Enhancing biodiversity on arable farms in the context of environmental certification schemes

Manhoudt, A.G.E.

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AVAILABILITY OF SHELTER SITES FOR SMALL MAMMALS AND BIRDS ON DUTCH ORGANIC AND CONVENTIONAL ARABLE FARMS

Astrid Manhoudt and Geert de Snoo

Summary

In agricultural landscapes as elsewhere, birds and mammals require suitable shelter for nesting, resting, foraging and overwintering. Shelter availability is determined by the vegetation structure of semi-natural habitats and crops, as these vary across space and time. A habitat method has been developed to assess on-farm shelter availability for bird and mammal species based on vegetation height and cover. Using general data on vegetation structure, shelter habitat availability was derived for four individual species in summer or winter. This pilot study was performed in one province of the Netherlands for the nesting of the skylark (*Alauda arvensis*) and harvest mouse (*Micromys minutus*) in summer and for the wintering of the partridge (*Perdix perdix*) and brown hare (*Lepus europaeus*). Differences between three farm types were investigated and potential causes of any differences discussed in relation to farm layout, semi-natural habitat management regime and implementation of agri-environmental schemes. Three types of farm were selected for study: *conventional farms* with an intensive ditch bank mowing regime; *conventional-plus farms* with field margins implemented under the Dutch Agri-Environmental Scheme and an extensive ditch bank mowing regime; and *organic-plus farms* with field margin strips implemented jointly under an Agri-Environmental Scheme or an on-farm conservation plan and again with an extensive ditch bank mowing regime.

Because of their crop rotation schemes, *organic-plus farms* had larger expanses of uncovered soil than *conventional farms* in both autumn and winter. The sown field margins on *conventional-plus farms* and the additional conservation plans implemented on *organic-plus farms* resulted in higher percentage areas of semi-natural habitat per farm and larger areas of completely covered soil than on *conventional farms*.

In summer, the *organic-plus farms* provide less suitable shelter habitat for skylarks and harvest mice than *conventional farms*, owing to differences in crop rotation schemes. In winter, none of the farm types provide any suitable shelter habitat for the brown hare. In the case of the partridge, organic-plus farms and *conventional-plus farms* perform better during winter than *conventional farms*, thanks to the presence of field margins.

The developed shelter-habitat method can easily be used to calculated the amount of suitable habitat on a given farm in a specific season, based on defined shelter-requirements for a given species. A

comparison of different farming systems in relation to the species requirements showed differences related to crop rotation, farm layout and management regimes. Although significant differences in shelter site availability existed, these appear not to be strictly related to the different types of farms. It is argued here that consistent attention for this characteristic has the potential to improve our habitat method. The method can then usefully contribute to further development of farming methods geared to improving biodiversity. It can also be used for overall assessment of farm holdings for the purpose of benchmarking or environmental labelling schemes.

5.1 Introduction

Bird and mammal diversity in agricultural landscapes has declined dramatically in Europe since the Second World War (Baldock, 1990; Swift and Anderson, 1993; Fuller *et al.*, 1995; Delbaere, 1998). This decline in species numbers can be ascribed to changes in food availability and loss of suitable nesting and shelter habitats. Many studies addressing these issues have focused on food availability or nesting habitats for bird and mammal species (Sotherton *et al.,* 1985; Potts, 1986; Chamberlain *et al.*, 1999; Duelli *et al.*, 1999; Wilson *et al.,* 1999; Smart *et al.*, 2000; Donald *et al.*, 2001; Holland *et al.*, 2002; Smeding and de Snoo, 2003; Asteraki *et al.,* 2004). This article focuses on the shelter for birds and small mammals provided by semi-natural habitats and crops on arable farms in summer as well as in winter, which until now has received little attention from researchers.

Shelter opportunities for small mammals and birds are dependent on vegetation height and cover as these vary with the seasons (e.g. Wilson *et al.,* 1997; Maisonneuve and Rioux, 2001) as well as on the diversity of semi-natural habitats and crops on the farm and in the surrounding landscape (Arnold, 1983; Fitzgibbon, 1997; Hinsley and Bellamy, 2000; Fuller *et al.,* 2001; Benton *et al.,* 2003). Differences in on-farm vegetation structure will depend on 1) the farming system, 2) the farm layout and 3) how semi-natural habitats are managed.

Empirical comparisons of farming systems have shown that bird diversity is significantly higher on organic farms than on *conventional farms* (Fuller *et al.,* 1995; Wilson *et al.,* 1997; Chamberlain *et al.,* 1999; Norton, 2002). Although mammal species diversity has not often been studied in this respect, differences are to be expected here, too. Factors proposed to account for differences between farming systems have included crop protection and rotation schemes, land use intensity and food resources (Fuller *et al.,* 1995; Wilson *et al.,* 1997; Chamberlain *et al.,* 1999; Norton, 2002). In addition to these factors, variation in vegetation structure might also explain some of the differences.

In terms of farm layout, the vegetation structure will also be influenced by the implementation of agri-environmental schemes (LNV, 1997; LASER, 2004) or other kinds of on-farm conservation plan (Vereijken *et al.,* 1997; Smeding and Joenje, 1999; Visser, 2000). The agri-environmental schemes for improving fauna diversity are implemented on many arable farms (Kleijn and Sutherland, 2003; van Duuren *et al.,* 2003), conventional as well as organic. Most often permanent field margin strips are created under these schemes. Also, other on-farm conservation plans have been frequently adopted by organic and conventional farmers (Melman *et al.*, 2004). Most of these plans encourage creation of field margins sown with grass and herb mixtures. Most of these prescribed field margin are often implemented under Dutch agri-environmental schemes as well. Therefore, agri-environmental schemes and on-farm conservation plans are likely to influence farm layout and therefore vegetation structure, too.

Finally, the vegetation structure of semi-natural habitats on a given farm holding will be influenced by the management regime in force. Intensively managed semi-natural habitats such as ditch banks that are frequently mown or clipped will develop shorter herbaceous vegetation, which may reduce the amount of shelter available to mammal and bird species for nesting and resting.

The objective of this study was to develop a method to assess on-farm shelter availability for birds and mammals determined as a function of the vegetation structure (height and cover) of semi-natural habitats and crops on arable farms. A pilot study was performed to determine the amount of suitable shelter habitat for the nesting of the skylark (*Alauda arvensis*) and harvest mouse (*Micromys minutus*) in summer and for the wintering of the partridge (*Perdix perdix*) and brown hare (*Lepus europaeus*). For each of these species, differences in the amount of suitable habitat per farm were derived from general data on vegetation structure of crops and semi-natural habitats per farm and investigated in relation to farming systems, farm layouts and management regimes.

5.2 Methods

General information

A total of 15 arable farms were visited in the Dutch coastal province Zeeland (marine clay soil). Three types of farm were selected for study: 1) *conventional farms* with an intensive ditch bank mowing regime: first cut in May, with at least 3 cuts a year; 2) *conventional-plus farms* with field margins implemented under the Dutch Agri-Environmental Scheme (AES) and an extensive ditch bank mowing regime: first cut in June, with 2 or fewer cuts a year, and 3) *organic-plus farms* with field margin strips implemented jointly under an Agri-Environmental Scheme or an on-farm conservation plan (Vereijken *et al.,* 1997; Smeding and Joenje, 1999; Visser, 2000) and again with an extensive ditch bank mowing regime.

While the field margins on the *conventional-plus farms* simply implement Dutch Agri-Environmental Schemes (LASER, 2004), the conservation plans on the *organic-plus farms* also seek to increase the amount of variation in on-farm semi-natural habitat and improve connectivity between semi-natural habitats on the farm and with the surrounding landscape. The latter also aim specifically to create and maintain at least 5% of semi-natural habitat on the farm (Vereijken *et al.,* 1997; Smeding and Joenje, 1999; Visser, 2000). The sown field margins prescribed under these plans are usually implemented partly or wholly under the terms of an Agri-Environmental Scheme (LASER, 2004).

For each type of farm, five farm holdings were selected for study. Data was collected on each farm on the number of crops and semi-natural habitats and the area encompassed by each. The sample included one organic mixed farm, where only arable production was taken into account.

Measurements

In all crops and semi-natural habitats on the farm, vegetation and crop height and cover was monitored every two months for one year (2002). The herbaceous vegetation height in the semi-natural habitats was measured as well as the crop height on the fields. Height measurements were performed by lowering a circular foam disc (diam. = 16 cm, weight = 10 g) onto the vegetation. In addition, percentage vegetation cover was estimated per square meter on the same place. In the most common crops (summer and winter wheat, ware potatoes and sugar beet) and semi-natural habitats (ditch banks, hedgerows and field margin strips) 10 measurements of height and cover were made each time. In other crops, e.g. onions, beans and sugar maize, only one estimate of crop height and cover was made.

Data analysis

For the commonest arable crops (summer and winter wheat, ware potatoes and sugar beet) and semi-natural habitats (ditch banks, field margins and hedgerows), average vegetation height and cover were calculated per crop or semi-natural habitat for each moment of measuring. Differences in vegetation height and cover between the three types of farm were tested using a separate nested General Linear Model-univariate analysis after logarithmic transformation per measuring date (SPSS 11.0; Sokal and Rohlf, 1981). Post hoc tests (Least Significant Differences) were performed by means of ANOVA-univariate analysis (SPSS 11.0).

Per type of farm, the average percentage of total farm area was calculated for each class of vegetation height and cover as a function of time (height: 0 cm, 1-25 cm, 26-50 cm, 51-75 cm, 76-100 cm and >100 cm; cover: 0%, 1-25%, 26-50%, 51-75% and 76-100%). The majority of the arable crops were included in the calculations, with only vegetables and several rare arable crops being excluded. On average, 91% of the farm area was taken into account. Differences in vegetation cover between the three farm types were tested using ANOVA-univariate analysis (LSD) after logarithmic transformation per measuring date (SPSS 11.0).

Estimation of winter and summer shelter habitat availability

Summer habitat

For the pilot study, one bird and one mammal species were selected for each season: for summer the skylark (*Alauda arvensis*) and harvest mouse (*Micromys minutus*) and for winter the grey partridge (*Perdix perdix*) and brown hare (*Lepus europaeus*). These are characteristic species of arable farms for which key conservation targets are today in force, given the marked decline in numbers in recent years (Tew *et al.,* 1994; Panek, 1997; Wilson *et al.,* 1997; Chamberlain *et al.,* 1999; Chamberlain and Fuller, 2000; Edwards *et al.,* 2000; Bence *et al.,* 2003). For each species a specific shelter function was selected, e.g. nesting or resting.

The skylark (*Alauda arvensis*) nests in a variety of crops during summer, depending on percentage vegetation cover and vegetation height. If the vegetation becomes too tall and dense, it will not return to the same nest for the next brood, probably for reasons of impaired orientation and locomotion on the ground (Toepfer and Stubbe, 2001). Varying figures are reported in the literature for optimum vegetation height and cover (Chamberlain *et al.,* 1999; Wilson *et al.,* 1997; Toepfer and Stubbe, 2001). For this species, we defined the optimal shelter for nesting as 20 to 50 cm for vegetation height and 35 to 90% cover. As the skylark seeks a new nesting site for each brood, the average percentage of suitable habitat was calculated for the period April to June (Table 1).

The harvest mouse (*Micromys minutus*) lives on ditch banks and in field margins and cereal crops in the summer. As it builds its grass-woven nest above-ground, the species needs tall vegetation for nesting. Its nesting height ranges from 20 to 100 cm above grade (Broekhuizen *et al.,* 1992; Lange *et al.,* 1994; Bence *et al.,* 2003), although total vegetation height should be at least twice that. We took a minimum height of 60 cm for harvest mouse nesting (personal communication P. Twisk) with 80% cover prior to nesting (Table 1). The average percentage of suitable habitat during the period April to August was calculated for the relevant crops and habitats: summer and winter wheat, ditch banks and field margin strips.

Table 1: Habitat requirements in summer for the skylark (*Alauda arvensis*) and harvest mouse (*Micromys minutes*) and in winter for the partridge (*Perdix perdix*) and brown hare (*Lepus europaeus*) in relation to vegetation height and cover for nesting or shelter in a specific period of the year.

	Function	Criteria: 1. height	2. cover	3. period
Summer:				
skylark	nesting	min. 20 cm	min. 35%	April - June
		max. 50 cm	max. 90%	
harvest mouse	nesting	>> 60 cm	min. 80%	April - August
Winter:				
partridge	shelter	>> 20 cm	-	October - February
brown hare	shelter	>> 40 cm	min. 50%	October - February

Winter habitat

Survival of grey partridges (*Perdix perdix*) depends mainly on insect food availability (Panek, 1997; Holland *et al.,* 2002 and others), but adequate availability of resting and nesting shelter throughout the year are also important (LNV, 1991). In winter there is often little shelter available to protect partridges from predators. Based on body length, we presumed that a minimum winter vegetation height of 20 cm is required to provide adequate shelter and protection and for each farm we therefore calculated the minimum area with vegetation higher than 20 cm available in winter (Table 1).

The brown hare (*Lepus europaeus*) is a largely nocturnal animal that forages on grassy vegetation and crops (Lange *et al.,* 1994). During daytime it rests in a ‘form’, a shallow depression generally shielded by shrubs and bushes, to protect itself from predators (Angelici *et al.,* 1999). In most cases these are to be found in vegetation with a minimum height of 40 cm and 50% cover (Meriggi and Verri, 1990). In winter, suitable sites are limited. For each farm we therefore calculated the minimum area with the required vegetation height of 40 cm and 50% cover in winter (Table 1).

5.3 Results

Farm characteristics

The average percentage of semi-natural habitat per farm was lowest on the *conventional farms* (2.3 ± 0.4%), with *organic-plus farms* and *conventional-plus farms* both scoring significantly higher at 7.3% semi-natural habitat per farm (P < 0.05; Table 2). The average number of semi-natural habitats per farm did not differ significantly among farm types (conventional: 4.4 ± 0.5; organic-plus: 6.0 ± 1.2; conventional-plus: 6.4 ± 2.3). Most frequently seen semi-natural habitats were ditches, ditch banks, field margins and hedgerows. Other types of semi-natural habitat found were e.g. trimmed hedges, pools and tree rows. The *organic-plus farms* had a higher number of arable crops (8.0 ± 1.2; P = 0.062) than both types of *conventional farms* (on average 6), a difference nearly statistically significant.

Table 2: Average number of crops and semi-natural habitats, percentage area of semi-natural habitat, and average farm area per farm type (ANOVA: * = P < 0.05; a = no significant difference between groups).

	Organic-plus farms	*Conventional farms*	*Conventional-plus farms*
Semi-natural habitats:			
percentage area of farm	7.3 ± 7.5%[a]	2.3 ± 0.4%[*]	7.3 ± 2.8%[a]
no. of habitats	6.0 ± 1.2	4.4 ± 0.5	6.4 ± 2.3
Crops:			
total area of crop	44 ± 24.3 ha	35.5 ± 18.2 ha	60.9 ± 36.0 ha
no. of crops	8.0 ± 1.2	6.2 ± 1.3	6.0 ± 1.6

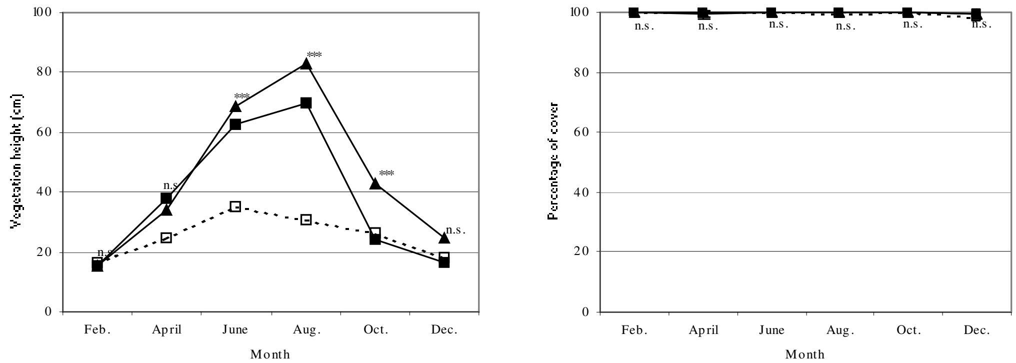
Vegetation height and cover of semi-natural habitats and crops

Ditch banks under an extensive mowing regime on *conventional-plus farms* as well as on *organic-plus farms* had significantly taller vegetations in spring and summer than under an intensive mowing regime on the *conventional farms* (Figure 1A; P < 0.001). Only in winter and early spring was there no difference in vegetation height among farm types. All ditch banks had full vegetation cover all year round, i.e. 100% cover (Figure 1A).

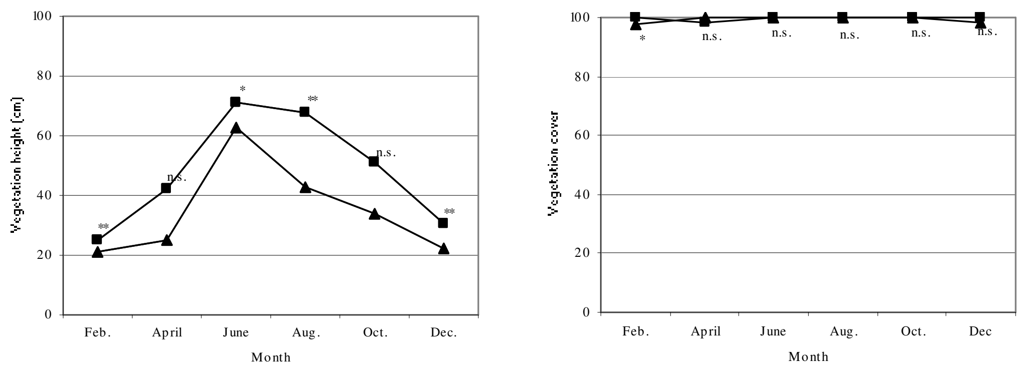
The vegetation in the field margins was significantly taller on *conventional-plus farms* than on *organic-plus farms* for most of the year (Figure 1B; P < 0.001). Only in April and October was no difference found, owing to the high degree of variance among farms. The field margins had full vegetation cover for most of the year (significantly different in February only: P< 0.05) on all organic-plus and *conventional-plus farms*.

The height of herbaceous vegetation at the bottom of the hedgerows varied little among farm types, although it was significantly or nearly significantly lower on the *conventional farms* than on the *conventional-plus* and *organic-plus farms* (Figure 1C: P< 0.05 in April, August till December and P = 0.06 in February). On most dates, vegetation cover was significantly or nearly significantly higher on *organic-plus farms* than on both types of conventional farm (Figure 1C: P < 0.05 in February, August till December and P = 0.063 and 0.092 in April and June, respectively). The high amount of herbaceous vegetation cover beneath hedgerows on *organic-plus farms* was due to one farm having a relatively young hedgerow, which therefore still had a very open bush and tree layer.

A Ditch banks



B Field margin strip



C Hedgerows

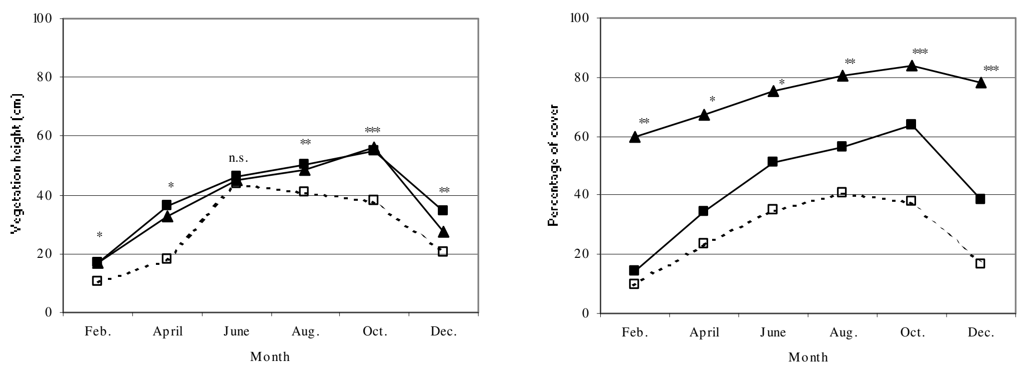
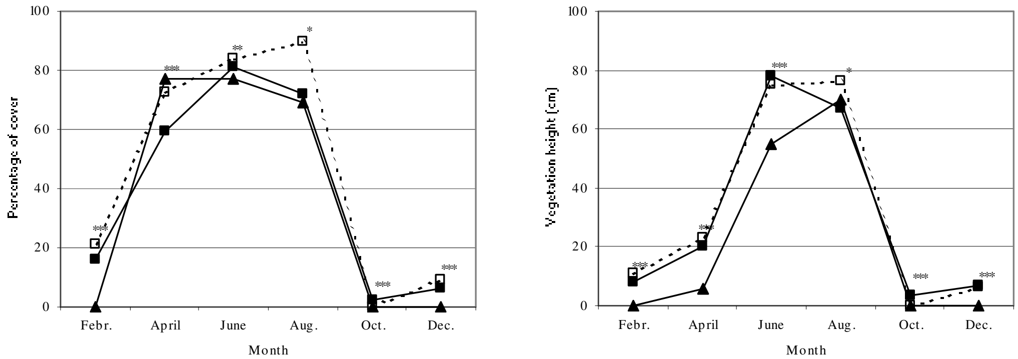


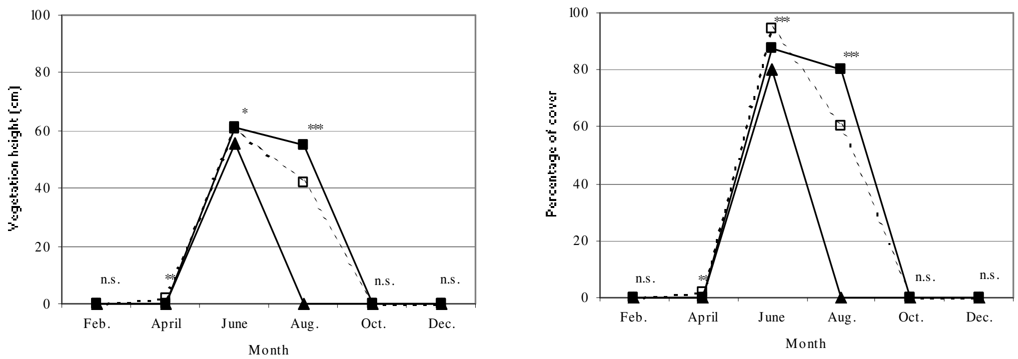
Figure 1: Average vegetation height (cm)and average vegetation cover (percentage) as a function of time for the semi-natural habitats ditch banks (A), field margins (B) and hedgerows (C) and for the crops summer and winter wheat (D), ware potatoes (E), sugar beet (F) on *organic-plus farms* (▲; n = 5), *conventional farms* (□; n = 5) and *conventional-plus farms* (■; n = 5) (GLM-univariate analyse with n.s. = not significant; *: P < 0.05; ** = P < 0.01 and *** = P < 0.001).

Figure 1 *continued.*

D Summer and winter wheat



E Ware potatoes



F Sugar beet

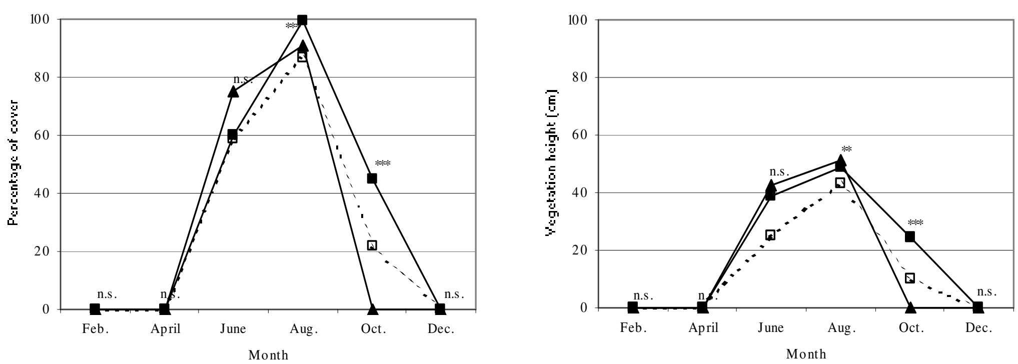


Figure legend: *organic-plus farms* (▲), *conventional farms* (□) and *conventional-plus farms* (■) (n.s. = not significant; *: $P < 0.05$; ** = $P < 0.01$ and *** = $P < 0.001$).

Although there were only minor differences in crop height in summer and winter wheat (Figure 1D), vegetation height in winter, spring and early summer was higher on both types of conventional farm than on *organic-plus farms* ($P < 0.05$). The crop height of ware potatoes remained significantly lower on *organic-plus farms* throughout the cropping season (Figure 1E: $P < 0.05$). On these farms the potato harvest started earlier because of the increased risk of late blight infestation (Phytophtora infestans) and in August there was therefore no crop cover. Differences in the sugar beet crop (Figure 1F) were established only later in the season. However, no consistent time sequence emerged for crop height and cover. For example, in August the vegetation was higher on *conventional-plus farms* ($P < 0.001$), while in October all farm types showed significant mutual differences ($P < 0.001$), the latter due to different times of harvest.

Vegetation height and cover per farm type

Comparison of overall vegetation height and cover on each farm (Figure 2) showed that a larger fraction was bare of vegetation in autumn and winter on *organic-plus farms* ($P < 0.05$ in October, December and February) than on both types of conventional farm. This difference was due to the cultivation of spring wheat opposed to winter wheat and grass seed (all sown in autumn) on both types of conventional farm (Figure 2). Furthermore, the *conventional farms* had a slightly greater percentage area with winter vegetation (38% of the farm) than the *conventional-plus farms* (32% of the farm), because of the higher relative share of winter wheat and grass seeds in their crop rotation.

The field margins on the *conventional-plus* and *organic-plus farms* meant that these holdings had a greater area with 100% vegetation cover throughout the year: on average 6.8% and 10.4%, respectively compared to 1.4% on *conventional farms*.

In summer, the farm area with 100% vegetation cover was significantly smaller on the *organic-plus farms* than on either type of conventional farm ($P < 0.001$). Moreover, the maximum of 100% covered soil was attained later in the season: in August on the *organic-plus farms*, as opposed to June on the *conventional farms* (owing to later germination of different bean species and sugar maize).

Shelter habitats in summer and winter

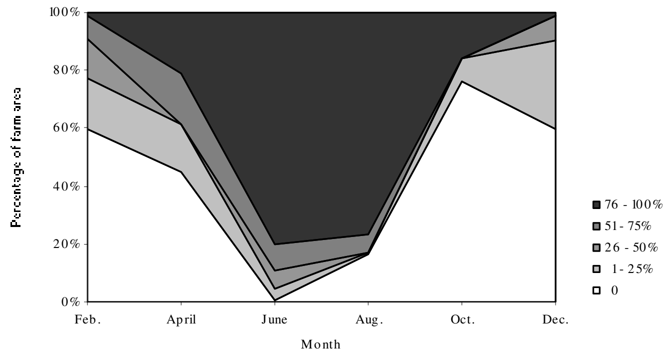
In summer the available nesting habitat for the skylark was lower on both organic-plus and *conventional-plus farms* (18.7% of the farm area) than on *conventional farms* (28.8% of the farm area, Table 3). This difference was due to the higher amount of winter wheat and sugar beet on the *conventional farms* compared with the others.

Table 3: Average percentage of suitable farm area in spring and summer for nesting of the skylark (*Alauda arvensis*) and harvest mouse (*Micromys minutes*) and minimum percentage of suitable shelter habitat in winter for the partridge (*Perdix perdix*) and brown hare (*Lepus europaeus*) per farm type.

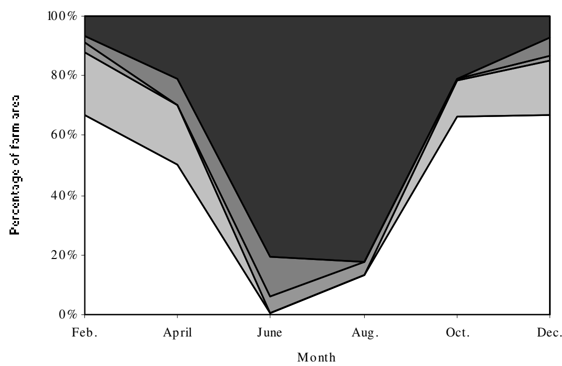
Farm type	*Organic-plus farms*	*Conventional farms*	*Conventional-plus farms*
Summer:			
skylark	18.7%	28.8%	18.7%
harvest mouse	13.8%	27.7%	23.8%
Winter:			
partridge	3.1%	0.3%	4.9%
brown hare	0%	0%	0%

Shelter site availability

A Conventional farms



B Conventional-plus farms



C Organic-plus farms

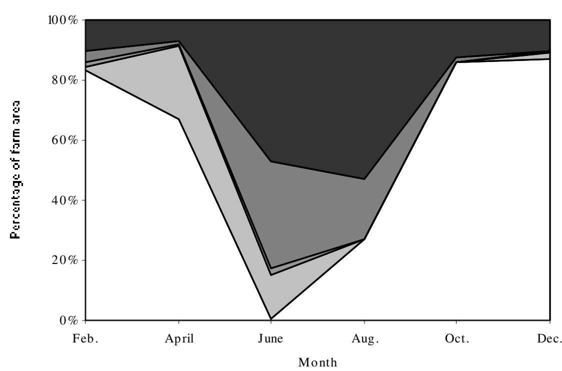
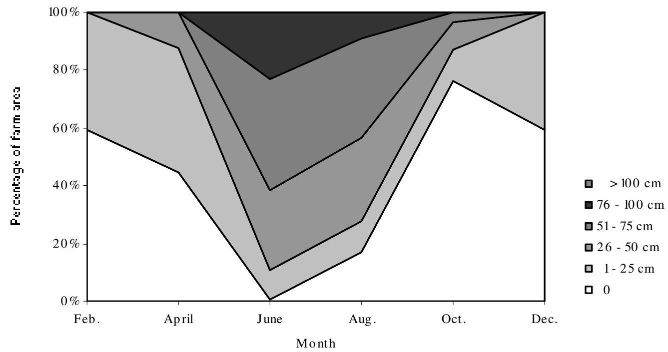
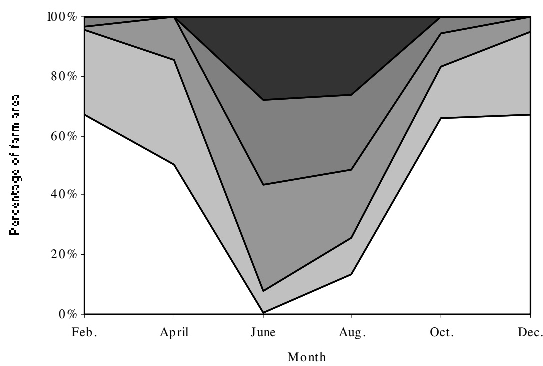


Figure 2: Average percentage of farm area per class of vegetation cover (column this page; percentage) and vegetation height (column next page; cm) as a function of time for *conventional farms* (A), *conventional-plus farms* (B) and *organic-plus farms* (C).

A Conventional farms



B Conventional-plus farms



C Organic-plus farms

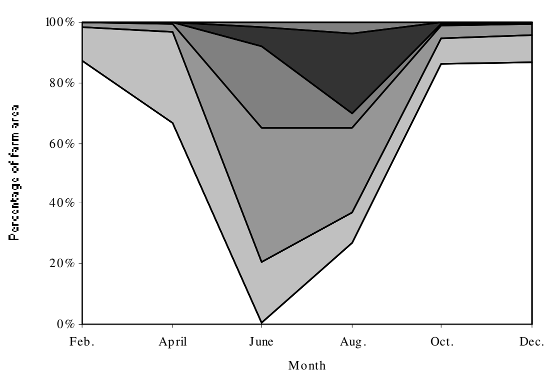


Figure 2 *continued*

On *organic-plus farms*, an average of 13.8% of the farm area provided suitable nesting habitat for the harvest mouse, in the form of ditch banks early in the season and spring wheat later on (Table 3). Both types of *conventional farms* provided greater areas of suitable nesting habitat (conventional 27.7% and conventional-plus 23.8%) than *organic-plus farms* (13.8%), owing to the tillage of winter wheat that offered suitable shelter at the start of the breeding season. Also, the extensive ditch bank mowing regime on the conventional-plus and *organic-plus farms* increased the amount of nesting habitat present.

Only a small area of the farm was suitable for winter shelter for the partridge: 0.3% on *conventional farms* up to 4.9% on *conventional-plus farms* (Table 3). The higher average percentages on *conventional-plus* and *organic-plus farms* were due to the presence of field margins.

On the basis of a minimum vegetation height of 40 cm and 50% cover for the brown hare in winter, none of the farm types provided any suitable shelter opportunities (Table 3).

5.4 Discussion

We first discuss farm layout and the vegetation structure of semi-natural habitats and crops. We then give an overall assessment of the three farm types on the basis of the method presented here, the 'shelter habitat method'. This is followed by a detailed discussion of summer and winter shelter habitats for the four individual species and the possible application of the habitat method in an environmental certification scheme.

Farm layout and vegetation structure

On both the *conventional-plus* and *organic-plus farms*, the average amount of semi-natural habitat is three times higher than on basic *conventional farms*, a result of field margins implemented under an Agri-Environmental Scheme or on-farm conservation plan.

An extensive mowing regime of ditch banks leads to denser and taller herbaceous vegetation on the banks compared with the intensive management on *conventional farms*. The presence of field margins increased the percentage of semi-natural habitats and the area with 100% year-long vegetation coverage on both *conventional-plus* and *organic-plus farms*. Nonetheless, the latter farms have more bare soil in autumn and winter than *conventional farms*, because of differences in crop rotation.

In this study, no organic farms without field margins strips were included. The results for this type of farm are anticipated to be similar to those for *conventional farms* without such margins, although the different crop rotation will have impact more negatively on the availability of shelter sites for birds and small mammals.

Farm types

The three farm types had different patterns of summer and winter shelter availability for the species considered. Overall, the *organic-plus farms* provided less suitable habitat for two out of four species (skylark and harvest mouse) than both types of *conventional farms*. For both these animals, reduced shelter availability on *organic-plus farms* was due to a difference in crop rotation (spring wheat rather than winter wheat). In the case of the partridge, the *conventional-plus* and *organic-plus farms* performed better than the other *conventional farms*. On both types of farm the presence of field margin strips increased the amount of suitable shelter habitat compared with the other *conventional farms*. For one species, the brown hare, none of the farms provided any suitable shelter habitat in the winter.

The method presented here allows the amount of suitable shelter habitat available for a given species to be quantitatively assessed. In this study only a small number of farms were inventoried, in one province of the Netherlands only, and an extension to other regions and larger samples would certainly improve results. As the study was limited to arable farms, no vegetable crops were included, nor pastureland on mixed organic farms. Inclusion of these will increase the amount of vegetation cover in winter (pastures) and the variation in vegetation height and cover in summer (vegetables).

Summer and winter habitats

In summer the two types of conventional farm provide the greatest amount of suitable nesting habitat for the skylark. On the *organic-plus farms* there is only a small amount of suitable habitat, because of spring cereal tillage, creating very open vegetation early in the season (Wilson *et al.,* 1997; Chamberlain and Siriwardena, 2000). Still, other studies have shown that organic farms have higher skylark densities, even early in the season (Wilson *et al.,* 1997; Chamberlain *et al.,* 1999; Donald and Vickery, 1999; Morris *et al.*, in press). There must therefore be other factors of influence in addition to vegetation structure. These include the greater abundance of invertebrate food sources on the organic farms due to the discontinued use of synthetic pesticides and artificial fertilisers (Wilson *et al.,* 1997; Morris *et al.*, in press) and increased habitat heterogeneity on a scale above that of the individual farm (Benton *et al.,* 2003). The optimum vegetation structure is found when both spring and winter wheat are cultivated on the farms, enabling the skylark to shift from crop to crop in the course of the season (Wilson *et al.,* 1997; Chamberlain *et al.,* 1999).

Both types of conventional farm have a greater percentage area of suitable nesting habitat for the harvest mouse in summer than the *organic-plus farms*. At the same time, though, the presence of late-mown ditch banks on both *conventional-plus* and *organic-plus farms* should create additional nesting scope for this species. This was not reflected in the calculated percentages, however, because of a high relative share of winter wheat on the other *conventional farms*, resulting in the highest percentage area of suitable habitat. Research on the effects of reduced ditch bank mowing and clearing frequencies have shown that this does indeed increase mice densities (Huijser *et al.,* 2001) and so in our research higher densities are to be expected on *organic-plus* and *conventional-plus farms*. As with the skylark, cultivation of spring wheat on organic farms disadvantages the harvest mouse compared to the situation on *conventional farms*, for in April and June the height of this spring-sown crop is too low for nesting. However, the presence of field margins sown with grass and herb mixtures as part of an agri-environmental scheme or on-farm conservation plan on both *organic-plus* and *conventional-plus farms* does lead to increased presence of harvest mice (Game Conservancy Trust, 1999; Bence *et al.,* 2003) as well as other mouse species (Remmelzwaal and Voslamber, 1996).

In winter, the *organic-plus* and *conventional-plus farms* provide more suitable shelter habitat for the partridge than the other *conventional farms*. The field margins implemented under on-farm conservation plans or agri-environmental schemes for improving fauna diversity lead to an increase of the amount of taller and denser on-farm vegetation in winter as well as in spring and summer. They provide more permanent protective cover and in most cases insect food in greater abundance and therefore increase partridge (chick) survival in winter and summer (Panek, 1997; Holland *et al.,* 2002). Although Chamberlain *et al. (*1999) found no effect of organic farming or field margin presence on partridge numbers, higher partridge survival can be expected on organic farms, as pesticide use is prohibited (Sotherton *et al.,* 1985; Potts, 1986).

None of the farms had any suitable shelter habitat for brown hares during winter. Including hedgerows as a possible site of shelter (Tapper and Hobson, 2002) would give percentage area figures of 1.2% on *organic-plus farms*, 0.3% on *conventional farms* and 0.8% on *conventional-plus farms*. This overestimates the amount of suitable habitat, however, as the bush and tree layer of some hedgerows is completely closed. The shorter type of vegetation (20 cm) used by the partridge might also provide suitable shelter for hares (pers. communication P. Twisk). In winter, hares depend for shelter on cropland perimeters rather than on the fields themselves, where no refuges are to be found (Meriggi and Alieri, 1989). The number of brown hares on both *organic-plus* and *conventional-plus farms* may therefore benefit from the presence of sown field margins, as well as from greater habitat diversity (Tapper and Barnes, 1986; Meriggi and Alieri, 1989; Lewandowski and Nowakowski, 1993). Although all the autumn-sown crops were still too short to provide shelter during winter, these are important food resources for brown hares (Tapper and Barnes, 1986; Lange *et al.,* 1994; Broekhuizen *et al.,* 1992; Edwards *et al.,* 2000). Unfortunately, it is usually spring wheat that are grown on Dutch organic farms, which limits the winter foraging scope of hares.

Methodological implications and possible applications

To assess on-farm biodiversity for other bird or mammals species this method can readily be adapted once the specific requirements for vegetation height and cover are known. The amount of habitat available in a given season can be calculated in a variety of ways, for example by taking the average or minimum amount of available habitat present in a given period. For species selecting a suitable habitat more than once a season, such as the skylark (Toepfer and Stubbe, 2001), the average amount of habitat can be used. For other species, the minimum available habitat during a given period is more important, as these species will abandon the farm when the required shelter is no longer available, as in the case of the partridge in winter. For some species like the brown hare, the presence of suitable habitat is more important than the amount and so even a very small area may already provide sufficient shelter. In other words, the percentage of habitat area per farm is by no means equally important for every species. In this study a first step was made to assess shelter site availability for birds and mammals. A suitable follow-up to this study will be validation of the method using empirical data on the presence of selected bird and mammal species on the different types of farm. Also, the selection of the habitat criteria per species will require further investigation. However, increasing the on-farm habitat heterogeneity based on the found study results is expected to create a higher amount of suitable habitat for the species studied as well as for the on-farm species diversity in general (Benton *et al.*, 2003).

This method can be used to compare different types of farm and farm management. In this study we showed that differences in farm layout, crop rotation schemes and management regimes all affect the amount of habitat available for the species studied. Although significant differences in shelter site availability existed, these appear not to be strictly related to the different types of farms. It is argued here that consistent attention for this characteristic has the potential to improve our habitat method. The method can then usefully contribute to further development of farming methods geared to improving biodiversity. It can also be used for overall assessment of farm holdings for the purpose of benchmarking or environmental labelling schemes.

5.5 Conclusions

The developed shelter-habitat method can easily be used to calculated the amount of suitable habitat on a given farm in a specific season, based on defined shelter-requirements for a given species. A comparison of different farming systems in relation to the species requirements showed differences related to crop rotation, farm layout and management regimes.

The extended farm nature layout on *organic-plus* and *conventional-plus farms* led to a higher percentage of semi-natural habitats per farm, whether or not part of on-farm conservation plan or an agri-environmental scheme. Nonetheless, *organic-plus farms* had a larger amount of bare soil in autumn and winter than *conventional farms*.

The species in our pilot study are all expected to respond differently to the three types of farm based on our model. When all species were taken into account, the *organic-plus farms* offered less suitable habitat area in the summer for two out of four species (skylark and harvest mouse) than the *conventional farms*. In both cases the *organic-plus farms* were less suitable, owing to differences in crop rotation. For the partridge, the organic-plus and *conventional-plus farms* performed better in winter than the *conventional farms*. In this case the presence of field margin strips increased the amount of habitat area on both organic-plus and *conventional-plus farms* compared to the *conventional farms*. For the brown hare, based on our criteria none of the farms provided any suitable habitat area in the winter.

Although significant differences in shelter site availability existed, these appear not to be strictly related to the different types of farms. It is argued here that consistent attention for this characteristic has the potential to improve our habitat method. The method can then usefully contribute to further development of farming methods geared to improving biodiversity. It can also be used for overall assessment of farm holdings for the purpose of benchmarking or environmental labelling schemes.

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