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Short communication



Mixing-in native thorny shrubs greatly improves the habitat quality of short rotation coppice strips within a modern agroforestry system for breeding birds

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ABSTRACT

Silvoarable agroforestry systems (AFS) with short rotation coppice strips (CS) are novel land-use systems that combine fast-growing trees with croplands to simultaneously produce woody biomass and arable crops. Since their effects on biodiversity remain underexplored, we studied nesting site selection and breeding success of tree- and shrub-breeding birds in three different CS variants, located on an AFS experimental site in northern Germany: CS-C (poplar clones only), CS-A (aspen trees and poplar clones) and CS-E (native woody species and poplar clones). Thereby, the study focused on the question of whether CS can be enhanced for breeding birds by integrating native woody plants that typically grow in hedgerows (variant CS-E). CS-E significantly outperformed CS-C and CS-A, hosting two-thirds of all nests, 70 % of breeding attempts, and two-thirds of successful broods, despite comprising only one-third of the CS area. Native woody plants, covering only about 10 % of the total CS area, accounted for nearly 70 % of all nests and two-thirds of breeding attempts and successful broods. By contrast, poplars (aspen and poplar clones as the actual crop), occupying nearly 90 % of the CS area, accounted for only 30 % of all nests and breeding attempts, respectively, and 22 % of successful broods. Number of nests per 1000 trees was 13 times higher in native woody plants (26.0) than in poplars (2.0) and thorny shrubs of the Rosaceae family such as *Rosa* or *Crataegus* species and *Pyrus pyraster* were particularly preferred for nesting. To improve the habitat quality for breeding birds, we therefore recommend the integration of native woody plants, especially thorny Rosaceae species, into CS in modern AFS.

1. Introduction

Silvoarable agroforestry systems (AFS) with short rotation coppice strips (CS) are novel land-use systems that combine fast-growing trees like poplars (*Populus* spec.) with croplands to simultaneously produce woody biomass and arable crops (Veldkamp et al., 2023). In contrast to traditional AFS, for example farmland divided by hedgerows, they are adapted to modern farming practices (e.g. by adjusting the width of the crop alleys to the requirements of modern agricultural machinery) and specially bred, high-yielding tree varieties are cultivated within the tree strips (Nerlich et al., 2013). Through CS, new elements are introduced into agricultural

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landscapes, which can contribute to their structural enrichment and thus to the promotion of biodiversity (Tsonkova et al., 2012). Initial studies have already shown some positive effects on biodiversity that can be achieved by modern AFS using different species groups like vascular plants, spiders or birds as indicators (Glemnitz et al., 2013; Zitzmann and Langhof, 2023; Matevski et al., 2024). However, the knowledge of the actual potential of these novel land-use systems to promote biodiversity in agricultural landscapes is still limited (Boinot et al., 2022; Kletty et al., 2023), not least because there are only a few experimental sites so far (Beer and Theuvsen, 2019). Among others, it remains unclear which habitat potential different variants of CS offer and whether measures such as the selection and composition of woody species within the tree strips can be used to strategically promote biodiversity (Zitzmann and Langhof, 2023). In this study, we therefore investigated the importance of three different CS variants as habitat for tree- and shrub-breeding birds and how these variants differ in terms of nesting site selection and breeding success. Thereby, we particularly focused on the question of whether the habitat quality of CS for breeding birds can be increased by mixing-in native woody plants that usually grow in hedgerows.

2. Study site and methods

2.1. Study site

This study was conducted at an AFS experimental site (17.7 ha) in the municipality of Lehre (Helmstedt district, Lower Saxony, Northern Germany, coordinates: 52°19'54.7"N 10°37'52.8"E), established in 2008. The landscape in the vicinity of the AFS is characterized by agricultural land (mainly arable land, partly grassland), some hedgerows and groves and an extensive woodland. A total of nine CS are located on the site (Fig. 1A), each 225 m long and 10 m wide. The arable land between the CS is used for growing maize, oilseed rape and barley. Each CS consists of three 75 m long sections representing different CS variants (Fig. 1B):

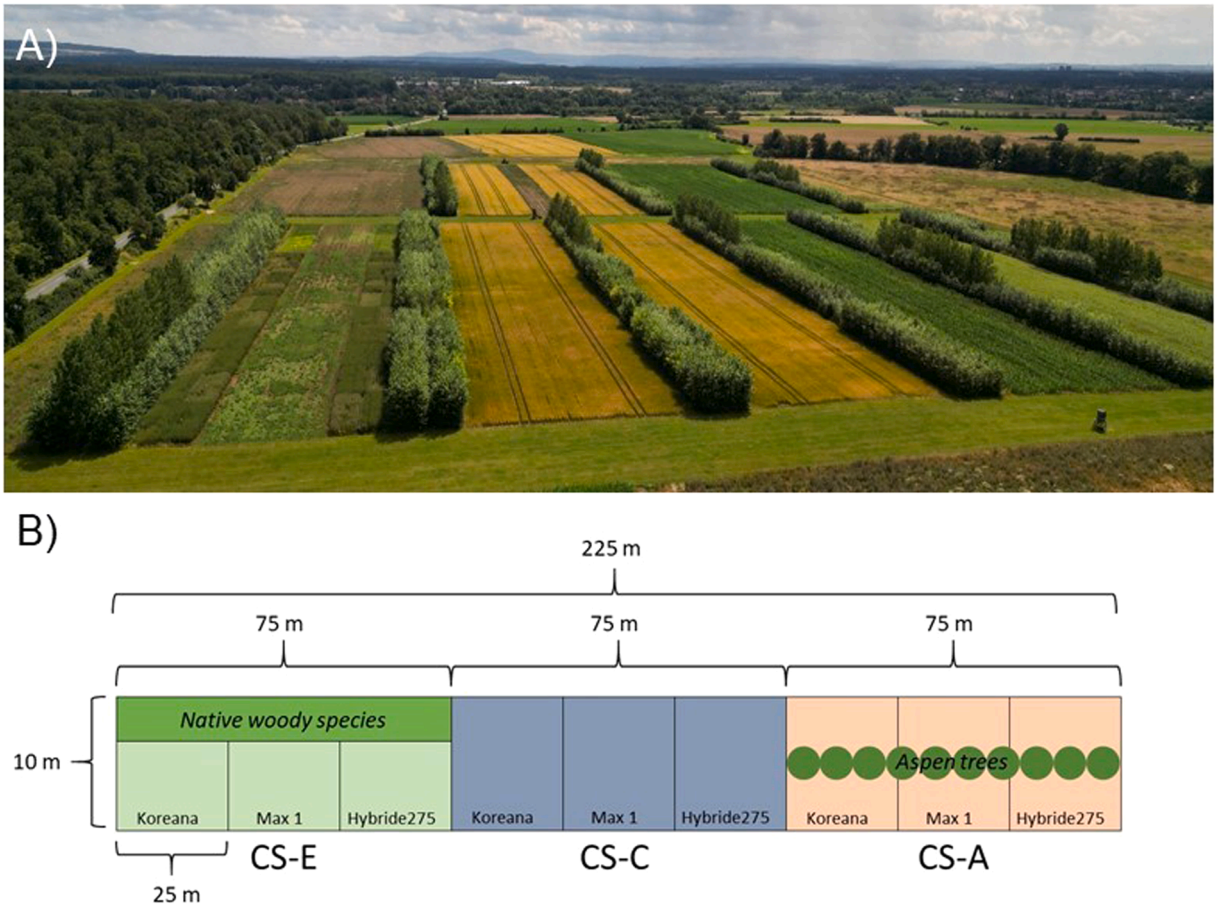


Fig. 1. A) Aerial photo of the study site, looking towards south. Strips no. 1–6 (from right to left) are shown in the foreground and strips no. 7–9 in the background. Photo taken by Jana Linnebank, 31 July 2024. B) Illustration of a short rotation coppice strip (CS) with the three variants (CS-C = Conventional, CS-A = Aspen, CS-E = Ecological), each planted in 75 m sections.

- CS-C ("Conventional") consists of six poplar rows (planting scheme 2 ×0.5 m, i.e. 10,000 trees/ha) with three fast-growing poplar clones ("Koreana", "Max 1" and "Hybride 275") in equal proportions (25 m sections) and is intended for full use in short rotation (harvesting every 3–6 years).
- CS-A ("Aspen") consists of four rows of poplars analogous to CS-C. The two middle poplar rows were replaced by a row of aspen (*Populus tremula*), which were planted at a spacing of 1.5 m and are used for timber production.
- CS-E ("Ecological") also consists of four rows of poplars analogous to CS-C. In addition, two rows of 16 native species of small trees and shrubs (*Cornus sanguinea, Crataegus laevigata, Crataegus monogyna, Ligustrum vulgare, Malus sylvestris, Prunus padus, Prunus spinosa, Pyrus pyraster, Rhamnus cathartica, Ribes rubrum, Rosa canina, Rosa rubiginosa, Rubus fruticosus, Sambucus nigra, Sorbus aucuparia, Viburnum opulus*), typically growing in German hedgerows, were planted in order to improve their habitat quality and biodiversity value.

The poplar clones and the native woody species in the CS-E sections were last harvested in January 2021. During the study period in spring and early summer 2024, the poplar clones in all CS variants were on average 7 m high, while the native woody species in CS-E reached average heights of 3 m. Aspen in CS-A have not been harvested since their establishment and were about 15 m high. Eight of the total nine CS within the AFS were included in the study (strip no. 5 was excluded, see Fig. 1A).

2.2. Methods

2.2.1. Survey methods

In this study, only nests located within the vegetation above the ground were considered. To get an overview of the distribution of nests from the previous breeding season(s) and to avoid confusion with nests from the current season, a survey of "old nests" in the CS was carried out in mid-March 2024. For this purpose, all tree strips were searched by four persons each, old nests were marked and their location (strip ID, CS variant, woody species) was recorded. Starting in mid-April, when some bird species already started breeding in northern Germany (Andretzke et al., 2005), searches for nests of the current breeding season were carried out on seven dates at intervals of 8–17 days between them, with four persons per tree strip. These nests ("new nests") were also marked and their location recorded. The nests found were revisited on each of the subsequent dates for the search for new nests and on a further seven dates between these nest searches (i.e. on average about once a week) to check whether they were actually being used for breeding. If there was evidence of breeding (adult birds on the nest, warning adults around the nest, eggs or fledglings in the nest), the nest was observed with a "Dörr SnapShot Mini Black 12MP" camera trap to monitor breeding success. Depending on the local conditions, the cameras were attached to existing structures (trunks, branches) at a distance of 50–150 cm from the nest and aligned towards the nest. The cameras took a photo every four hours, so that no further visits were necessary to change their memory cards or batteries. Cameras were removed after several weeks, so that the observation took place until the young birds were potentially ready to fledge and no further personal visits to check the nests were necessary. Only five nests with indications of breeding could not be observed with camera traps due to their concealed location. These were subsequently checked by us on each of the following sampling dates. A successful brood was assumed if at least one young bird per nest fledged. We assumed that young birds fledged when the species-specific nestling period according to Andretzke et al. (2005) was reached or exceeded and young birds were still observed by the camera traps or by us up to this point. The search for nests ended on 27 June 2024, after which only known nests with breeding attempts were monitored with camera traps for several weeks.

After completing nest surveys, the number of trees (from the poplar clones Koreana, Hybride 275 and Max 1, as well as *Populus tremula* and native woody plants) per section was counted in November 2024 in order to determine the number of nests found per 1000 trees and make values comparable and in order to use the number of trees per section as an offset in the statistical analysis. Please note that the actual number of aspens was much higher than the number of planted aspens, as this species spread considerably through root breeding since the establishment of the AFS. Similarly, individual native woody plants spread from the CS-E variant to the other two CS variants.

2.2.2. Data preparation and statistical analysis

Based on the data collected, we determined how many nests were present in which CS variant and in which woody species. In addition, the number of nests per 1000 trees was calculated for the different poplar species/clones and the native woody plants. The three CS variants were compared with regard to the number of nests (old nests, new nests, total no. of nests) detected per section ($n = 8$ sections per variant). For this purpose, generalized linear mixed-effect models (GLMM) from the package "glmmTMB" (Brooks et al., 2017) were fitted in R version 4.4.1 (R Core Team, 2024), with CS variant as explanatory variable. Strip ID was integrated as a random effect to consider that three sections of different CS variants were nested within the same tree strip (Fig. 1B). The number of trees per section was included as an offset in order to account for different tree numbers and to standardize the data. Type II Wald Chi^2 tests were used as significance tests for the models. Since the data showed no signs of overdispersion, we assumed the Poisson distribution. Multiple comparisons of means between CS variants were conducted using Tukey post-hoc tests (command "glht" in R package "multcomp"; Hothorn et al., 2008). Data concerning breeding attempts and success was mainly analyzed descriptively due to the small sample size. In addition, we used Fisher's exact test (command "fisher.test" in R) to check whether poplars and native woody species in the CS (regardless of the variant) differed with regard to the following aspects: i) the relation of nests with breeding attempts to nests without breeding attempts and ii) the relation of successful to unsuccessful broods. For all statistical tests, p-values < 0.05 were considered as significant.

3. Results

3.1. Distribution of nests among CS variants and woody species

We found a total of 78 nests (33 old and 45 new nests), of which two thirds were in CS-E, around a quarter in CS-C and just under 10 % in CS-A. Almost 70 % of these nests were located in native woody species and around 30 % in trees of the genus *Populus* (Table 1A). The total number of nests found in native woody plants was slightly higher than the number of nests found in CS-E, as some native woody plants spread from CS-E into the other CS variants. As a result, we also found nests in native woody plants in the CS-C and CS-A variants, although these were not deliberately planted here. The proportion of nests in native woody plants (of the total number of nests) was 85 % in CS-E (i.e. 15 % of nests in poplars), 44 % in CS-C and 29 % in CS-A. The overall largest proportion of nests (62 %) was found in woody species of the Rosaceae family, with particularly large numbers being located in the thorny shrubs *Crataegus* spec. (*C. laevigata* and *C. monogyna*), *Rosa* spec. (*R. canina* and *R. rubiginosa*), *Pyrus pyraster* and *Prunus spinosa* (Table 1A). Of the total of 54 nests in native woody plants, as many as 83 % were found in these Rosaceae species mentioned above.

From the 33 old nests, more than 75 % were in CS-E, just under 20 % in CS-C and only 6 % in CS-A. Almost 90 % of the old nests were found in native woody plants, the remaining 10 % in trees of the genus *Populus*. From the 45 nests of the current season, 60 % were found in CS-E, just under 30 % in CS-C and about 10 % in CS-A. More than half of the 45 new nests were located in native woody species, a further 42 % in trees of the genus *Populus* and one in herbaceous vegetation (*Rumex* spec.).

Among the poplar species/clones, the number of nests (total, old nests and new nests) per 1000 trees was highest in Koreana and Hybride 275 (Table 2B). The total number of nests found here was about 3–6 times higher than in Max 1 and *Populus tremula*. Across all poplar species/clones, 2.0 nests (0.3 old nests, 1.6 new nests) per 1000 trees were found. By far the highest number of nests per 1000 trees was found in the native woody species with 26.0 (14.0 old nests, 12.1 new nests). Thus, the total number of nests found here was 13 times higher than in trees of the genus *Populus*.

The number of nests per section ($n = 8$ sections per variant) differed significantly between the CS variants, with the highest number being found in CS-E and the lowest in CS-A, while CS-C took an intermediate position (Table 2A).

3.2. Breeding success in the different CS variants and woody species

In 24 (53 %) of the 45 nests of the current breeding season, we did not find any indications of a breeding attempt (Table 3). We observed breeding attempts (egg laying) in 21 (47 %) nests, including 15 (71 %) in CS-E, four (19 %) in CS-C and two (10 %) in CS-A. Of these, nine nests belonged to Blackbirds (*Turdus merula*), eight to Song thrushes (*Turdus philomelos*), three to Yellowhammers (*Emberiza citronella*) and one to the Garden warbler (*Sylvia borin*). Although more nests in the current breeding season were established in native woody plants than in poplars (Table 1A), the ratio of nests with breeding attempts to nests without breeding attempts did not differ between native woody plants (14 nests with and 11 nests without breeding attempts) and poplars (6 with, 13 without) (Fisher's exact test: $p = 0.14$; odds ratio: 0.37). However, despite this non-significant difference, the probability of a breeding attempt being started was about 2.7 times higher in native woody plants than in poplars.

From the 21 documented breeding attempts, we recorded the loss of clutches in 12 nests (Tables 1 and 3): ten due to predation (destroyed eggs within or under the nest), one due to the nest falling (clone Koreana) and one through abandonment of the egg clutch

Table 1
A) Number of nests found (old nests from past season(s), new nests from the current breeding season and total number of nests) and B) Number of successful and unsuccessful breeding attempts from the current breeding season and their distribution among different woody species.

Woody species	**A) Number (proportion) of nests**		Total	**B) Breeding attempts current season**		Total
	Old nests	New nests		unsuccessful	successful	
Crataegus spec.	13 (39.4 %)	3 (6.7 %)	16 (20.5 %)	1	–	1
Rosa spec.	7 (21.2 %)	7 (15.6 %)	14 (17.9 %)	2	2	4
Pyrus pyraster	2 (6.1 %)	6 (13.3 %)	8 (10.3 %)	2	3	5
Populus 'Hybride 275'	2 (6.1 %)	6 (13.3 %)	8 (10.3 %)	–	1	1
Populus 'Koreana'	1 (3 %)	6 (13.3 %)	7 (9 %)	3	–	3
Prunus spinosa	4 (12.1 %)	3 (6.7 %)	7 (9 %)	–	–	–
Populus 'Max 1'	1 (3 %)	3 (6.7 %)	4 (5.1 %)	–	–	–
Populus tremula	–	4 (8.9 %)	4 (5.1 %)	1	1	2
Ligustrum vulgare	1 (3 %)	2 (4.4 %)	3 (3.8 %)	1	–	1
Malus sylvestris	1 (3 %)	1 (2.2 %)	2 (2.5 %)	1	–	1
Cornus sanguinea	1 (3 %)	–	1 (1.3 %)	–	–	–
Carpinus betulus	–	1 (2.2 %)	1 (1.3 %)	1	–	1
Sambucus nigra	–	1 (2.2 %)	1 (1.3 %)	–	1	1
Prunus padus	–	1 (2.2 %)	1 (1.3 %)	–	–	–
Rumex spec.	–	1 (2.2 %)	1 (1.3 %)	–	1	1
Total	**33**	**45**	**78**	**12**	**9**	**21**
in poplars	4 (12.1 %)	19 (42.2 %)	23 (29.5 %)	4	2	6
in native woody species[a]	29 (87.9 %)	25 (55.6 %)	54 (69.2 %)	8	6	14
in herbs	–	1 (2.2 %)	1 (1.3 %)	–	1	1

[a] As some native woody plants spread from CS-E into the other CS variants, the total number of nests found in native woody plants (69 %) was slightly higher than the number of nests found in CS-E (67 %).

Table 2
A) Mean ± standard error of nests per section with $n = 8$ sections per short rotation coppice strip (CS) variant (CS-C = Conventional, CS-A = Aspen, CS-E = Ecological). Differences between variants were tested with GLMMs and Chi^2 type-II tests. Multiple comparisons of means were done using Tukey post-hoc tests and different letters indicate significant differences ($p < 0.05$) between individual variants. B) Number of nests found per 1000 woody plants in the different poplar species/clones and in the native woody species.

A) Nests per CS variant	CS-E	CS-C	CS-A	Chi^2	*p*
Total nests	6.5 ± 1.6^a	2.4 ± 0.8^b	0.9 ± 0.3^c	39.73	< 0.001
Nests past season(s)	3.1 ± 0.8^a	0.8 ± 0.3^b	0.3 ± 0.3^b	21.75	< 0.001
Nests current season	3.4 ± 1.0^a	1.6 ± 0.5^a	0.6 ± 0.3^b	17.66	< 0.001

B) Nests per 1000 woody plants	Hybride 275	Max 1	Koreana	Aspen	Native woody species
Total nests	3.4	1.2	5.2	0.9	26.0
Nests past season(s)	0.8	0.3	0.7	–	14.0
Nests current season	2.5	0.9	4.4	0.9	12.1

Table 3
Distribution of nests (current breeding season) and successful and unsuccessful broods across the three tree strip variants (CS-C = Conventional, CS-A = Aspen, CS-E = Ecological).

	CS-E	CS-C	CS-A	Total
No. of nests	27	13	5	45
thereof not occupied (%)	12 (44.4 %)	9 (69.2 %)	3 (60 %)	24 (53.3 %)
Observed breeding attempt	15	4	2	21
thereof successful (%)	6 (40 %)	2 (50 %)	1 (50 %)	9 (42.9 %)
thereof unsuccessful (%)	9 (60 %)	2 (50 %)	1 (50 %)	12 (57.1 %)

(nest left, eggs not incubated). In nine nests (5x song thrush, 3x blackbird, 1x garden warbler), breeding was successful and young birds hatched, with at least one fledging in each nest. Of these, six were in CS-E, two in CS-C and one in CS-A (Table 3) resp. six in native woody plants (five of them in thorny shrubs of the Rosaceae family), two in poplars and one in herbaceous vegetation (Table 1B). Although considerably more nests with breeding attempts were found in native woody plants, Fisher's test revealed no difference ($p = 1.00$) in the ratio of successful to unsuccessful broods between poplars (2 successes, 4 failures) and native woody plants (6 successes, 8 failures).

4. Discussion

Our results demonstrate the outstanding importance of native woody plants and the CS-E variant for nesting site selection and breeding success of birds in the studied AFS. Two-thirds of all nests, 70 % of breeding attempts and two-thirds of successful broods were recorded in CS-E, although this variant only accounted for one-third of the CS area. The importance of native woody species becomes even more obvious considering that about 70 % of all nests and two-thirds of breeding attempts and successful broods were registered in these species, although only about 10 % (one third of the area of CS-E, see Fig. 1B, including some native woody plants that spread into CS-C and CS-A) of the total CS area was covered with them. These findings clearly demonstrate the high enhancement potential for breeding birds associated with the integration of native woody plants in CS. In addition, the CS-E variant also had a positive but unintended side effect on the other two CS variants, as native woody plants spontaneously spread into them and thus a fairly high proportion of nests were also found in native woody plants there. Furthermore, we found clear differences regarding the importance of different native woody species, with thorny shrubs of the Rosaceae family being particularly preferred – possibly because they offer particularly good protection from predators and/or favorable structural conditions for a stable nest attachment (cf. Dunn et al., 2016). The presence of thorny shrubs is also highlighted as an important quality feature for breeding birds in other studies on hedgerows (Starkmann and Tenbergen, 1994; Walker et al., 2005; Sybertz et al., 2020). We therefore conclude that the CS-E variant with high proportions of thorny shrubs of the Rosaceae family, such as *Rosa* and *Crataegus* species or *Pyrus pyraster*, promises a high enhancement potential for tree- and shrub-breeding birds in modern silvoarable AFS with CS. In addition, the CS-E variant is likely to be particularly beneficial if the patches with native woody plants are retained during the regular harvest of the poplar clones, thus providing high-quality nesting habitats for birds in the breeding season immediately after harvesting (Zitzmann and Langhof, 2023).

Compared to the native woody plants, the importance of poplars (as the actual crop) as nesting habitats for birds was very low: only 30 % of all nests and breeding attempts, respectively, and 22 % of successful broods were registered in poplars, although they covered almost 90 % of the CS area and accounted for 85 % of the tree individuals in the CS. However, despite the clear preference for native woody plants and especially thorny shrubs for nesting, we found no significant difference between poplars and native woody plants in terms of the relation of breeding successes to failures. This indicates, at least in the area investigated here and with a small sample of a few nests from just a few bird species, that breeding success in poplars is not necessarily lower than in native woody plants and that the poplars in the CS investigated here did not act as ecological traps (see analogously to this Dhondt et al., 2007 for willow short rotation coppice plantations in the USA). Although we found no significant difference in breeding success rates, the native woody plants still promoted the successful reproduction of birds in much greater numbers than the poplars, as a considerably larger number of breeding

attempts (on a much smaller area) took place here.

Regarding the number of nests within the different poplar species/varieties, we found clear differences with the clone Max 1 and *Populus tremula* harboring considerably fewer nests per 1000 trees than the clones Hybride 275 and Koreana. Dhondt et al. (2004) also found significant differences between different poplar and willow clones in short rotation coppice plantations in the USA and attributed the preference of certain clones to their specific growth- and branching-structure, which, depending on the clone, offered more or less favorable conditions for nest construction and shelter. This may also be the reason for the observed differences between the various poplars in our study. However, since only few nests were found in poplars compared to their availability and the sample size is therefore small, no reliable recommendations for a specific clone can be derived on this basis. For this reason, further studies should be carried out to determine which poplar clones are particularly important for breeding birds. It is also possible that other tree genera suitable for CS, such as willows (*Salix* spp.), also differ significantly in their importance compared to poplars, and that the tree genus is therefore even more relevant for nesting site selection. Studies on short rotation coppice plantations in the UK (Sage and Robertson, 1996) and Germany (Gruß and Schulz, 2011) revealed that plantations with willows are colonized by more bird species and in higher densities than those with poplars and at least suggest this, although no nest searches were carried out in these studies. Consequently, further studies should investigate the influence of different woody species used as crops in modern AFS with CS (a.o. poplar, willow, robinia) on nesting site selection and breeding success of birds. Similarly, further studies on nesting site selection, nest densities and breeding success of CS compared to hedgerows, representing woody features in traditional AFS and thus are the counterpart to CS in modern AFS (Nerlich et al., 2013), should be carried out (cf. Zitzmann and Langhof, 2023).

With regard to our survey methods, the results on the unsuccessful broods could have been influenced by the fact that breeding attempts took place in further nests, but we did not note them, as we only checked the nests about once a week and only started a camera trap monitoring if there was an actual indication of nest use (eggs, adult birds at the nest, etc.). Therefore, breeding attempts could have taken place between our controls and failed, which we may have missed if no traces (destroyed clutches, dead chicks) were visible to us. This limits the comparability of the proportions of unsuccessful broods and predation rates determined here with other studies where more frequent controls were carried out (cf. Dhondt et al., 2004 and Bibby et al., 2000). However, this does not affect the comparability between the CS variants and woody species in our study, as all nests and variants were always checked on the same day. In addition, our data on actual breeding success is highly reliable, as we ensured that we did not miss any successful broods through our weekly controls and subsequent camera trap observation.

Finally, we want to emphasize that this investigation is a case study on a single experimental site, within a single breeding season involving a limited number of nests and bird species. Our study provides first insights into the use of CS in modern AFS of the temperate zone by breeding birds and how these tree strips can be enhanced for them. However, further studies covering a larger number of plots across different geographical and climatic conditions are needed to verify these results and draw generalized conclusions.

Ethics Statement

The Lower Nature Conservation Authority of the district of Helmstedt authorized the survey (file number: 16–605105–415/23).

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CRediT authorship contribution statement

FZ had the initial idea for the project, JL and FZ developed methods, JL collected data with contributions from FZ, FZ and JL analyzed data, wrote the initial draft of the paper and edited it. Both authors read and approved the final version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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