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Original research article

Are they even there? How agri-environment schemes investments reach their target species in Dutch dairy-farmland, the case of meadow birds

Luis Barba-Escoto [a,e,*], Ruth A. Howison [a,b,e], Rienk W. Fokkema [a,e], Jean-Yves Duriaux-Chavarría [a], Marie Stessens [a,e], Egbert van der Velde [a,e], Jos C.E.W. Hooijmeijer [a,e], Theunis Piersma [a,d,e], Pablo A. Tittonell [a,c]

[a] Conservation Ecology Group, Groningen Institute for Evolutionary Life Science (GELIFES), University of Groningen, Groningen, the Netherlands
[b] Knowledge Infrastructures Department, Campus Fryslân, University of Groningen, Groningen, the Netherlands
[c] Agroecology, Environment and Systems Group, Instituto de Investigaciones Forestales y Agropecuarias de Bariloche (IFAB), INTA-CONICET, San Carlos de Bariloche, Argentina
[d] NIOZ Royal Netherlands Institute for Sea Research, Department of Coastal Systems, Den Burg, the Netherlands
[e] BirdEyes, Centre for Global Ecological Change at the Faculties of Science & Engineering and Campus Fryslân, University of Groningen, Leeuwarden, the Netherlands

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ABSTRACT

Agri-environmental schemes (AES) implemented by farmer collectives for meadow bird protection in The Netherlands create complex landscape mosaics due to the variability of options and combinations farmers use. We propose a method to simplify this complexity, using the number of meadow birds potentially benefiting as the measure of success, and evaluate how AES combinations affect management success as a function of monetary investments. Between 2016 and 2022, we conducted field surveys to measure the density and distribution of Black-tailed Godwits across three land-use types: AES, site-protected areas, and intensive agriculture. AES fields were categorized into nest protection, inundation, delayed mowing, and herb-rich grasslands. We analysed the relationship between these managements, the area they cover, and godwit numbers, while also examining land area and subsidies. Intensive agriculture covered 74.3 % of the area but hosted only 23.2 % of the godwit population at low densities (0.063 godwits/ha). In contrast, protected areas (6.2 % of the area) and AES fields (19.5 %) supported 24.7 % and 52.1 % of the population at higher densities (0.48 and 0.46 godwits/ha, respectively). Among AES types, delayed mowing and herb-rich grasslands showed the highest godwit densities (0.66 and 1.25 godwits/ha, respectively) covering smaller areas (6 % and 1.1 %). These AES types pay the highest subsidies, while nest protection, covering 10.5 % of the area with lower godwit densities, pays the lowest. Although AES fields hosted about half of the godwit population, area-wise the focus remained on nest protection, and with intensive agriculture dominated the landscape. This may limit effectiveness at a population level, calling for re-evaluating conservation priorities and funding.

* Correspondence to: Groningen Institute of Evolutionary Life Sciences, University of Groningen, Conservation Ecology Group (CEG), P.O. Box 11103, Groningen 9700 CC, the Netherlands.

E-mail addresses: l.barba.escoto@rug.nl, lbarbaescoto@gmail.com (L. Barba-Escoto).

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1. Introduction

Agri-environment schemes (AES) subsidize farmers to adopt practices that target biodiversity and ecosystem services protection, and in particular aim to prevent the decline of species numbers, including meadow bird populations (Hasler et al., 2022). In the European Union (EU), AES were introduced by the Common Agricultural Policy (CAP) (Schomers and Matzdorf, 2013), but simultaneously the CAP has driven the industrialization of agriculture, contributing to biodiversity decline (Kortleve et al., 2024). Funding for AES has been significantly lower than the subsidies to intensify agriculture (Öhlund et al., 2015). Despite these efforts, the effectiveness of AES for meadow bird protection has been questioned for quite some time (Kleijn et al., 2001; Kleijn and Sutherland, 2003; Breeuwer et al., 2009). This raises concerns that such investments may not be a cost-effective use of taxpayers' money to achieve the stated goals. Assessing the ecological pertinence of AES measures alongside their economic performance is a step to shaping informed and effective conservation policies.

The Netherlands is a country which hosts a relatively high diversity of meadow-breeding birds and has implemented AES measures via farmer collectives in attempts to preserve them. Meadow birds (Dutch: "weidevogels") are deeply rooted, both culturally and ecologically in the landscapes of The Netherlands (Beintema, 1986). Most of these long-distance migratory species have historically chosen to breed annually in Dutch grasslands (Verhoeven et al., 2021). Meadow birds, originating in natural grasslands, adapted to European agriculture (Beintema, 1983), benefiting from traditional low-intensity farming practices (Queiroz et al., 2014; Sutherland, 2004), and establishing large populations (Batáry et al., 2015; Silva-Monteiro et al., 2021). Meadow birds prefer conditions provided by low intensity farming which includes management with high water tables, low-density grazing cattle, and high plant diversity and heterogeneity (Groen et al., 2012). These elements contribute to the consideration of meadow birds as indicator species for both biodiversity and sustainable farming practices (Beintema, 1983). With the modernization of agriculture in the last quarter of the 20th century, the industrialization of agriculture has been associated with farm bird population declines and population collapses in Europe (Donald et al., 2001). The Black-tailed Godwit, *Limosa limosa limosa* (hereafter called 'godwit') is an iconic meadow bird of The Netherlands, elected the national bird in 2015 and considered a flag species for meadow birds (Kentie et al., 2016). The population of godwits is in severe decline and is affected by agricultural intensification (Li et al., 2023; Silva-Monteiro et al., 2021).

Grasslands of intensive dairy farms are often managed as rye grass (*Lolium perenne* L.) monocultures, drained, with deep groundwater levels, and low vegetation heterogeneity both horizontal and vertical (Groen et al., 2012). Such management reduce the availability and quality of food for godwits, particularly surface-dwelling and above-ground arthropods (Litovska et al., 2025; Schekkerman and Beintema, 2007; Schroeder et al., 2012; Silva-Monteiro et al., 2023), which is correlated with chicks' poorer growth (Loonstra et al., 2018), potentially increased mortality (Kentie et al., 2013). The low water tables and repeated slurry injection provokes desiccation and affects the capacity to probe for adults looking for prey such as earthworms in the soil (Onrust et al., 2019). Additionally, early and repeated mowing disrupts nesting and chick development (Kentie et al., 2015), particularly as climate change pushes agricultural activities earlier, misaligning with the birds' breeding phases (Kentie et al., 2018; Schroeder et al., 2012).

The protection of meadow birds in The Netherlands follows both land-sparing and land-sharing perspectives (Feniuk et al., 2019), with two key meadow bird conservation strategies (MCS): (i) site protection areas managed by nature organizations using low-intensity agriculture, and (ii) agri-environment schemes (AES) offering subsidies to farmers for implementing specific management aimed at meadow bird protection. Between 2010 and 2016, only 6.8 % of the 375,299 ha protected for meadow birds in The Netherlands corresponded to site protection areas, while 83.8 % to nest protection via AES or by volunteers (Roodbergen and Teunissen, 2019). Other measures, such as delayed mowing and the maintenance of herb-rich grasslands, covered 5.6 % of the area. The total investments in AES in this period was of €47.4 million (Roodbergen and Teunissen, 2014, 2019). However, studies have found AES ineffective, showing lower bird densities in AES fields compared to non-AES fields or no positive changes in population growth rates(e.g., Kleijn et al., 2001; Breeuwer et al., 2009).

Since 2016, the Dutch Government introduced a reform to AES administration, channelling funds from provincial governments to farmer collectives, who then contract farmers to implement AES voluntarily. This new system, the Agricultural Nature and Landscape Management (ANLb), seeks to enhance cooperation and coordination at the landscape level for improved results (Barghusen et al., 2022). Despite increasing AES investments since these program started (Boonstra et al., 2021), studies on its cost-effectiveness are rare (Ansell et al., 2016; White et al., 2022). The question remains whether AES are effectively providing the target habitat (Staley et al., 2022; Zingg et al., 2019).

With AES as one of the primary tools for meadow bird conservation at in The Netherlands, and with a godwit population that keeps kept declining at a rate of 3.7 % per year (Kentie et al., 2016, Oosterveld et al., 2020), the new AES clearly needs scrutiny. Considering that the AES investments have increased (Ait Sidhoum et al., 2023) and that field implementation is complex, our study aims to offer what has been, surprisingly, absent, i.e. an assessment of the costs and ecological benefits of the new AES program for meadow bird protection in The Netherlands. The farmers who voluntarily implement AES may select the AES measures that best fit their production systems, weighing their cost-benefits and applicability relative to their social and ecological contexts. Farmers select more than one AES or even different AES variants with different area requirements and combine these in their various fields. This results in mosaics of AES which make assessments of their ecological and cost-effectiveness complicated task.

We performed a case study of landscape management for meadow birds by one farmer collective in South-west Friesland (hereafter 'SWF') in The Netherlands. Our objective was to characterise the diversity of AES currently implemented, how they are combined, their area coverage and costs, and whether these efforts match with the population and density of godwits (as a meadow bird species indicator). We compared the performance of AES against godwit densities in protected sites and in intensively managed grasslands. We expect this analysis to contribute to informing decisions on the implementation of conservation programs, by re-allocating budget to interventions that may have a better prospect at hosting meadow birds.

2. Material and methods

2.1. Study area

The study area situated in the municipality of Súd-west-west Fryslân (South-west Friesland, SWF) is a core area for breeding meadow birds in The Netherlands. SWF covers 19,813 ha (Fig. 1) and is divided in water-management units called 'polders' further divided into fields averaging 3.1 ha in size (min 0.01, max 61.0, SD = 2.6), with occasional subdivisions for variable management (Groen et al., 2012; Howison et al., 2018). The land predominantly produces fodder for dairy farming. Approximately 68 % of the land (90,787 ha) is classified as 'permanent' grassland (which, nevertheless, can be turned over after 5 years), 14 % is grassland with intermittent crop rotations, 12 % is classified as crop rotation and 4 % contains arable fields (Craft et al., 2022).

2.2. AES management variants and site protection areas

We used data on the implemented AES between 2016 and 2022 by the farmers' collective 'Collectief Súdwestkust' in SWF. The data consisted of georeferenced polygons of each AES deployed in the field. The site protection areas managed by 'It Fryske Gea' and 'Staatsbosbeheer' were included as references in the analysis as their management prioritizes meadow bird conservation. The spatial extent and distribution of all the fields in the area conforms with the Basic Registration of Crop Parcels (BRP) National Database (Nationaal Georegister, 2023). The location of site protected fields and their associated management remained constant throughout the study period, with the exception of small areas recently converted to site protection. We classified the agricultural fields in the area according to the MCS that is implemented (or not) i.e., site protection, AES and intensive fields not managed for meadow birds (Fig. 1, Table 1).

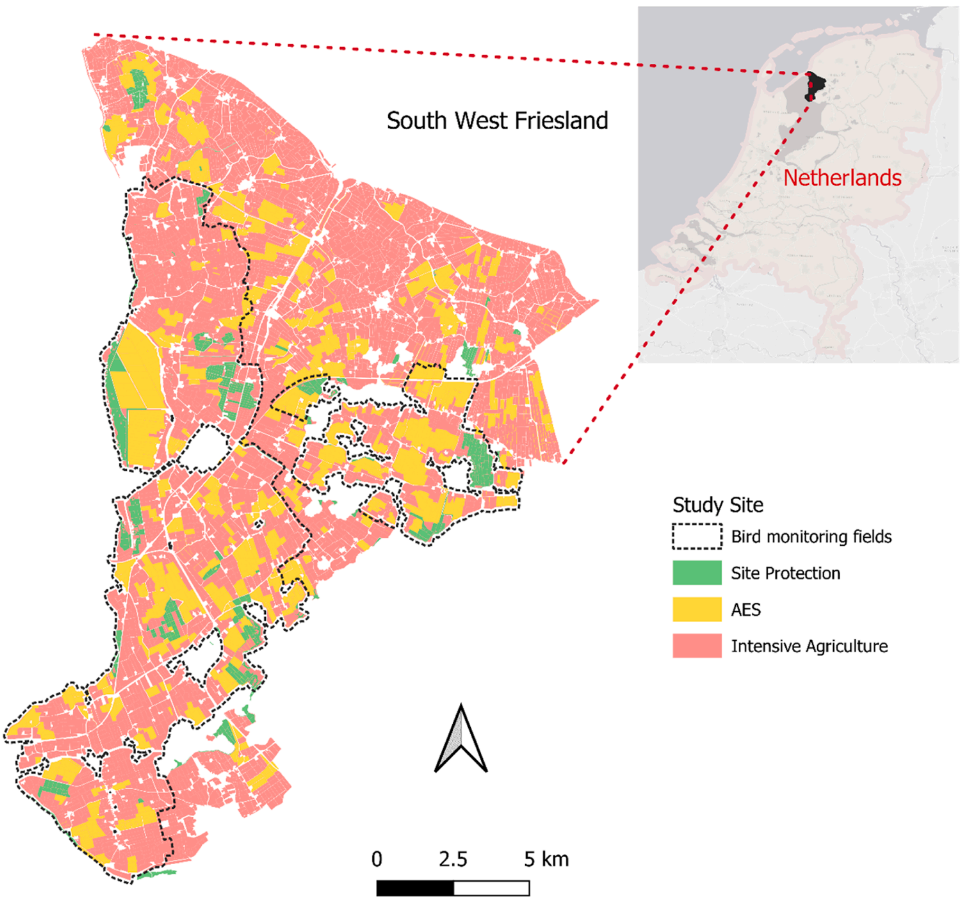

Fig. 1. Study area in South-west Friesland and the area in which meadow bird conservation strategies were implemented, i.e., site protection areas, Agri-environment schemes in the period 2016–2022 implemented by the Collectief Súdwestkust, and intensive agricultural fields not managed for meadow birds. The dotted line shows the area monitored for godwits in the same period.

Table 1
Definition of the Meadow Bird conservation Strategies (MCS) and the Agri-Environment Schemes (AES). Detailed information about each package and its variants can be found in Boerennatuur (2024).

Meadow bird conservation strategies	Description
Site protection	Areas designed for conservation managed by nature management organizations 'It Fryske Gea' and 'Staatsbosbeheer'.
Agri-Environment Schemes	Subsidies for practices at field level that provide habitat for targeted species-specific life-cycle stages. This requires that farmer collectives make a contract with individual farmers for a monetary compensation.
Intensive agriculture	Fields that are not managed by nature management organizations or subsidized under agri-environment schemes, and that are managed as high-input driven agriculture.
Agri-environment schemes management practices and description	
Chick Fields	A (portion of the) field that is not mowed for 2,3 or 4 weeks when one or more breeding attempt(s) of meadow birds are reported (by local volunteers) in the field, between May and August.
Nest Protection	A portion (at least 50 m^2) of the field around a nest will not be mown until the eggs hatch or are lost.
Delayed Mowing	The mowing in the field is delayed for a certain period, from the 1April till June or July.
Extensive Grazing	Grazing with cattle in limited densities from the 1 May until 15 June.
Fallow Rows	In arable land, strips of crops stubble are left uncultivated.
Botanically Rich Margins	A 4 m wide strip of at least four botanically valuable species that flanks the borders of the fields, and it is not mown from April to October.
Herb-Rich Grassland	A field containing at least 4 herbaceous species, with restricted herbicide and fertilization use, mowing at least only once per year after the date between15 June and 8 July.
High Water Table	Ditch water is raised between 20 and 40 cm relative to the average ground level, from 15 March to 15 June.
Solid Manure Fertilization	Application of 10–20 tons solid stall manure per hectare, instead of soil injection of slurry, between1 February and the start of the delayed mowing period, or between the end of the resting period and 15 September.
Inundated patches	A patch in the field that is filled with shallow water for a period that varies from February to May or July.
Restricted Fertilization	Application of liquid manure or artificial fertilizer is not allowed from 15 February till the end of the rest period.

2.3. Monitoring of godwits

Godwit monitoring was conducted in a subset of the study area comprising 2,806 fields equivalent to 10,116 ha (Fig. 1). Every year in April, at the beginning of the breeding season, we carried out three census counts of the godwit population, but for the analysis we considered the data for weeks 15 & 16 when most birds were occupying territories but not yet invisible because of them sitting on nests or disappearing in high vegetation. On each field we recorded the number of territorial birds. Birds were assumed to be territorial when displaying or showing courtship behaviour (courting, courtship flights, copulation) or by chasing away other birds, sitting on posts or alarm calling. These behaviours are generally displayed in the specific area in which the godwits will attempt to nest (Nijland and van Paassen, 2007; Hooijmeijer et al., 2024). In practice, each individual godwit was counted as territorial unless clearly non-territorial i.e. in a foraging group. In subsequent analyses, the count of territorial godwits per field is expressed as a density i.e., godwits per hectare (godwits.ha^{-1}). We estimated the density of godwits on every field for all years. For analysing the distribution of the population, we estimated godwit as the total number of godwits per year aggregated per MCS and convert it to proportions.

2.4. Diversity, availability and combination of AES

All statistical analyses and calculations were carried out using R 4.2.2 (Core Team, R 2024). The diversity of AES was evaluated by listing all the AES variants implemented in SWF between 2016 and 2022. Descriptions of each AES were sourced from the official ANLb documents, which detail the specific requirements for each variant (Overzicht Beheerpakketten Agrarisch Natuur & Landschapsbeheer, Boerennatuur, 2024). We grouped these variants into broader AES categories based on their intended management goals for meadow bird protection (i.e., different life stages protection, foraging habitat quality, etc.).

Based on the compiled categories of AES, the availability of AES was represented as the relative proportion of AES categories relative to the total AES area, for the total period and the result was plotted in a bar chart. To show changes in the diversity and availability of AES categories, we estimated the annual cumulative area of each AES categories, and represented these as stacked columns for each year. For an in-depth analysis of how AES variants were combined, a co-occurrence network analysis was performed, with fields as the sample unit and as nodes the main AES categories (Tittonell et al., 2022). This method allows to see which AES variants are most frequently combined with each other. We constructed the network with the R package *circlize* 0.4.15 (Gu et al., 2014). And, to infer the most prominent pairs of AES associations, we also performed a correlation analysis on the co-occurrence of AES pairs. We used the *corrplot* package to visualize this correlations (Wei et al., 2017).

2.5. Categorization of fields by AES stacking

To categorize fields based on AES stacking, we performed a non-metric multidimensional scaling (NMDS) ordination based on a Bray–Curtis similarity using *Vegan* 2.6–4 (Oksanen et al., 2024). on the 6394 AES managed fields during 2016–2022. The area covered by each AES varied, spanning the entire meadow or only specific sections. To standardize comparisons, we calculated the proportional AES intervention area per hectare. We included field area in the ordination data set. Using the NMDS multivariate space we grouped the fields into groups based on hierarchical clustering and Ward's criterion (Murtagh and Legendre, 2014). We termed these groups of fields as 'AES subsidy types'. Within each AES subsidy type, we analysed how individual AES are combined by calculating the co-occurrence of individual AES and constructing a network per type to visualize the differences. To summarize the differences between groups we calculated descriptive statistics (mean, s.d., and median) of the variables used for ordination.

2.6. Comparison of bird densities and population distribution between conservation strategies

We compared meadow bird densities across different MCS categories and AES subsidy types. To test for significant differences in godwit densities between these groups, we used a Kruskal-Wallis test followed by a Wilcoxon rank-sum post-hoc test, due to unequal sample sizes (Wilcoxon, 1945). The analysis was limited to the study area where godwit monitoring took place (Fig. 1). To evaluate the availability and quality of habitat for godwits, we estimated the proportion of land under MCS and AES subsidy types across the seven-year period, along with godwit population distribution which is the associated proportion of the godwit population.

2.7. Cost of implementation and area coverage of AES

Using the NMDS ordination, we examined the relationship between management, godwits density and investments (€/ha). For an analysis of costs and area coverage between AES subsidy types, we estimated the monetary compensation for each type at field level based on the rates established by the ANLb (Boerennatuur, 2024). Within the AES field types, we calculated for each field the compensations received by the farmers by calculating the area of each AES variant and its equivalent in euros, and then next this amount

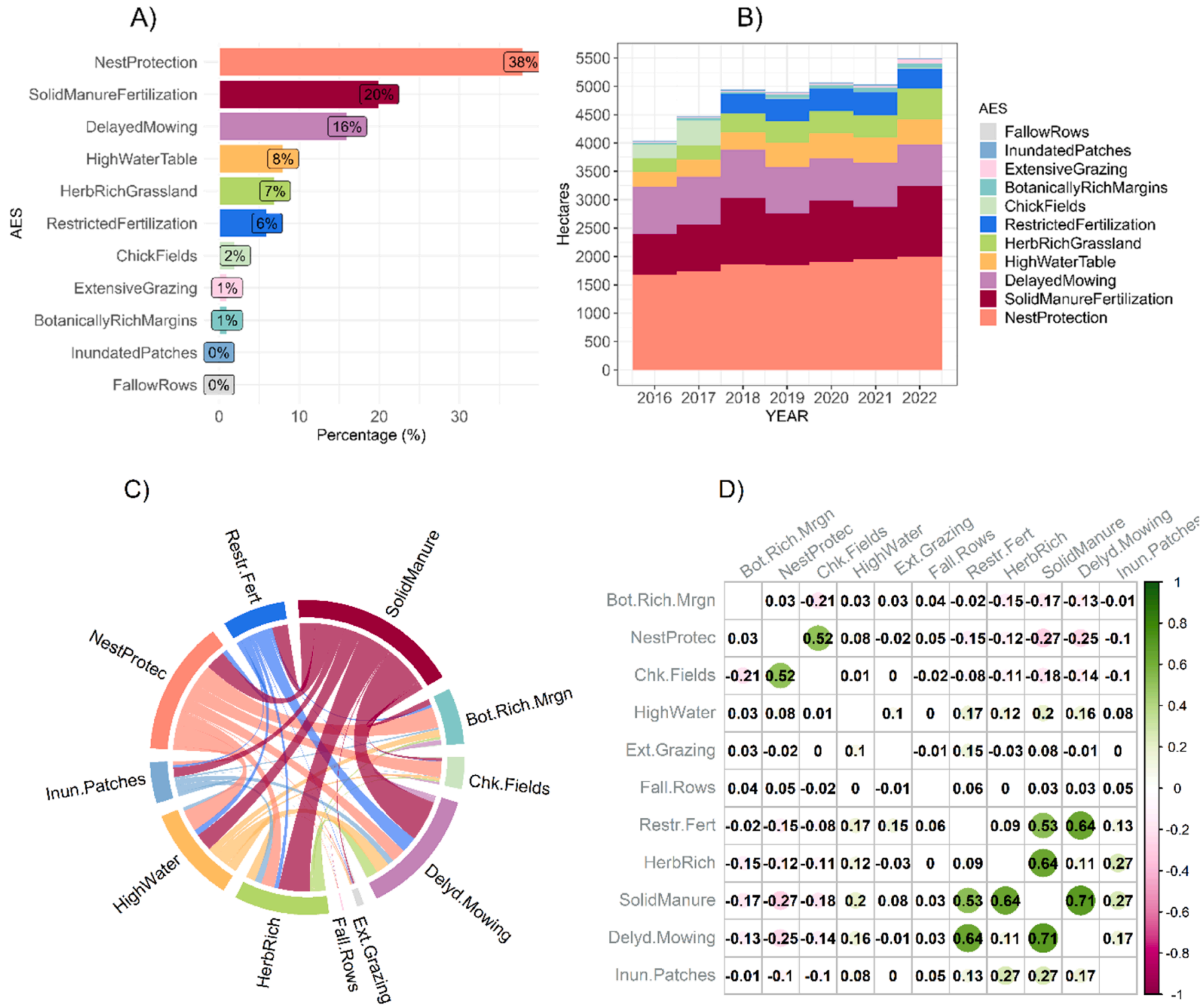

Fig. 2. A) Cumulative relative area of each AES implemented in the landscape of SWF 2016–2022. B) Area of each AES per year. C) Co-occurrence frequency of AES, the line thickness depicts the frequency of in which an AES co-occur with another. D) Level of co-occurrence between different AES based on correlation, the larger the dot the higher the frequency of co-occurrence.

was summed to express the cost of the AES type per ha. We plotted the results as boxplots to compare their variability. To compare the areas implemented and their costs between AES subsidy types, we calculated the total area under each AES subsidy type between 2016 and 2022 and its equivalent aggregated cost.

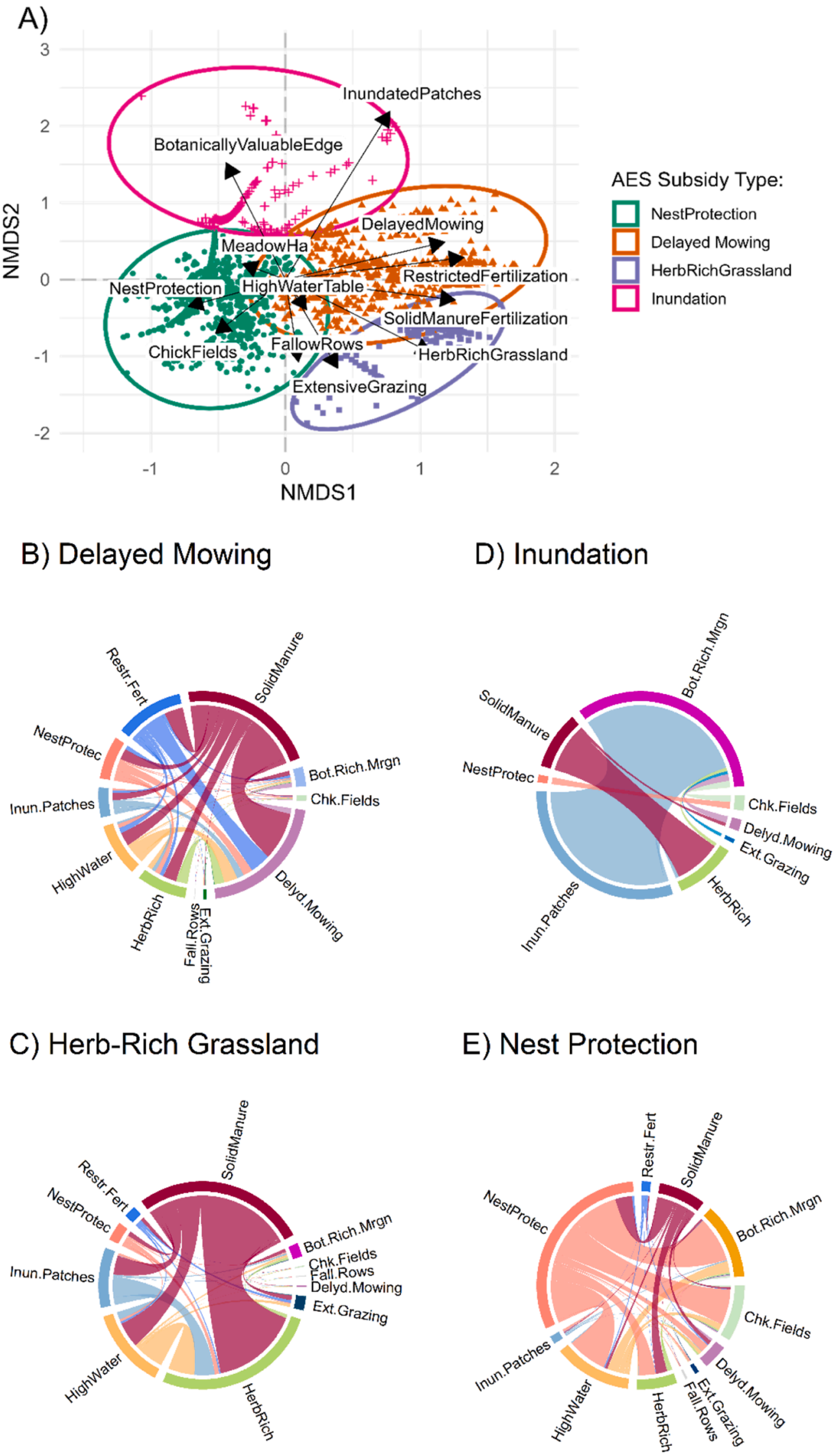

Fig. 3. A) Non-metric multidimensional scaling ordination of fields (colored points) according field area and to AES (superimposed arrows) defined by the proportion of AES at field level. The clustering of fields is shown as ellipses. B-E) Co-occurrence of AES at field level by AES subsidy Type.

3. Results

3.1. Diversity, availability and combination of AES

From 2016–2022, 45 variants of AES were implemented for meadow bird conservation. The variants differed on aspects such as: date of implementation, duration, minimal area required, crop type, minimum number of plant species (for pasture mixtures), and type of- and quantity of manure application, among others. We aggregated the AES variants into 11 main categories (Table 1).

Nest protection (38 %), solid manure fertilization (20 %), and delayed mowing (16 %) only, corresponded to 74 % of the AES protected area (Fig. 2.A). The AES area increased annually (Fig. 2.B) from 4,042 ha in 2016 to 5,498 ha in 2022, with only chick fields and delayed mowing decreasing over time. Interventions such as inundated patches, extensive grazing and solid manure fertilization varied in their level of implementation. The total area managed with AES in this period was 27,010 ha (19.5 % of the landscape), while the cumulative area of AES due to stacking of AES measures reached 33,973 ha.

AES were often stacked (Fig. 2.C) (e.g., delayed mowing combined with solid manure fertilization and a high-water table) or scattered across the field (e.g., botanically rich margins combined with nest protection). These combinations changed over time. In 2016 and 2017, the most frequent combinations were solid manure fertilization with delayed mowing, and nest protection with chick fields. After 2017, chick fields were selectively implemented, reducing their frequency. Solid manure fertilization had the highest connectivity with other AES, except in 2022, when nest protection was the most frequently combined intervention. Restricted fertilization, introduced after 2017, became frequently combined with solid manure fertilization and delayed mowing. Other AES, like extensive grazing (since 2016) and fallow rows (since 2021), were vey uncommon. From 2018 onwards, the most frequent AES combined in pairs were solid manure with delayed mowing, solid manure with herb-rich grasslands, solid manure with restricted fertilization, delayed mowing with restricted fertilization, and nest protection with chick fields (Fig. 2.D).

3.2. Categorization of fields by AES combination and stacking

The NMDS resulted in a 2-dimensional ordination (Fig. 3.A) with a stress value of 0.17, indicating a fair model fit (Dexter et al., 2018). The NMDS first axis correlated positively with the low-intensity management measures delayed mowing, extensive grazing, herb-rich grassland, solid manure fertilization, inundated patches, and restricted fertilization, while correlating negatively with nest protection, botanically rich margins, fallow rows, chick fields, and larger areas.

Clustering revealed four AES subsidy field types named after the AES which area-wise where implemented the most: (1) nest protection fields, (2) delayed mowing fields, (3) herb-rich grasslands, and (4) inundation fields with botanically rich margins. Each type varies in size and consists of more than one AES with different area proportions. For instance, nest protection fields (4.4 +/- 2.5 ha in field size) typically combine nest protection (87 +/- 25.7 % of the field), high water tables (7 +/- 20.8 %), and botanically rich margins (1.5 +/- 4.1 %). Inundation fields are small (3.3 +/- 2.3 ha) with botanically rich margins (14.6 +/-25.6 %) and large inundated patches (8.8 +/- 45.7 %). Delayed mowing fields (5 +/- 3.5 ha) feature delayed mowing (71.5 +/- 37.1 %), solid manure fertilization (64 +/- 40 %), restricted fertilization (in 23.7 +/- 39.6 % of the area) and high-water tables (13 +/- 28.0 %). Some of them can be grazed extensively, have nest protection (9.0 +/- 20.9 %) or have a small area under herb-rich grassland (8.5 +/- 20.6 %). Herb-rich grasslands are smaller meadows (2.6 +/- 1.4 ha) with a big proportion (84.1 +/- 34.0 %) cultivated with at least 4 different herbs, solid manure (78.9 +/- 34.0 %), inundated patches (3.0 +/- 11.0 %) or high-water tables (14.7 +/- 26.9 %), some may be grazed extensively (5.4 +/- 23.4 %).Table 2

3.3. Comparison of bird densities between conservation strategies

During 2016–2022 the average density of godwits per field was 0.2 (+/-0.6) godwits per hectare. Godwit densities differed significantly between meadow bird conservation strategies (Kruskal-Wallis test, $X^2 = 3257$, $p < 2.0$ e-12) (Fig. 4.A). A Wilcoxon rank-sum *post hoc* test revealed no significant difference between site protection fields (2303 fields) and AES-subsidized fields (3651 fields) ($p = 0.3$), but both had significantly higher densities than intensively farmed fields ($p < 2.0$e-12). Site protection fields averaged 0.48 (+/- 0.90) godwits.ha^{-1}, AES 0.46 (+/- 0.95) godwits.ha^{-1}, whereas intensive agriculture ($n = 13,668$) had the lowest density at 0.063 (+/- 0.28) godwits.ha^{-1}.

However, aggregating all AES subsidy types (as in Fig. 4.A) masks a large part of the variation in densities between individual types (Fig. 4.B). A Kruskal-Wallis test ($X^2 = 519$, $p < 2.0$ e-16). Indeed, a Wilcoxon *post hoc test* showed significant differences across the four AES types. Nest protection fields showed the lowest density (0.2 +/- 0.4 godwits.ha^{-1}, $n = 1900$) followed by fields with inundation (0.36 +/-1.3, $n = 259$), delayed mowing (0.66 +/-1.0 godwits.ha^{-1}, $n = 1\,139$) and herb-rich grasslands (1.25 +/-1.6 godwits.ha^{-1}, $n = 353$).

3.4. Availability of conservation strategies in the landscape and godwits population distribution

From 2016–2022 the land use in the area comprised 74 % high-intensity agriculture, 20 % AES, and 6 % site protection. The distribution of godwits across these areas was 23 % in intensive agriculture, 52 % in AES fields, and 25 % in site protected areas (Fig. 5.A). Among AES subsidy types, nest protection fields covered the largest area (10.5 %), followed by delayed mowing (6 %), inundation (1.9 %) and herb-rich grassland (1.1 %). Regarding the distribution of the godwit population, 28.6 % was concentrated in delayed mowing fields, 13 % in nest protection fields, 9.1 % in herb-rich grasslands and 1.4 % in inundated fields.

Table 2
For the four different AES subsidy types, the proportional area of the different AES categories as well as field size are depicted.

		Nest protection (n = 3,319)			Inundation (n = 784)			Delayed mowing (n = 1,693)			Herb-rich grassland (n = 598)		
AES category	**Unit**	**mean**	**sd**	**median**	**mean**	**sd**	**median**	**mean**	**sd**	**median**	**mean**	**sd**	**median**
BotanicallyRichMargins	% of the field	1.5	4.1	0.0	14.6	25.6	5.5	0.7	3.1	0.0	0.3	1.7	0.0
ChickFields	% of the field	4.5	18.2	0.0	1.6	11.3	0.0	0.5	5.1	0.0	0.6	7.4	0.0
DelayedMowing	% of the field	0.5	3.5	0.0	0.1	0.8	0.0	71.5	37.1	89.7	0.0	0.5	0.0
ExtensiveGrazing	% of the field	0.7	8.0	0.0	0.5	6.8	0.0	0.6	6.4	0.0	5.4	23.4	0.0
FallowRows	% of the field	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0
HerbRichGrassland	% of the field	0.7	3.4	0.0	0.2	1.9	0.0	8.5	20.6	0.0	84.1	27.9	94.0
HighWaterTable	% of the field	7.4	20.8	0.0	5.4	14.0	0.0	13.0	28.0	0.0	14.7	26.9	0.0
InundatedPatches	% of the field	0.1	1.5	0.0	8.8	45.7	0.0	1.0	4.3	0.0	3.3	11.3	0.0
NestProtection	% of the field	87.0	25.7	94.0	0.0	0.3	0.0	9.0	20.9	0.0	0.7	3.6	0.0
RestrictedFertilization	% of the field	0.1	2.2	0.0	0.0	0.0	0.0	23.7	39.6	0.0	4.0	21.7	0.0
SolidManureFertilization	% of the field	0.7	3.2	0.0	0.0	0.4	0.0	64.0	40.7	83.5	78.9	34.0	93.6
Field Area	Hectares	4.4	2.5	4.0	3.3	2.3	3.0	5.0	3.5	3.8	2.6	1.4	2.3

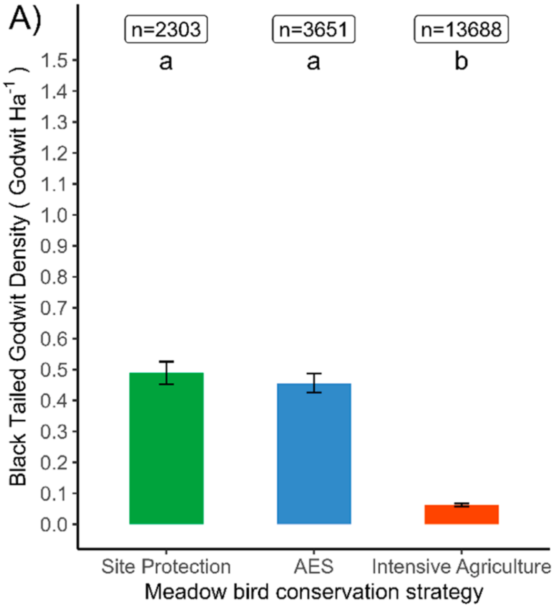

Fig. 4. A) Average density of godwits in fields with different meadow bird conservation strategies. B) The different AES fields according to the AES subsidy types in the period 2016–2022. In boxes n denotes the fields sample size and the error bars the confidence interval.

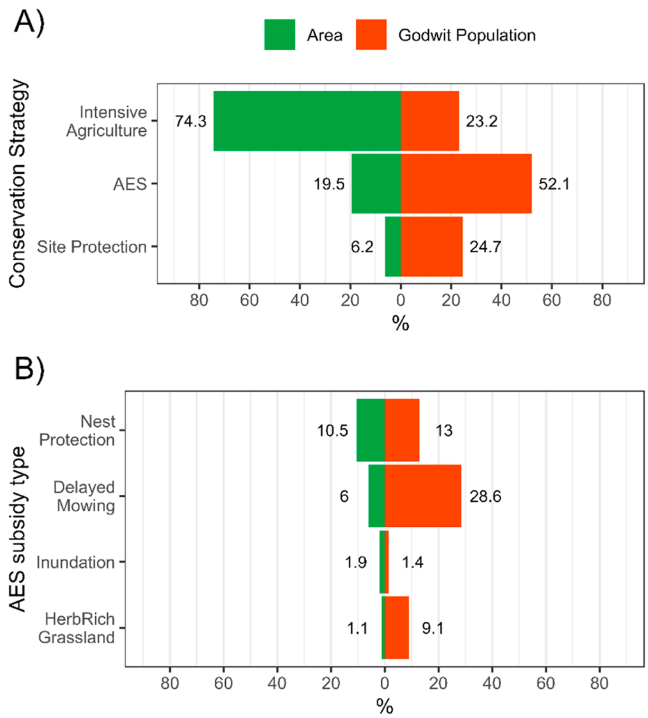

Fig. 5. A) The land area contribution of different meadow bird conservation strategies and the proportion of the godwit population hosted by each management strategy for the period of 2016–2022. B) The area under management by different AES subsidy types for the period 2016–2022 and the proportion of the godwit population hosted by each AES subsidy type.

3.5. Cost of implementation and area coverage of AES

The costs of implementing AES measures varied based on the type of subsidy provided to farmers. Fig. 6.A shows that higher AES subsidies (> €1,200/ha) associated with higher godwit densities, while lower subsidies associated with lower godwit densities. In particular, the highest density of godwit was detected in inundated fields (top-center in Fig. 3.A and Fig. 6.A) and herb-rich grasslands (right bottom corner Fig. 3.A and Fig. 6.A).

The comparison of costs among AES subsidy types showed that herb-rich grassland had the highest implementation cost, averaging €1,287 ± 301/ha (Fig. 6.B), followed by delayed mowing at €653 ± 308/ha. Inundation fields costs varied the most, averaging €352 ± 804/ha, while nest protection was the least expensive at €147 ± 110/ha. Regarding the comparisons between total costs vs the total area covered by each AES type (Fig. 6.C), nest protection fields made up 52 % of AES-covered land (14,518 ha), allocating 19.4 % of the budget. Delayed mowing accounted for 31 % of the area (8,387 ha) and 58.8 % of the budget. Inundation fields covered 10 % of the area (2,576 ha) only using 2.8 % of the budget, while herb-rich grasslands covered just 6 % (1,528 ha) but required 19.1 % of the investment.

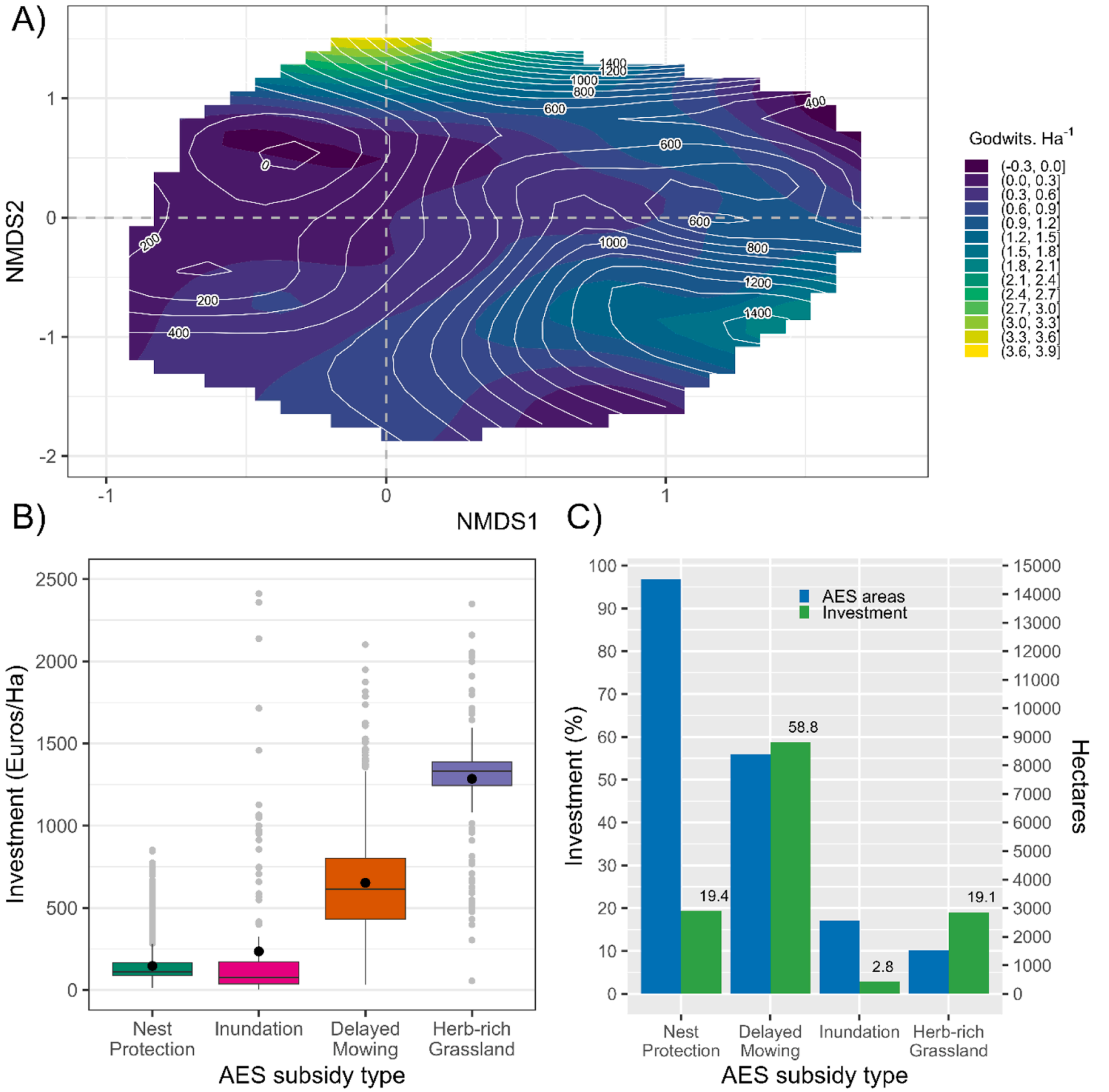

Fig. 6. A) The fitted density of godwits (contour bands) in the multidimensional space of AES and the investment in euros per ha (contour lines). B) Average Investment required for each AES subsidy type. C) The area covered by each AES subsidy type for the period 2016–2022 and the proportion of the total subsidies spent to protect the area.

4. Discussion

In this study we uncovered some of the intricacies of the implementation of Agri-environment schemes (AES) at field and landscape levels. Proposing (1) the abundance of a target species(density and population distributiopn), the Black-tailed Godwit, and (2) a numerical categorization of AES fields, as quantitative common yardsticks, we evaluated the costs-benefits of AES for the conservation of meadow birds. We developed a typology of fields that summarizes the combinations of AES practices and estimated the different AES types availability across the landscape. We then analysed how the distribution of godwits correlated with the availability and quality of management practices for their protection. In the following sections we discuss our findings in the light of existing knowledge to provide recommendations to optimize current AES investment for effective meadow bird conservation.

4.1. The complexity in AES implementation

Our findings revealed that AES are highly diverse, and the complexity of assessing the performance of AES combinations stems from the interaction of several factors. First, different AES target different aspects of the life cycle of meadow birds, with some AES targeting the protection of nests or chicks (i.e. nest protection, delayed mowing, chick fields) while others aim to provide foraging habitat for adults and chicks and thus promote chick survival (i.e. herb-rich meadows, inundation plots, botanical herb-rich edges, delayed mowing, solid manure). Of course, AES may be multifunctional and display synergic effects when combined. Another source of AES variation, and hence performance, is their timing and duration, specific area requirements, number of cows grazing, number of plant species and even the duration of the AES contract, among others.

The implementation of AES in the landscapes may be adapted over time. By considering the avilability of different AES and variants, we showed that the area managed under various AES increased in South-west Friesland between 2016 and 2022. Many interventions (high-water tables, inundated fields, botanically rich field margins, and solid manure) were introduced after 2016 and some became more prominent over time, adding to the complexity. The combination and stacking of AES at the field level is highly heterogeneous, but we organized it in a few meaningful categories. We named AES field types based on the most conspicuous AES, i.e., nest protection fields, delayed mowing, herb-rich-grasslands and inundation fields. However, the combinations are vast, most fields have more than one AES in place at the same time and they are commonly stacked vertically (i.e., delayed mowing with high water tables and solid manure application) or horizontally.

In contrast to our approach, previous studies have often treated AES as fixed categories, without fully accounting for their diversity at field level or the complexity of combining multiple AES practices. For example, earlier research commonly focused on binary comparisons, such as fields with AES versus fields without AES, without exploring the full extent of AES (Breeuwer et al., 2009; Kleijn and Van Zuijlen, 2004). While some studies have considered different grassland types (Kentie et al., 2013, 2014, 2015), they did not fully capture the combination of practices as we have done in our classification. Kentie et al. (2015) provided a broader range of AES grassland types but, like other studies, did not quantitatively assess the effects of multiple AES combinations at once, as we did. Other studies have tested the effect of single or combined AES but in a broader context comparing the outcomes of different studies (Franks et al., 2018). More recent reports in SWF still have not consider all the AES variability for the analysis of trends in meadow birds (Oosterveld et al., 2020). Our study fills this gap by offering a more detailed analysis of AES diversity, particularly in terms of their combinations in space and time. Studies of AES effectiveness, in other countries as well, commonly classify AES in a few categories (low-high tier bird-friendly farming) without accounting for a possible large variability at field level (Sharps et al., 2023). Others like ours, while acknowledging there is different types of AES for the same species may consider AES into a single category to facilitate comparisons to other types of management, but still do not make further investigation on the variability intra AES (Bellebaum and Koffijberg, 2018).

4.2. Meadow bird conservation strategies at field and landscape scale

The densities of meadow birds at field level varied significantly across meadow bird conservation strategies and subsidy types (Fig. 4). Although the study did not aim to evaluate how AES interventions affect meadow bird population growth rates, we do show that areas designated for meadow bird conservation, through AES or site protection, host higher densities of godwits compared to intensive agricultural land. In part this could be due to a better performance of the birds in these areas, but as AES measures as well as site protection are targeted to areas with higher meadow bird numbers in the first place. This means that there is a 'legacy bias' so that overall numbers cannot do it alone. Instead, we need evaluations of time trends (as in Redhead et al., 2022a and 2022b; Rigal et al., 2023).

Across Europe, AES have generally been shown to have a positive impact on meadow bird populations (positive trends in population growth or productivity *i.e.,* nest or chick survival, number of fledglings, recruitment), with site protection exerting even greater effects (Franks et al., 2018). In The Netherlands, Breeuwer et al. (2009) analysed godwit densities from 1990 to 2002 and found higher densities in areas with AES interventions, although such differences already existed before the AES agreements were made. Recent monitoring in The Netherlands indicated higher godwit numbers in site protection areas compared with AES areas, while AES areas hosted higher godwit numbers than intensive agricultural land (van Turnhout et al., 2019). Our findings align with these patterns but show in particular that herb-rich grasslands and delayed mowing fields supported higher godwit densities than protected sites, underscoring their potential value in conservation strategies.

Most of the AES area in our study region is dedicated to nest protection. Fields with nest protection, which had the lowest density of godwits among the different AES fields, still hosted higher densities of godwits than intensive agricultural land. However, after nest protection, mowing can be harmful, even when an area around the nest ('grass island') remains unmown increasing the risk of nest predation (Kentie et al., 2013). The mowing frequency in The Netherlands has increased and the date of the first cut in spring has advanced two weeks since the early 1980s, coinciding with both the nest and chick-rearing phase of godwits (Kleijn et al., 2010; Roodbergen and Teunissen, 2014). Delaying the first mowing date and reducing mowing frequency has a large potential for providing suitable habitat as well as for increasing chick survival (Franks et al., 2018). On the other hand, differential mowing at small scales may create a helpful mosaic of heterogeneity in sward height (Schekkerman and Beintema, 2007), but may also increase chick survival by predation (Schekkerman et al., 2009). The positive association we detected between godwits and herb-rich grasslands with high water tables tallies with previous findings in our study area. Groen et al. (2012) documented a density of 84 breeding godwits/100 ha in herb-rich grasslands, while in grassland monocultures with intensive management densities were as low as 20 godwits/100 ha. These differences were confirmed later by Howison et al. (2018) and Li et al. (2023).

At the level of the southwest Frisian landscape we found that the most of the godwit population (77 %) is concentrated in the AES fields and protected sites, although about a fourth of the population is still found in intensive agricultural land. In particular, around 40 % of the observed population of godwits is concentrated in areas with delayed mowing and herb-rich grassland, which comprise only 7 % of the landscape. A large part of the breeding population is thus clustered in only a tiny part of the landscape, exposed to threats associated with fragmentation i.e. such as increased predation risks (Kaasiku et al., 2022). While these best-performing AES are scarce in the landscape, they host an important share of the godwit population. Their promotion may have an important role for meadow bird conservation and to the overall sustainability and multifunctionality of the landscape. However more information might be required for an effective management for meadow birds.

Our analysis focused on a single iconic meadow bird species in a region of intensive dairy farming. Future research should consider a diversity of landscapes and that AES, site protection, and other conservation strategies may depend on factors like connectivity, area size, and landscape-level effects. AES-supported habitats might be surrounded by infrastructure that deters godwits from breeding (Canonne et al., 2024), while high-potential AES fields may exist as isolated "islands" in intensively farmed areas (De Felici et al., 2019). Although AES measures for godwits may benefit other meadow birds (Howison et al., 2019), multispecies assessments are needed to optimize strategies for broader connectivity. To assess its true impact, long-term godwit population trends, including pre-ANLb data should be analysed (Barba et al., forthcoming). Finally Evaluating nest and chick survival could provide a fuller picture of AES success in meadow bird conservation. However, the current situation still offers limited solutions and subsidies will continue to be one of the main instruments for biodiversity conservation in Europe.

4.3. Enlarging the area coverage of conservation strategies through subsidies?

Despite an eightfold increase in AES investments in The Netherlands since 2001, with €35 million spent annually in 2010–2016 (Roodbergen and Teunissen, 2019; Teunissen and van Paassen, 2013), only 15 % of suitable meadow bird habitat is under AES (Melman and Sierdsema, 2017b) with most funds supporting nest protection. Nest protection practices have been shown to be less effective as the creation of grass islands after mowing can increase predation risk (Kentie et al., 2015). Furthermore, empirical findings underscore that it is likely is the nesting phase, but rather the offspring survival phase that protection measures should focus on to turn the tide for meadow birds such as godwits (Roodbergen et al., 2012; M. Stessens et al. in prep.). Measures such as herb-rich grasslands and delayed mowing could be more effective in promoting chick survival (Kentie et al., 2013), but our analysis shows they are currently only applied at a limited scale, possibly related to the fact that they require the highest subsidies (Fig. 6) and a change in the farming system (Vermunt et al., 2022; Westerink et al., 2024).

However, it is unclear whether increasing these subsidies will reverse the overall decline of meadow birds, given that 75 % of the landscape remains intensive agricultural land, and most of the area with AES is nest protection with low performance for meadow birds. While the AES area expanded between 2016 and 2022, the godwit population continued to decline, though possibly at a slower rate (Hooijmeijer et al., 2024). Recent studies in other countries distinguishing between low and high-tier bird-friendly AES management, suggest increasing farm land bird populations is possible when in the landscape 10–29 % of the area is managed with high-tier AES management and 30 % with low-tier, and if implemented in sites with already high bird abundances(Sharps et al., 2023).

This leads us to two key questions, whether the current AES budget is sufficient to cover enough area with effective measures to support stable meadow bird populations or whether the farming and food systems can adapt to low-intensity agriculture. The willingness of farmers to implement AES specially species-rich grasslands remains limited (Cullen et al., 2021; Westerink et al., 2024). Nevertheless some recent evidence that a hybrid scheme, i.e., results-based schemes plus action-based schemes (the current situation) has a better acceptance between farmers (Thiermann et al., 2023). Yet the AES compensation system might not be the best solution when the market keeps demanding high yields and incentivizes high input management agriculture (Heyl et al., 2022). Such questions, however, must be addressed from a multidimensional perspective (Tittonell, 2023), avoiding to focus the debate on single, isolated indicators of sustainability (e.g. Tittonell, 2021). For instance, fields managed as herb-rich, with high water tables, solid manure application and henceforth the necessary later mowing will not only result in better habitat for breeding godwits but also bring societal benefits such as increased biodiversity, carbon sequestration and reduced nutrient and pesticide pollution (e.g., Dal Ferro et al., 2016; Poláková et al., 2022). Furthermore, livestock grazing on species-diverse diets produce more nutritious meat and milk (Loza et al., 2023; Van Vliet et al., 2021). Food nutritional value, animal welfare and ecosystem services of local and global importance need to be factored in when assessing the impact of investments in biodiversity conservation. A transition towards more sustainable forms of agriculture (e.g. Vermunt et al., 2022; Boix-Fayos and de Vente, 2023) faces many challenges, such as initial yield penalties and systemic changes along the value chain, that need to supported by conducive sectoral policies.

Ethics statement

✔Not applicable: This manuscript does not include human or animal research.

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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

The data that has been used is confidential.

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