Effect of Green Belts in sandy arable fields on ground beetles of Schleswig-Holstein (northern Germany)

Ulrich IRMLER, Tabea SOMMER & Helge NEUMANN

Abstract: Effect of Green Belts in sandy arable fields on ground beetles of Schleswig-Holstein (northern Germany) - The effect of green belts on the ground beetles of organic arable fields on sandy soils was investigated at Langenlehsten in south-eastern Schleswig-Holstein (northern Germany) using pitfall traps from April to July 2012. The conversion from conventional to organic farming with green belts had taken place three years prior to the investigation. The species richness of ground beetles was not affected by the green belts. However, Shannon diversity and evenness showed higher values in green belts. Only four species out of 54 had higher dominance in green belts compared to arable fields. Location within fields (centre vs. margin) and field size had no influence on species richness, Shannon diversity or evenness. The Langenlehsten sites differ significantly from other arable fields in Schleswig-Holstein on account of their marginal geographic location. An overall comparison between large numbers of arable fields in Schleswig-Holstein including the Langenlehsten sites found that sand content of soils was the major factor affecting species richness of arable fields, but organic farming might have an additional effect. Taking previous findings into consideration as well, a conceptual model was developed to evaluate the benefit of green belts. According to this model, it was still too soon after conversion from conventional to organic farming and the establishment of green belts to notably affect ground beetle assemblages at the Langenlehsten sites. Significant effects can be expected after ten to fifteen years at the earliest.

1 Introduction

The loss of biodiversity in the agricultural landscape of Middle Europe has frequently been documented for soil fauna (e.g. Heydemann & Meyer 1983, Gall & Orians 1992, Paoletti et al. 1992, Irmler 2003) and pollinators, both of which benefit from organic farming (Andersson et al. 2013, Hole et al. 2005). One of the most negative effects for arthropods is the impenetrability of intensively managed arable fields. In particular for ground-dwelling beetles, intensively managed fields act as barriers, as was proven in a long-term study during the transition from conventional to organic management (Schröter & Irmler 2013). According to this study, the main positive effect of organic management on biodiversity is the elimination of the barrier effect. Therefore, the establishment of grass or flower belts, set-aside areas, grass buffers or similar structures was proposed to mitigate the negative effects of modern agricultural management and to facilitate the passage of arthropods through arable fields (Olson & Wäckers 2007, Kovacs-Hostyanszki et al. 2011, Korpela et al. 2013, Josefsson et al. 2013). However, the effects of green belts on ground beetles under organic farming conditions have rarely been studied so far. In the state of Schleswig-Holstein, the effect of green belts in organic farming on ground beetles was investigated in a project which was, however, restricted to loamy soils and mainly considered the age of green belts (Ranjha & Irmler 2013a).

The following project focused on sandy soils, which are common in wide parts of northern Germany located at the margins of former glaciers. Ground beetle assemblages of newly established green belts were investigated to address the following questions: 1) Do green belts have an effect on adjacent arable fields under organic management? 2) Do green belts facilitate the penetrability of arable fields? 3) Is the effect of green belts influenced by the size of arable fields? 4) Do the effects of green belts differ between loamy and sandy soils?

Angewandte Carabidologie 11 (2015): 3–11
ISSN: 2190-7862 (Internet)

2 Sites and methods

The green belts were established in an EU Special Protected Area (SPA) near Langenlehsten in the south-eastern part of Schleswig-Holstein, adjacent to the Mecklenburg-Vorpommern border (10°44E, 53°29N). The arable fields and green belts investigated are part of a specially managed subarea that was established in 2009 to support the local populations of threatened farmland birds, in particular, Ortolan Bunting (*Emberiza hortulana*), Skylark (*Alauda arvensis*), Wood Lark (*Lullula arborea*), and Bunting (*Emberiza calandra*). Conservation management of the subarea includes organic farming as well as constraints relating to the establishment of green belts, types and spatial distribution of arable crops, and periods of mechanical weed control (Lütt & Neumann 2010). Prior to the establishment of conservation management, the arable fields in the study area were cultivated conventionally. The total area is 110.1 ha, including 1.2 ha of woodland. It comprises a western area with comparably small-sized fields mostly divided by hedges, and an eastern area with larger-sized arable fields without hedges between them. The average size of the arable fields was 2 ha in the area with small fields and 4.5 ha in the area with larger fields. The total sand content of the soils was on average 79 % in the area with small fields and 81 % in the area with larger fields.

During the study year 2012, seven arable crops were cultivated, but adjacent to the studied green belts only winter rye was planted. The 9 m-wide green belts were established by natural succession two to three years prior to the study year. The vegetation of the green belts and the adjacent fields was identified as *Aphano-Matricarietum chamomillae*. The green belts were characterised by a higher proportion of perennials and a higher diversity of plant species compared to the adjacent fields (Sommer 2013).

The investigation was carried out using pitfall traps. One pitfall trap each was installed at distances of 15 m and 80 m from the field margin in both the green belts and the adjacent arable fields. The distance between the green belt traps and the arable field traps was 15 m. In total, 4 fields and their respective green belts were selected in the area with small and large fields. Thus, 4 types of sites were differentiated in both arable fields and green belts: marginal and central sites and small and large field areas. Pitfall traps were normal jam jars with openings of 5.6 cm diameter. Each pitfall trap had a 20 x 20 cm cover of transparent plastic to protect the trap against rainfall. They were filled with 10 % vinegar and a detergent to reduce surface tension. The investigation lasted from April 11th until harvesting began on July 25th. The pitfall traps were changed at 3-week intervals.

Data on arable fields from the rest of Schleswig-Holstein were derived from Irmler & Gürlich (2004). For the comparison of the Langenlehsten samples with those of the remaining Schleswig-Holstein the contents of three traps for each arable field opened from April to the end of July were used, because only these values are available for the arable field sites in the rest of Schleswig-Holstein. Therefore, three samples from the Langenlehsten area were combined to form one sample for this comparison.
Statistical analysis was carried out using the programms Statistica (Statsoft 2004) or Past 3.02 (Hammer et al. 2014). Nested ANOVA was used to find significant differences among the following three parameters: land use (green belts vs. arable fields), location (margin vs. centre) and field size (small vs. large); a U-Test was used for the field vs. green belt and for the small-sized vs. large-sized field comparison. Detrended Correspondence Analysis (DCA) was used to separate assemblages of ground beetles both for the 16 sites at Langenlehsten and for the subsumption of the Langenlehsten sites to the arable fields of Schleswig-Holstein. Rarefaction analysis was performed to calculate species richness of field types. The relationship between soil sand content and species richness along the gradient of the soil sand content was analysed using the Pearson correlation. To test the impact of the soil sand content and the kind of farming management on the species richness of traps, the sand content was grouped into < 50 %, 50–70 % and >70 % sand content. NPMANOVA was used to detect effects of soil sand content and farming practice (organic vs. conventional) on the number of species.

3 Results

3.1 Ground beetle assemblages of arable fields and green belts in Langenlehsten

In total, 54 species of ground beetles were found in the study area with a total of 48 species in arable fields and 50 species in green belts (Table 1). Both marginal and central traps had a total of 48 and 50 species, re-

Tab. 1: Dominance (%) of the most frequent species (more than 0.2 %) found in the four site groups.

	Arable field		Green Belt	
Species	Margin	Centre	Margin	Centre
Poecilus lepidus	62,9	66,5	44,7	38,9
Harpalus rufipes	7,4	7,5	10,7	8,7
Amara consularis	3,9	1,9	4,7	6,1
Calathus erratus	3,5	2,4	2,8	2,5
Poecilus versicolor	3,3	3,3	2,8	1,0
Amara fulva	2,2	1,6	1,9	2,7
Poecilus cupreus	1,8	2,0	3,8	1,3
Harpalus affinis	1,6	1,2	1,3	1,6
Syntomus truncatellus	1,5	2,0	3,7	2,9
Bembidion lampros	1,3	1,3	1,8	1,5
Anchomenus dorsalis	0,6	0,4	0,1	0,2
Carabus cancellatus	0,4	0,6	0,1	.
Calathus cinctus	0,4	0,3	0,5	0,6
Notiophilus aquaticus	0,3	0,3	1,0	0,5
Harpalus signaticornis	0,3	0,5	0,2	0,8
Broscus cephalotes	0,3	0,6	0,2	0,2
Harpalus distinguendus	0,3	0,3	1,5	6,0
Harpalus froelichii	0,2	0,2	0,5	1,4
Amara apricaria	0,7	0,9	1,1	2,8
Harpalus tardus	1,9	1,7	3,9	5,1
Amara aenea	1,5	0,7	3,8	5,7
Amara similata	0,8	0,2	2,3	2,2
Harpalus smaragdinus	0,2	0,3	1,5	1,9
Calathus fuscipes	1,5	1,3	2,7	3,5
Notiophilus palustris	0,2	0,2	0,3	.
Agonum sexpunctatum	0,2	0,3	0,1	.
Loricera pilicornis	0,1	0,3	0,1	0,1

spectively. The areas with both small and large fields had 47 and 46 species, respectively. The dominant ground beetle was *Poecilus lepidus* with a dominance ranging between 39 % and 63 % in the four site groups. All other species were considerably rarer, with the second most frequent species, *Harpalus rufipes*, having a maximum dominance of ca. 10 %.

The homogeneous character of the carabid assemblages is also expressed in the results of the DCA (Fig. 1). The eigenvalue of the first axis was only 0.28, which is much lower than the 0.5 value that is necessary for a significant differentiation of assemblages (Ter Braak 1987). The extremely weak separation between arable fields and green belts identified by the DCA is mainly caused by the four species *Harpalus tardus*, *Amara aenea*, *A. similata*, and *H. smaragdinus*, with significantly higher dominance in the green belts than in the arable fields according to the U-test ($p < 0.05$) (Fig. 2). The U-test also revealed that only *Calathus fuscipes* had significantly higher numbers of individuals in the green belts of the area with large-sized fields ($p < 0.05$).

The results of the nested ANOVA for single pitfall traps showed that only the type of land use has an effect on Shannon diversity and evenness (Table 2). Both Shannon diversity and evenness were significantly higher in the green belts than at the other types of sites. This effect can certainly be referred to the lower dominance values of *P. lepidus* in the green belts compared to the arable fields. No differences due to the location of the traps–at either margin, centre or in the area with either small or large fields–were observed at all. Species richness was also very similar throughout all traps for all differentiated parameters ranging between 22.8 and 23.4 species per trap.

3.1 Subsumption of Langenlehsten sites to the arable fields of Schleswig-Holstein

The results of the DCA of the arable field sites in Schleswig-Holstein showed that the sites at Langenlehsten have a marginal position, which corresponds with the geographical location of the area (Fig. 3). Overall, the type of farming management (organic vs. conventional) has a lower effect on the ordination pattern of the assemblages than the sand content of the soils. Arable fields on soils with high sand content were grouped together irrespective of their kind of farming management. Thus, the first axis of the DCA mainly represents a sand content gradient with loamy soils on the left and sandy soils on the right. The marginal position of the Langenlehsten sites in the DCA can be explained by the high dominance of *P. lepidus*. According to Irmler & Gürlich (2004), this species is found only on sandy dry grassland, heaths and dunes in the rest of Schleswig-Holstein, but never on arable fields. The occurrence of many species, e.g. *Amara fulva*, *Calathus erratus*, *Carabus cancellatus* etc, is responsible for the similarity of the ground beetle assemblages of arable fields on sandy soils between central Schleswig-Holstein and the south-eastern sites at Langenlehsten.

Organic or conventional farming management might have an additional effect because more conventionally managed fields are on the right side of the DCA than on the left side. This effect is supported by the potential species richness of the arable fields estimated by the rarefaction method that resulted

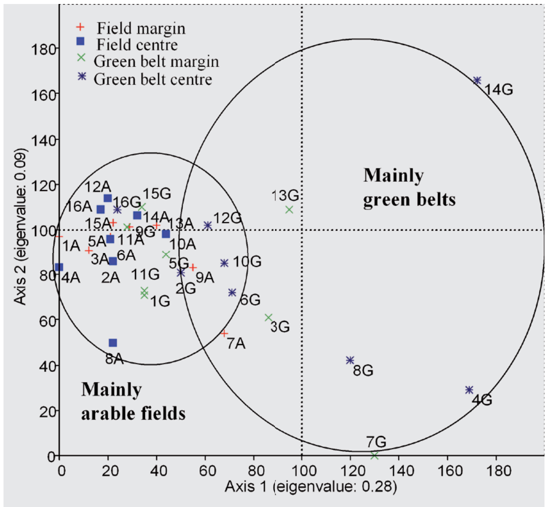

Fig. 1: Results of the Detrended Correspondence Analysis of the 16 sites with green belts at Langenlehsten; A: arable field, G: green belt.

in 90 ± 2.6 species for the 16 organic fields and 79 ± 4.3 species for the same number of conventional fields (Fig. 4). However, an analysis of species richness per three traps shows that there was hardly any difference between organic and conventional fields, with 26 ± 5.6 per 3 traps and 26 ± 6.3 per 3 traps on organic and conventional fields, respectively. In agreement with the findings of the DCA, the results of the correlation analysis shows that the soil sand content has the greatest effect on species richness, although the relationship is weak (number of species = 0.12 sand content + 18.89; $p = 0.03$, $r^2 = 0.14$) (Fig. 5). The low impact of the kind of management

Tab. 2: Average values with standard deviation (s.d.) per trap for species richness, endangered species of the 'Red List' (RL; GÜRLICH et al. 2011), Shannon diversity and evenness for the three differentiated parameters and results of nested ANOVA (DF: degree of freedom, p: error of probability, significant values underlined).

	Land use				Location				Field size			
	Field		Green belt		Margin		Centre		Large		small	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	sS.d.	Mean	s.d.	Mean	s.a.
species richness	22,8	3,8	23,4	4,2	23,3	2,9	22,9	4,9	23,3	3,4	22,9	4,6
RL-species	6,6	1,3	6,7	2,2	6,5	1,2	6,8	2,3	7,2	1,8	6,1	1,7
Shannon diversity (H)	1,49	0,37	2,03	0,39	1,77	0,41	1,75	0,53	1,68	0,34	1,84	0,56
Evenness	0,21	0,08	0,36	0,16	0,28	0,14	0,29	0,16	0,25	0,08	0,32	0,19

	Land use	Location (Land use)	Field size (Land use * Location)
species richness	DF: 1; F: 0.140; p=0.716	DF: 2; F: 0.04; p=0.959	DF: 4; F: 0.46; p=0.764
Shannon diversity (H)	DF: 1; F: 18.81; p=0.001	DF: 2; F: 0.26; p=0.773	DF: 4; F: 0.42; p=0.791
Evenness	DF: 1; F: 10.93; p=0.003	DF: 2; F: 0.35; p=0.708	DF: 4; F: 1.31; p=0.293

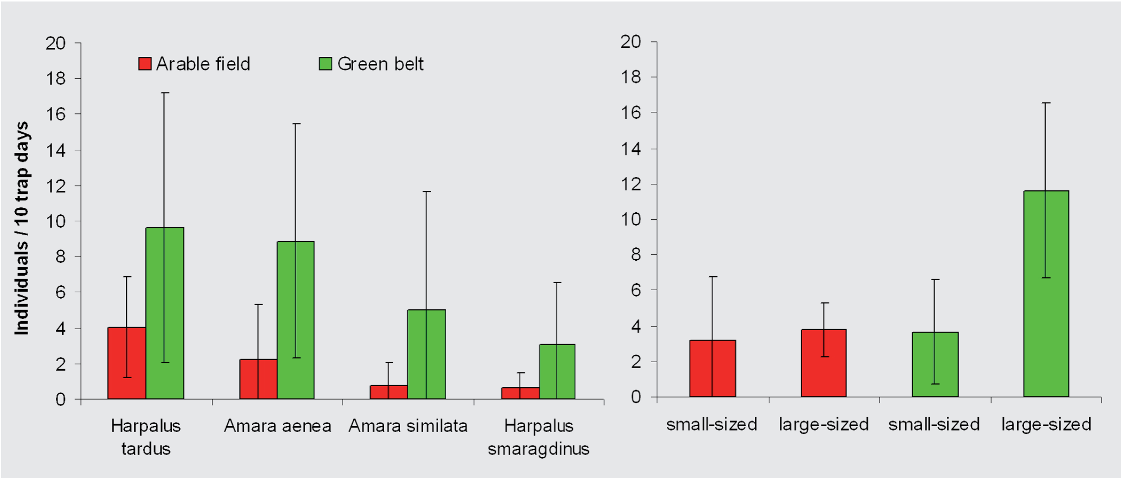

Fig. 2: Number of individuals of species with significant differences between arable fields and green belts (left) and between small-sized and large-sized fields for *Calathus fuscipes* (right).

is also supported by an NPMANOVA using soil sand content and farming practice as factors. The results showed that only sand content affects the number of species in the traps (sand content: F=3.66, p=0.02; farming management: F=0.01, p=0.98; interaction: F=-2.69, p=0.80). The Bonferroni corrected posthoc test found that only the field group with the highest sand content differs significantly from the remaining sites when the farming practice is disregarded (Table 3). As the Langenlehsten field sites account for 28 and 29 species per 3 traps, the arable sites in Langenlehsten have slightly lower numbers of species per trap than expected from the remaining sites with high sand content.

4 Discussion

The following considerations should help to develop a conceptual model for the evaluation of green belts. Many papers have already stressed the positive effect of organic agriculture on the biodiversity of arable fields (Heydemann & Meyer 1983, Irmler 2003, Hole et al. 2005, Flohre et al. 2011). Regarding the enhancement of total biodiversity through organic farming, the effect of green belts should be lower under organic farming than under conventional farming (Badenhausser & Cordeau 2012). This might certainly be one reason for the high similarity and the absence of differences between arable fields and green belts of the Langenlehsten sites.

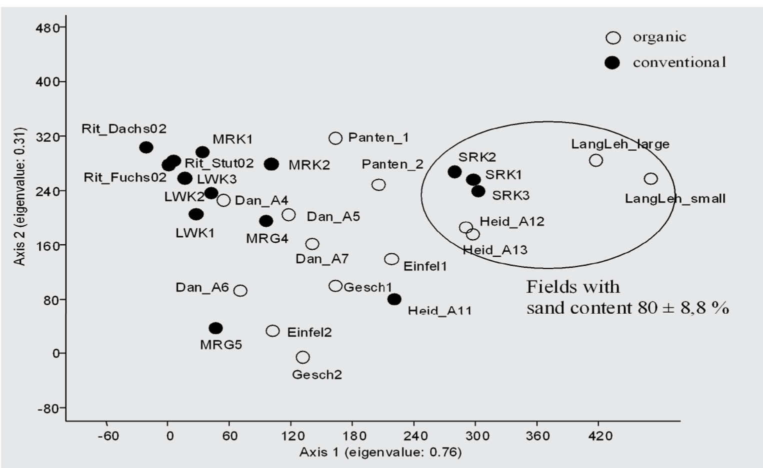

Fig. 3: Results of the Detrended Correspondence Analysis with both 14 arable field sites each under conventional and organic farming.

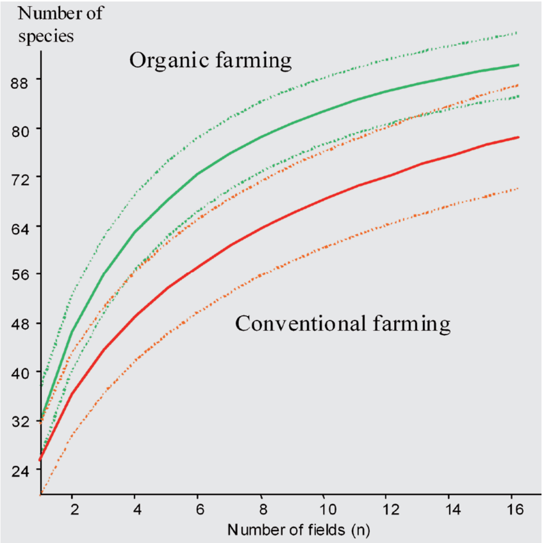

Fig. 4: Results of the Rarefaction analysis for 16 arable fields with organic (green) and conventional (red) farming (dotted lines indicate standard deviation).

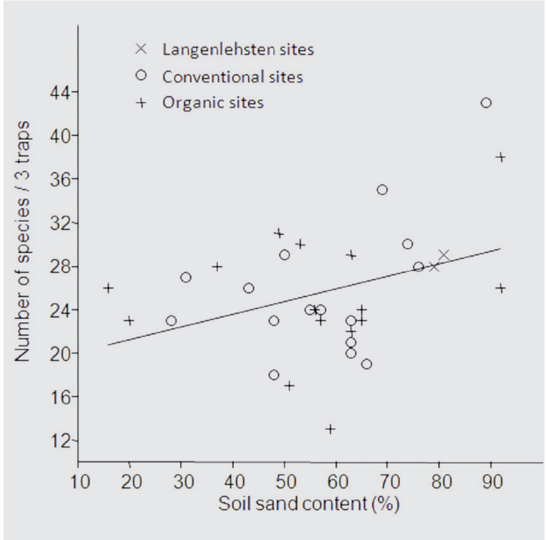

Fig. 5: Pearson correlation for 16 organic and 16 conventional field sites.

Another reason might be the short interval of three years since the establishment of organic farming at these sites. According to Schröter & Irmler (2013) the effect of organic farming on biodiversity depends on the length of time after conversion. During this process, the number of species showed no increase during the first 8 years if single traps or whole fields are taken into consideration. However, regarding different locations within the fields, many species of marginal areas invaded the fields and increased the species numbers in the field centres, which was interpreted as a breakdown of the barrier effect of conventional fields. In particular, the dominance structure of central sites changed. After conversion, the number of dominant species increased from initially two to four species to eight to ten species after eight years, equalling those of marginal sites.

Tab. 3: Average numbers of species for conventional and organic fields on arable sites of different soil sand groups with standard deviation (s.d.); *marks significant values according to NPMANOVA.

Sand (%)	Farming	N	Species	s.d.
< 50	Conventional	6	24,3	3,9
	Organic	5	25,0	5,3
50–70	Conventional	7	23,7	5,3
	Organic	8	23,5	5,2
>70	Conventional	3	*33,7	8,1
	Organic	4	*30,3	5,3

Therefore, the interval of three years after the conversion of the Langenlehsten sites was too short to be able to observe the positive effect of organic farming on the biodiversity of the agricultural fields in the area. The extreme dominance of *Poecilus lepidus* might be one indicator for the still disturbed assemblages in the area. *Poecilus lepidus* is classified as endangered in Schleswig-Holstein because it is characteristic of heaths and nutrient-poor grassland. Its dominance in the south-eastern agricultural fields of Schleswig-Holstein can be attributed to the sandy soils of the area and the continental summer-dry climate of this region that resembles that of Mecklenburg-Vorpommern. In this regard, the study region investigated here provides specific conditions and is not representative for the rest of Schleswig-Holstein. In other areas of Schleswig-Holstein, even on fields with high sand content, *Pterostichus melanarius* or *Amara fulva* developed similarly high dominances to *P. lepidus* at the Langlehsten sites (Irmler & Gürlich 2004). On the nearby fields of Ritzerau Manor, Schröter (2010) found that the dominance of *P. melanarius* decreased only slightly in the three years after conversion. In the third year, it was still the most dominant species, but dominance decreased later from 74 % in the first year to 14 % ten years later. Thus, it can be assumed that the high dominance of *P. lepidus* at the Langenlehsten sites will also decrease with passing time after the conversion.

Additionally, age also affects the green belt assemblages. Ranjha & Irmler (2013a) found that the species numbers in green belts only differ slightly from those in adjacent arable field sites after two to four years. Similar results are presented by Frank et al. (2012), who investigated wildflower areas of different ages. In their study, species richness showed no change during a succession of four years, but diversity and evenness increased with age. In the study by Ranjha & Irmler (2013a) a significant difference was found after 10 years not only in the green belts, but also in the adjacent fields. According to Ranjha & Irmler (2013b) and Ranjha & Irmler (2014) particularly species preferring woody habitats use green strips to pass through fields, whereas species preferring open habitats directly invade fields for their dispersion. Therefore, the dispersion process of ground beetles in the Langenlehsten area still seems to be influenced by the situation before conversion and the establishment of green belts. The positive function of green belts for the dispersion of ground beetles can only be recognized after at least ten years. The future development of ground beetle assemblages will be determined by the conservation management plan of the Special Protection Area 'Langenlehsten'. A long-term succession of green belts, which might promote the diversity of ground beetles, conflicts with bird protection requirements, as the green belts have to be ploughed at intervals of two to three years to recreate open soil and sparse vegetation for ground-breeding birds. However, green belts are tilled in rotation year by year to create a mosaic of younger and older belts.

Finally, another process must also be considered, namely the overall decrease in biodiversity in modern agricultural landscapes that are strongly influenced by conventional farming. For field sites on loamy soils, Irmler (2003) documented both ca. 25 ± 4 species and 34 ± 11 species on conventional and organic fields, respectively. The investigations for these results were made in the 1980s. No correspondent values have been published for fields on sandy soils such as those found at the Langenlehsten sites. Irmler & Gürlich (2004) published data, also from the 1980s, on the species richness of agricultural fields on sandy soils for 3 three conventional and two organic farms in central Schleswig-Holstein. According to these data, 31 species per 3 traps were found on conventional sites, whereas 42 species per 3 traps occurred on organic fields. The 28 or 29 species per 3 traps in the Langenlehsten sites investigated in 2012 are much closer to the figures for conventional sites than the organic sites of the 1980s. Because of the low number of replicates, these results cannot be statistically tested. However, the comparison might indicate that the success of the Langenlehsten experiment for ground beetles might be limited by an overall loss of biodiversity in the agricultural landscape.

A conceptual model for evaluating the success of green belts has to consider all these factors, as presented in Fig. 6. Sand content of soils is the overall primary factor for the species richness of ground beetles in arable landscapes. Agricultural landscapes on soils with more than 75 % sand content have significantly more species than sites with lower sand content regardless of the type of farming management. However, the potential species richness of the landscape can be influenced by farming practices, such as conventional vs. organic farming or the existence vs. absence of green belts. Nevertheless, to have an effect on ground beetles this provision needs time, which is estimated at ten to fifteen years at least. According to Ranjha & Irmler (2013a), moreover, it can be assumed that the overall biodiversity of the agricultural landscape might benefit from these changes, because field mar-

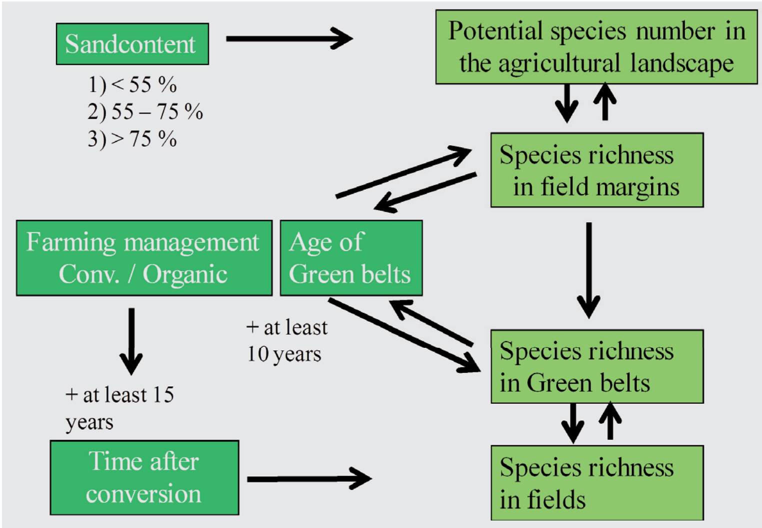

Fig. 6: Conceptual model to evaluate the effects of green belts in agricultural fields.

gins adjacent to old green belts develop higher species richness than those adjacent to young green belts. Relations between in-field diversity and landscape diversity in terms of farming intensity were found by various studies. Bohan & Haughton (2012) could explain their results of the wild bee population in Great Britain only with the effect of farming intensity on weed frequency. Batary et al. (2012) showed that agro-environmental management needs to be adjusted to the agroecosystems field size, because larger edge areas led to higher species richness on the landscape scale. The relationship between field diversity and landscape diversity is also supported by studies with different mixtures of organic and conventional farming (Purtauf et al. 2005), whereas Eyre et al. (2013) listed a number of different habitat structures, such as different crops, field boundaries, productivity and disturbance levels, that are responsible for a high diversity on the landscape level.

For the Langenlehsten sites, the time interval after conversion and the establishment of green belts was too short to conclusively evaluate the effect of the management changes. It might be that the overall species richness of the area is lower than it was 20 years ago given the overall extinction process in arable landscapes; nevertheless, results in other regions of northern Germany offer hope that in the Langenlehsten area, too, changes in farming management will increase biodiversity after ten to fifteen years.

References

ANDERSSON, G.K.S., EKROOS, J., STJERNMAN, M., RUNDLÖF, M. & H.G. SMITH (2013): Effects of farming intensity, crop rotation and landscape heterogeneity on field bean pollination. – Agriculture, Ecosystems and Environment 184: 145–148.

BADENHAUSSER, I. & S. CORDEAU (2012): Sown grass strip - A stable habitat for grasshoppers (Orthoptera: Acrididae) in dynamic agricultural landscapes. – Agriculture, Ecosystems and Environment 159: 105–111.

BATARY, P., HOLSZSCHUH, A., ORCIC, K.M., SAMUD, F. & T. TSCHARNTKE (2012): Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. – Agriculture, Ecosystems and Environment 146: 130–136.

BOHAN, D.A. & A.J. HAUGHTON (2012): Effects of local landscape richness on in-field weed metrics across the Great Britain scale. – Agriculture, Ecosystems and Environment 158: 208–215.

EYRE, M.D., LUFF, M.L. & C. LEIFERT (2013): Crop, field boundary, productivity and disturbance influences on ground beetles (Coleoptera, Carabidae) in the agroecosystem. – Agriculture, Ecosystems and Environment 165: 60–67.

FLOHRE, A., RUDNICK, M., TRASERC, G., TSCHARNTKE, T. & T. EGGERS (2011): Does soil biota benefit from organic farming in complex vs. simple landscapes? – Agriculture, Ecosystems and Environment 141: 210–214.

FRANK, T., AESCHBACHER, S. & J.G. ZALLER (2012): Habitat age affects beetle diversity in wildflower areas. – Agriculture, Ecosystems and Environment 152: 21–26.

GALL, G.A.E. & G.H. ORIANS (1992): Agriculture and biological conservation. – Agriculture, Ecosystems and Environment 42: 1–8.

GÜRLICH, S., SUIKAT, R. & W. ZIEGLER (2011): Die Käfer Schleswig-Holsteins–Rote Liste. Bd. 1-3. Ministerium für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (MLUR), Kiel.

HAMMER, Ø., HARPER, D.A.T. & P.D. RYAN (2014): PAST: Paleontological statistics software package for education and data analysis. – Palaeont. Electronica 4: 1–9.

HEYDEMANN, B. & H. MEYER (1983): Auswirkungen der Intensivkultur auf die Fauna in den Agrarbiotopen. – Schriftenreihe des Deutschen Rates für Landespflege 42: 174–191.

HOLE, D., PERKINS A.J., WILSON, J.D., ALEXANDER I.H., GRICE, P.V. & A.D. EVANS (2005): Does organic farming benefit biodiversity?–Biological Conservation 122: 113–130.

IRMLER, U. & S. GÜRLICH (2004): Die ökologische Einordnung der Laufkäfer (Coleoptera: Carabidae) in Schleswig–Holstein. – Faunistisch-Ökologische Mitteilungen Supplement 32: 3–113.

IRMLER, U. (2003): The spatial and temporal pattern of Carabid beetles on arable fields in northern Germany (Schleswig-Holstein) and their value as ecological indicators. – Agriculture, Ecosystems and Environment 98: 141–151.

JOSEFSSON, J., BERG, A., HIRON, M., PÄRT, T. & S. EGGERS (2013): Grass buffer strips benefit invertebrate and breeding skylark numbers in a heterogeneous agricultural landscape. – Agriculture, Ecosystems and Environment 181: 101–107.

KORPELA, E.-L., HYVÖNEN, T., LINDGREN, S. & M. KUUSSAARI (2013): Can pollination services, species diversity and conservation be simultaneously promoted by sown wildflower strips on farmland?–Agriculture, Ecosystems and Environment 179: 18–24.

KOVACS-HOSTYANSZKI, A., KÖRÖSI, A., ORCIB, K.M., BATARYC, P. & A. BALDI (2011): Set-aside promotes insect and plant diversity in a Central European country. – Agriculture, Ecosystems and Environment 141: 296–301.

LÜTT, S. & H. NEUMANN (2010): Schleswig-Holsteins Beitrag zum bundesweiten Biodiversitätsprojekt "100 Äcker für die Vielfalt". – Kieler Notizen zur Pflanzenkunde 37: 115–120.

OLSON, D.M. & F.L. WÄCKERS (2007): Management of field margins to maximize multiple ecological services. – Journal of Applied Ecology 44: 13–21.

PAOLETTI, M.G., PIMENTEL, D., STINNER, B.R. & D. STINNER (1992): Agroecosystem biodiversity: matching production and conservation biology. – Agriculture, Ecosystems and Environment 40: 3–23.

PURTAUF, T., ROSCHEWITZ, I., DAUBER, J., THIES, C., TSCHARNTKE, T. & V. WOLTERS (2005): Landscape context of organic and conventional farms: Influences on carabid beetle diversity. – Agriculture, Ecosystems and Environment 108: 165–174.

RANJHA, M.H. & U. IRMLER (2013A): Age of grassy strips influences biodiversity of ground beetles in organic agro-ecosystems. – Agricultural Sciences 4: 209–218.

RANJHA, M.H. & U. IRMLER (2013B): Which carabid species benefit from grassy strips in organic agriculture?–Angewandte Carabidologie 10: 13–22.

RANJHA, M.H. & U. IRMLER (2014): Movement of carabids from grassy strips to crop land in organic agriculture. – Journal of Insect Conservation 18: 457–467.

SCHRÖTER, L. (2010): Lauf- und Kurzflügelkäfer (Coleoptera: Carabidae, Staphylinidae) auf Ackerflächen während der Umstellung vom konventionellen zum ökologischen Anbau. – Faunistisch-Ökologische Mitteilungen Supplement 36: pp. 144.

SCHRÖTER, L. & U. IRMLER (2013) Organic cultivation reduces barrier effect of arable fields on species diversity. – Agriculture, Ecosystems and Environment 164: 176–180.

SOMMER, T. (2013): Bedeutung selbst begrünter Brachestreifen für die Segetalflora und Laufkäferfauna von Sandäckern im ökologischen Landbau. – Masterarbeit, Universität Kiel, pp. 64.

STATSOFT (2004): Inc. STATISTICA for Windows [Software-System for Data analysis] Version 6.

TER BRAAK, C.J.F. (1987): Ordination. In: JONGMAN R.H.G., TER BRAAK, C.J.F. & O.F.R. VAN TONGEREN (eds.). Data analysis in community and landscape ecology. – Pudoc, Wageningen.

Manuskripteingang: 6.1.2015

Addresses of authors

Ulrich Irmler
Institute for Ecosystem Research,
Dept. Applied Ecology,
University of Kiel,
Olshausenstrasse 40,
24098 Kiel,
E-mail: uirmler@ecology.uni-kiel.de

Tabea Sommer
Olendorp 39,
29320 Hermannsburg,
E-mail: TabeaSommer@gmx.de

Helge Neumann
Deutscher Verband für
Landschaftspflege (DVL) e. V.,
Artenagentur Schleswig-Holstein
Hamburger Chaussee 25,
24220 Flintbek,
E-mail: h.neumann@lpv.de