play key roles. An important stimulant for the establishment of multifunctional greenways would be the possibility to finance them with the help of agri-environmental payments (agri-environmental schemes, Leader).

6. Acknowledgements

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7. Appendix

Example 1 of plant species sown in wildflower strips (applied at Alnarp, Sweden)

Herbs
Achillea millefolium
Anthyllis vulneraria
Campanula rotundifolia
Centaurea jacea
Filipendula vulgaris
Galium verum
Hypericum perforatum
Hypochoeris maculata
Hypochoeris radicata
Knautia arvensis
Leucanthemum vulgare
Lotus corniculatus
Plantago lanceolata
Plantago media
Primula veris
Prunella vulgaris
Ranunculus acris
Ranunculus bulbosus
Rhinanthus serotinus
Rumex acetosa
Scabiosa columbaria
Senecio jacobaea
Succisa pratensis
Trifolium pratense
Vicia cracca
Grasses
Anthoxanthum odoratum
Avenula pratensis
Cynosurus cristatus
Festuca ovina
Festuca rubra
Phleum pratense ssp. bertolonii

Example 2 of plant species sown in wildflower strips (applied in wildflower strips in Switzerland)

Achillea millefolium
Agrostemma githago
Anthemis tinctoria
Centaurea cyanus
Centaurea jacea

Cichorium intybus
Daucus carota
Dipsacus fullonum
Echium vulgare
Hypericum perforatum
Leucanthemum vulgare
Malva moschata
Malva sylvestris
Origanum vulgare
Papaver rhoeas
Pastinaca sativa
Silena pratensis
Tanacetum vulgare
Verbascum lychnitis
Verbascum thapsus ssp

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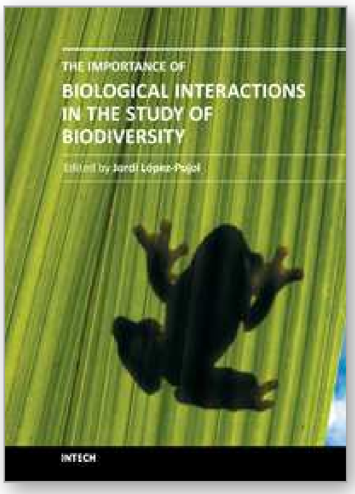

The Importance of Biological Interactions in the Study of Biodiversity
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The term biodiversity defines not only all the variety of life in the Earth but also their complex interactions. Under the current scenario of biodiversity loss, and in order to preserve it, it is essential to achieve a deep understanding on all the aspects related to the biological interactions, including their functioning and significance. This volume contains several contributions (nineteen in total) that illustrate the state of the art of the academic research in the field of biological interactions in its widest sense; that is, not only the interactions between living organisms are considered, but also those between living organisms and abiotic elements of the environment as well as those between living organisms and the humans.

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