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POLICY DIRECTION

Can rolling composite wildflower blocks increase biodiversity in agricultural landscapes better than wildflowers strips?

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Abstract

1. Biodiversity and abundance of wildlife has dramatically declined in agricultural landscapes. Sown, short-lived wildflower (WF) strips along the margins of crop fields are a widespread and often subsidised in agri-environmental schemes, intended to enhance biodiversity, provide refuges for wild plant and arthropod populations and to provide ecosystem services to crops. Meanwhile, WF elements are also criticised, since their functionality decreases with plant succession, the removal of aged WF strip poses an ecological trap for the attracted arthropod populations and only common and mobile species benefit. Further, insects in WF strips are impacted by pesticides from agricultural fields due to shared boundaries with crop fields and by edge effects.
2. The performance of the measure could be improved by combining several WF strips of different successional stages, each harbouring a unique community of plants and arthropods, into persistent, composite WF block, where successional stages exist in parallel. Monitoring data on many taxa in the literature shows, that a third of species are temporarily present in an ageing WF stip, thus offering composite WF blocks should increase cumulative species richness by 28%–39% compared to annual richness in WF strips. Persistence of composite WF blocks would offer reliable refuge for animal and plant populations, also supporting their predators and herbivores. Further, WF blocks have less boundaries to crops compared to WF strips of the same area, and are less impacted by edge effects and pesticides.
3. *Policy implications*. Here I suggest a change of conservation practice changing from successional WF strips to composite WF blocks. By regular removal and replacement of aged WF strips either within the block (rotational) or at its margins (rolling), the habitat heterogeneity in composite WF block could be perpetuated. Rolling composite WF blocks change locations over years, and the original location can be reconverted to arable land while a nearby WF block is still available to wildlife. A change in agricultural schemes would be necessary, since in some European countries clustered WF strips are explicitly not subsidised.

KEYWORDS
AES, agriculture, biodiversity, CAP, conservation scheme, field margins, insects

1 | INTRODUCTION

Wild animal populations have been suffering major declines in agricultural landscapes. The decline of insects is caused by the loss of breeding plants, feeding sites and habitat degradation (Habel et al., 2016; Hallmann et al., 2017; Thomas, 2016) and both diversity and abundance has declined (Dirzo et al., 2014), affecting ecosystem services such as pollination (Blaauw & Isaacs, 2014) or pest reduction (Tschumi et al., 2016), and resources for insectivorous vertebrates (Donald et al., 2006).

Sown, short-lived (ephemeral) wildflower (WF) strips are a widespread, decorative and well-intentioned landscape element to support insect populations, increase plant diversity at field margins, support birds by providing plant seeds and invertebrates and enhance amenity for people. Insect taxa respond differently to flower abundance, seed mixture, vegetation structure and management, age or shape of a WF strip (Frank et al., 2012; Haaland et al., 2011), but in general and not surprisingly, WF strips support higher insect abundance and species diversity than cropped habitats (Sutter et al., 2017 for review). WF strips increase ecosystem services of insects such as crop pollination in adjacent fields (Albrecht et al., 2020; Feltham et al., 2015; Ganser et al., 2018), contribute to biological pest control by favouring predators (Albrecht et al., 2020; Tschumi et al., 2016), and to provide food, oviposition sites and overwintering capacities (Ganser et al., 2019; Pfiffner & Luka, 2000) for arthropods, although some studies found no support for pollination (Nicholson et al., 2020) or pest control (Pfiffner et al., 2009) benefits of WF strips in adjacent crops. WF strips are often subsidised, for example via the Common Agriculture Policy (CAP) of the European Union, and sown with a recommended local mix of indigenous arable weeds, meadow and ruderal plant species, and vary in intensity of management and subsidised lifetime.

Meanwhile, WF strips were recently criticised as putative ecological traps and sink habitats (Table 1, Ganser et al., 2019). Farmers usually **remove WF strips** (Table 1a; Figure 1a) to prevent succession towards grass and bushland. Lifetime differs with subsidiary schemes (e.g. Germany after 2 years, Haaland et al., 2011, Switzerland after 4 years, Frank & Künzle, 2006). Animals are attracted to WF strips from a structurally poor landscape but are destroyed together with the removal of the refuge (**ecological trap**, Ganser et al., 2019, Kleijn & Sutherland, 2003). Second, **fitness** of individuals may be lower, since **body condition** in some ground beetles increase with the age of refuge (Barone & Frank, 2003; Frank & Reichhart, 2004; Frank et al., 2007), which potentially affects (Honěk, 1993). Third, more common and mobile insect species seem to be the main beneficiaries of WF strips, while benefit for **rare or immobile species** has been disputed (e.g. Meek et al., 2002; Pywell et al., 2005), such as overwintering arthropods (e.g. Ganser et al., 2019) or wild bees (Blaauw & Isaacs, 2014) which need time for establishment. Further, for insect and seed eaters, the resources in ephemeral WF strips are **unpredictable**.

With strip age and plant community succession, sown annual flowering plant species are replaced by perennials and plant diversity decreases (Table 1b, Frank & Künzle, 2006). Both arthropod diversity and abundance also **fluctuate with succession**. Ground beetle diversity, for example, is highest during the first year of uncongested plant cover and sunny soil (e.g. Reich & Hilgendorf, 2018). Overwintering species (Ganser et al., 2019) and zoophageous bugs only appeared in the later stages of a WF strip (Frank & Künzle, 2006), while absolute

TABLE 1 Comparison of effects of ephemeral wildflower strips and persistent, composite wildflower blocks on insect populations and insect diversity

Modality	Performance of ephemeral wildflower strips on insect populations (literature source, empirical data)	Predictions for effects of composite wildflower blocks
(a) Persistence	**Ecological trap**: scheduled removal of the refuge (1, 4)	**Persistence of local refuge** through replacement of aged zones
	Fitness reduction for species with multiannual life cycles, overwintering (2), soil living stages or species that increase body condition (8) over time in refuge (3, 9)	**Viable populations** for large variety of life-history requirements and for species with heterogeneous habitat requirements
	Mobile and abundant animal species profit from strips (4)	**Immobile**, mobile and slow colonisers also benefit
(b) Structure	**Single successional stage** of plant community **Loss of annual** plant species after first year **Successional replacement** of temporal arthropod community **Multiannual fluctuation** of insect abundance (highest in third year (2, 3, 7) unpredictable for consumer	**Parallel successional stages** in different zones, habitat heterogeneity Persistence of annuals in the first-year zone **Accumulation of arthropod richness** across successional stages **Predictable average** abundance of insect densities for consumers
(c) Shape	**Large edge effect**, high edge-to-area ratio; effects on microclimate and pesticide spillover from crops (5, 6)	**Small edge effect**, low edge-to-area ratio, special microclimate and reduced spillover

References: (1) Ganser et al. (2019), (2) Frank and Reichhart (2004), (3) Frank et al. (2007), (4) Kleijn and Sutherland (2003), (5) Botias et al. (2015), (6) Main et al. (2020), (7) Frank and Künzle (2006), (8) Barone and Frank (2003) and (9) Blaauw and Isaacs (2014).

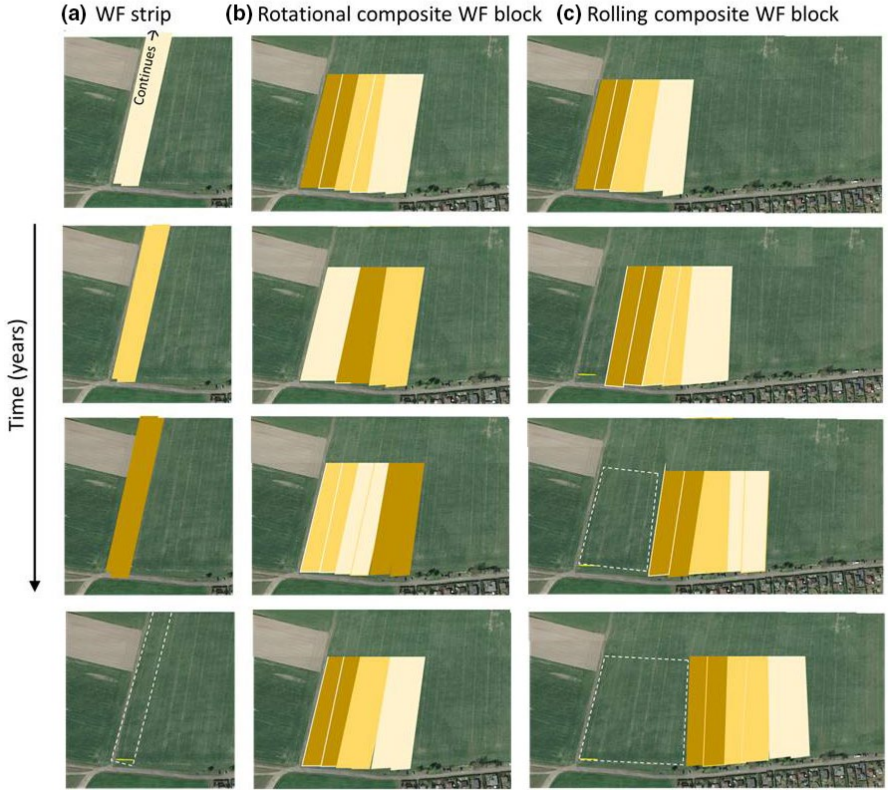

FIGURE 1 Life cycle of wildflower strips, light to dark: 1- to 3-year-old strip element. (a) Conventional short-lived wildflower (WF) strip sown in the first and removed after 3 years. Arthropod communities fluctuate with successional stage and finally disappear together with refuge, constructing an 'ecological trap' (Table 1). (b) Persistent, rotational, composite WF block, removal and re-sowing of WF strip elements, three successional stages are simultaneously available to wildlife. (c) Rolling, composite wildflower block and aged WF strips are removed at one end and new WF strips are sown at the other. (b) and (c) increase habitat heterogeneity and species richness and provide persistent refuges to wildlife. Compact shape reduces edge effects and pesticide spillover from the agricultural field. By reclaiming the area of the rolling strip for crops in (c) (dashed line), soil improvement through plants and animals may benefit agriculture

numbers of arthropods increased with age of a WF strip (Frank & Künzle, 2006; Frank & Reichhart, 2004; Frank et al., 2007).

Lastly, WF strips per definition are narrow. To allow integration into agricultural production processes, or to increase the recreational value of the landscape with an WFstrip to be seen from road, they run along field margins parallel to the furrow, mostly at a narrow width defined by sowing or mowing machinery. A high edge-to-area ratio prevents a stable core and produces edge effects along a long joint boundary with the crop field (Table 1c). This may be advantageous for the crops, as beneficial arthropods may easily reach adjoining arable areas, may be disadvantageous for the insect population inhabiting the strip. Agricultural activities in the crop, dust and **pesticides** from the adjacent field may impair insect life in a major proportion of the narrow WF strip (e.g. Botias et al., 2015; Main et al., 2020).

2 | COMPOSITE WILDFLOWER BLOCKS

Here I propose the use of composite, **persistent** wildflower (WF) blocks. WF blocks combine three or four parallel WF strip elements in different successional stages. By the replacement of aged WF strip elements every year (Figure 1), succession can be managed without the complete removal of the measure. Persistent landscape elements allow the establishment of **stable arthropod populations**. Species that are not profiting from WF strip, that is species with multiannual life cycles, and species which need a prolonged residency to thrive (Barone & Frank, 2003; Blaauw & Isaacs, 2014) could profit from persistent composite WF blocks (Table 1a). Furthermore, the direct contact of successional zones within a composite plot would facilitate the persistence of insect populations that have **low dispersal abilities**.

WF blocks may support biodiversity better than short-lived, single-aged WF strips (Table 1b). With the **simultaneous existence of different successional stages** of plants within a block, a positive effect of habitat heterogeneity on biodiversity can be expected (e.g. Benton et al., 2003; Weibull et al., 2000; Table 1b). To quantify the potential additional value of WF block for biodiversity, I collected literature records on species presence and population size for plants and insects in sown WF strips of different successional ages (Table 2a). Each successional stage of a sown WF strip harbours a specific temporary arthropod community, which is replaced by another community as the strip ages and a third of species colonise and disappear over time. Meanwhile, with spatial, simultaneous combination of successional habitat stages, species richness should accumulate. For different taxa, the **cumulative species richness**

TABLE 2 (a) Species richness and (b) population size (biomass or abundance) reported for selected taxa through **succession of wildflower (WF) strips** in crop fields; (means over replicated strip samples), cell colour indicates temporal dynamics within a study (darker: more species or higher population density respectively). **Composite projection** for a WF block accumulates species richness by including also temporary species. **Advantage of composite** is calculated relative to the average of temporary richness in successional ages of a WF strip. (b) Plant structure was calculated multiplying density and complexity estimates, animal densities by pitfall trapping or sweep netting. Abbreviations: freq., frequency; na, not applicable (strip was removed after 2 years); nr, not reported; nr. indiv., number of individuals; Ref., reference

			WF strip					Benefit of composite WF block
Taxon	Ref	Background	yr 1	yr 2	yr 3	yr 4	Composite	
(a) Species richness							Cumulative	
Sown annual plants, Switzerland	(1)	10.8	24	6.3	3.25	2.5	24	Persistence
Sown Perennials, Switzerland	(1)	4.75	23.3	26	20.3	20.1	26	Persistence
Sown and wild plant seeds, Finland	(7)		27	33	28	35	42	**Increase 36%**
30 most common bug species (Heteroptera), Switz.	(1)	11	24	26	23	21	30	**Increase 28%**
Ground beetles (Carabidae), Switzerland	(4)	22	33	29	na	na	43	**Increase 39%**
Butterflies (Lepidoptera), Germany	(5)	13	16	16	na	na	21	**Increase 31%**
Butterflies (Lepidoptera), Belgium*	(6)	nr	31	36	28	37	44	**Increase 33%**
(b) Biomass/Abundance							Mean across ages	
Plant structure (density + complexity)	(1)	4.1	6.6	9.8	7.2	9.3	8.2	Persistence
Plant seeds in soil (nr. of seeds)	(7)		72.6	17.9	14	17.3	30.4	Persistence
30 most common bug species (nr. indiv.)	(1)	40	300	450	460	465	419	Persistence
Overwintered Staphilinid beetles (nr. indiv.)	(2)	60	na	75	150	230	129	Persistence
Overwintered Carabid beetles (nr. indiv.)	(2)	7	na	17	29	28	21	Persistence
Five most common ground beetle species (nr. indiv.)	(3)	nr	378	347	469	304	419	Persistence
Ground beetles (nr. indiv)	(4)	395	1210	167	na	na	688.5	Persistence
Butterflies (Σ[species × freq. index])	(5)	29	41.6	42.5	na	na	42.05	Persistence
Butterflies (nr. indiv).	(6)	nr	83	183	101	175	135	Persistence

References: (1) Frank and Künzle (2006), (2) Frank and Reichhart (2004), (3) Frank et al. (2007) (1–3) Switzerland, investigated 20 WF strips over 4 years in a space-by-time replacement study, crop type: winter wheat, background: winter wheat; (4) Reich and Hilgendorf (2018), (5) Wix and Reich (2018), (4–5) Germany, three WF strips over 2 years in both space-by-time replacement and a longitudinal study of WF strips persisting only 2 years, background: crops, that is maize and wheat and field margins; (6) Kolkman et al. (2021), Belgium, long-term study on 20 WF strips; (7) Hyvönen and Huusela-Veistola (2011), Finland, longitudinal study with four replicate strip plots.

was 29%–39% higher than the mean annual richness reported for WF strips (Table 1). In addition, some of the studies reported only the most common species (but not the rare). Second, species with **heterogeneous habitat requirements** or species with **low dispersal abilities** are not encountered in WF strips and could therefore not be projected, although composite WF blocks would potentially satisfy their requirements. These mechanisms may increase the potential biodiversity in composite blocks beyond my (conservative) projection. The compiled studies were conducted in Central and Northern Europe, where WF stips are widespread schemes. Future studies in more southern regions with an overall higher biodiversity of plants and animals may yield different effect sizes.

Second, plant structural density, plant seeds, and density of insects fluctuate (Table 2b) with succession in WF strips (e.g. Frank & Künzle, 2006; Hyvönen & Huusela-Veistola, 2011; Kolkman et al., 2021). Assuming that densities also fluctuate across succession zones of a composite WF block, it would yet provide a stable average density. For animals foraging on insects and plants, a composite WF block would represent a **reliable and persistent food patch** in a depleted agricultural resource landscape with otherwise pulsed appearance and disappearance resources (sowing, growing, harvest). Economic benefits of pollination and pest control depend on the number of individual arthropods. Since their average density is not increased by composite blocks, increased benefits compared to WF strips should not be expected.

Further, the compact shape of a composite WF block may **reduce edge effects** and spillover of pesticides from crop fields (Table 1). Meanwhile, ecosystem services of composite WF blocks for agricultural fields (Pfiffner et al., 2009; Tschumi et al., 2016) may also suffer from decreased length of joined border compared to WF strip, but the persistence of insect populations and their ecosystem services over time may potentially outweigh these costs.

3 | MANAGEMENT AND SUBSIDIARY ISSUES

Persistent composite WF blocks can be created by either block-internally rotating WF strips of different ages on a stationary scheme

(Figure 1b), or by 'rolling' blocks over the landscape by addition of WF strips at one end and the removal of aged WF strips at the other end (Figure 1c), both to prevent establishment of perennial, grassy vegetation in aged strips. Both schemes allow to maintain a reasonable effort within agricultural practice, since annual removal and replacement consist of the management of convenient 'strip elements' parallel to tilling lines in the crop, with line dimensions adjusted to the width of sowing machines or cultivators.

Adding rows to existing WF strips increases the land area set aside temporarily for nature within an intensively farmed land use system, which may be justified by the projected increase in species richness of wildlife. To counterbalance harvest losses, the amount of compensation for set-asides within agri-environmental schemes could be connected to its biodiversity yield. However, farmers would also be able to keep the area constant by shortening the strip length (Figure 1b,c). The combined effects of WF block size and heterogeneity within the block on biodiversity and wildlife in these WF blocks meanwhile require further empirical research.

The rolling WF block scheme (Figure 1c) has an advantage over the stationary, rotational scheme (Figure 1b) by it returning its area to agriculture after being set aside for some years. This may improve soil structure and increase soil macrofauna (e.g. Frank & Reichhart, 2004; Pfiffner & Luka, 2000; Smith et al., 2008) in comparison to crop areas. Costs for setting aside areas may be variable with the rolling WF block scheme since the block may cover arable land of a better quality than WF strips that are often located in less valuable margins. The persistence of insect populations over time, and their persistent ecosystem services, may potentially outweigh these costs on other levels.

In agri-environmental schemes, the subsidies for single strip element are often regulated in width and the selection of plant species. Alas, the clustering of WF strips and the establishment of new WF strips side by side with old strips cannot be subsidised under some of the current regulations, for example the guidelines of County Brandenburg/Germany for European CAP period 2020–2025 (Richtlinie Brandenburg, 2021). In order to add composite WF blocks to agri-environmental schemes, the entire composite WF block must become subsidisabel as a landscape element, or the clustering and combination of WF strips must be explicitly allowed and facilitated.

4 | CONCLUSIONS

With biodiversity declining in our agricultural landscapes, measures supporting biodiversity and biomass of wildlife are urgently sought. Composite WF blocks introduced here can potentially increase species richness and population size of plants and insects by providing zones with different successional stages simultaneously. The combination may support additional species which a require age-heterogeneous habitats. Composite blocks could provide continuity of a refuge for insect population, also for immobile and overwintering species, and an attractive and persistent resource patches for larger animals preying on plants and insects, such as birds, bats, shrews or amphibians, which also suffered recent declines in population sizes and diversity (Donald et al., 2006).

Composite WF blocks potentially improve conservation of insect richness and restoration of insect biomass, compared to the current practice of providing short-lived WF strips. Existing subsidiary schemes subsidising WF strips can easily be converted to subsidise WF blocks by allowing the combination of differently aged strip elements in direct contact. Although a profound change in agricultural policy will be needed to restore biodiversity on a large scale, composite WF blocks may contribute to increase biodiversity of plant and animals on local scales.

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CONFLICT OF INTEREST

The author declares that there are no conflict of interest.

AUTHORS' CONTRIBUTIONS

J.A.E. developed the concept and design of the article; She performed the analysis of the data and wrote the first version of the manuscript; J.A.E. did all the revisions and approved the final version of the manuscript.

DATA AVAILABILITY STATEMENT

All data reviewed in Table 1 are available in the cited literature.

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