RESEARCH ARTICLE

Assessment of semi-natural habitats and landscape features on Irish farmland: New insights to inform EU Common Agricultural Policy implementation

Roser Rotchés-Ribalta ⦿, Sara Ruas, Karzan D. Ahmed,
Michael Gormally, James Moran, Jane Stout, Blánaid White,
Daire Ó hUallacháin

Abstract Concerns over the loss of biodiversity and ecosystem services in farmland have prompted the development of agri-environment policy measures aimed at reducing farming pressure and maintaining semi-natural habitats in farmed landscapes. However, further knowledge is needed to guarantee successful agri-environment measures implementation. The current study assessed the quantity and the quality of semi-natural habitats in farms across a gradient of farming intensities in two contrasting regions in Ireland. Policy protection seemed fundamental for semi-natural habitats preservation. Habitats not protected by agricultural policy relied on extensive farming and are in danger of disappearing if they are intensified or abandoned. Due to the lack of policy incentives for habitat quality, no correlations were found between farming intensity and share of semi-natural habitats with habitat quality. Therefore, extensive farming and retention of habitats alone may not reverse the decline of farmland quality and biodiversity and, thus, measures incentivising the environmental quality may be more successful.

Keywords Agricultural policy · Greening infrastructure · Habitat quality · Share of semi-natural habitats

INTRODUCTION

The intensification of agricultural systems has resulted in significant environmental impacts on water and soil quality, greenhouse gas emissions and biodiversity (Firbank et al. 2008; Stoate et al. 2009), limiting the delivery of multiple goods and services (Montoya et al. 2019). Sustainable farming practices are needed to enhance resilience and ensure successful long-term delivery of food and fibre production and wider ecosystem services (White et al. 2019). Increasing concerns over the loss of biodiversity and ecosystem services in agricultural landscapes have resulted in the development of national and international agri-environment policies aiming to reduce farming pressure and maintain natural habitats in farmed landscapes, to help reverse the decline of biodiversity in these systems, as required by international commitments, e.g. the Aichi Targets (CBD et al. 2011) and the EU Biodiveristy Strategy (European Commission 2011).

The European Union (EU) allocates a significant budget to promote the conservation of the natural environment and halt the loss and degradation of semi-natural habitats in farmland. The Common Agricultural Policy (CAP) encourages farmers to adopt more sustainable actions, and compensate them for the costs incurred and income foregone (European Commission 2013). Pillar I of the CAP, which include "Green payments", subjects farmers to certain cross-compliance entry-level criteria [€12 billion a year is allocated to this payment (European Court of Auditors 2017)]. Pillar II (Rural Development Programmes) incorporates voluntary schemes that incentivise farmers to adopt additional sustainable practices [i.e. Agri-environment measures, with almost €34.4 billion spent from 2007 to 2013 (IEEP 2008)]. However, results till date regarding effectiveness of agri-environment measures in conserving biodiversity and ecosystem services are not conclusive (Mauchline et al. 2012; Batáry et al. 2015): some studies reported positive effects (Batáry et al. 2011; Scheper et al. 2013); while others found no significant changes as a result of these measures (Kleijn et al. 2004).

In 2018, the European Commission presented a proposal on the future legislative framework for the CAP, including the new "green architecture" for the period 2021–2027 (European Commission 2018). Following criticism of current greening measures (European Court of Auditors 2017), recommendations included enhanced baseline conditionality and "eco-schemes" funded under Pillar I. Baseline conditionality requirements could see all farmers required to retain a minimum share of agricultural area (determined by individual Member states) devoted to "non-productive" features or semi-natural habitats (European Commission 2018).

Retention of semi-natural habitats and habitat heterogeneity benefits biodiversity and ecosystem services in agricultural landscapes (Benton et al. 2003; Donald and Evans 2006; García-Feced et al. 2014) and might be an appropriate approach to support sustainability in agricultural systems (Wezel et al. 2014). However, recent studies found that similar schemes (e.g. Ecological Focus Areas, at 5% of farmed area) did not set sufficiently ambitious environmental targets for share of semi-natural habitats and, thus, are unlikely to provide significant benefits (European Court of Auditors 2017; Cole et al. 2020). There is therefore an urgent need to evaluate the current status of semi-natural habitats on farms in each Member State to inform policy makers and establish appropriate thresholds of habitat retention and increase the chances of CAP implementation improving the protection of habitats in farmland.

In general, the aim of "greening" measures implemented till date in the EU has been to retain landscape features or a minimum area of EFAs on farms, with little attention paid to improve habitat quality and delivery of ecosystem services. The exceptions are some targeted/zonal agri-environment schemes (Batáry et al. 2015) and Results-Based Agri-environment Payments Schemes (RBAPS) (Herzon et al. 2018; Maher et al. 2018). These approaches demonstrate that schemes which consider habitat quality may achieve more success at improving ecological condition and biodiversity conservation (Klimek et al. 2008; Herzon et al. 2018), than those focusing exclusively on habitat quantity.

Agricultural landscapes dominate the countryside of many European Member States, and the Republic of Ireland in particular, where approximately 64% of land area is dedicated to agriculture (DAFM 2018b). As part of the Rural Development Programme, the Republic of Ireland (Ireland hereafter) has implemented schemes aimed at protecting habitats and the environment (European Commission 2016). For instance, hedgerows and treelines are protected under Agricultural Policy in Ireland, due to their significance in the Irish agricultural landscape, covering 4% of the total land area (Forest Service 2018) and 11% of

farmed area (Sheridan et al. 2017). However, several other semi-natural habitats (e.g. heathlands, peatlands, woodlands) are not afforded protection under Agricultural Policy, despite their value for biodiversity and ecosystem services (Department of Culture Heritage and the Gaeltacht 2019).

In order to build evidence-base for the design of CAP measures, this study aimed to:

(a) measure and compare the current share, richness and composition of semi-natural habitats in Irish farms across a gradient of farming intensities;
(b) assess how current agricultural policy impacts on the conservation of semi-natural habitats on Irish farms; and
(c) assess the extent to which habitat quality is related to the share of semi-natural habitats in Irish farms at different farming intensities.

The results from this study can support policy makers to design optimal approaches to ensure successful delivery of environmental outcomes associated with semi-natural habitats in agricultural landscapes under the upcoming CAP reform for 2021–2027.

MATERIALS AND METHODS

Study site selection

Two study areas in Ireland with contrasting climatic, topographic and farming conditions were selected: N-W Ireland, Sligo (in an area of 16.5 km × 8.2 km) and S-E Ireland, Wexford (15.8 km × 15.7 km) (Fig. 1). Both areas presented a gradient of farming intensities over relatively short distances. Mean annual temperature and precipitation in Sligo are 9.6 °C and 1260.1 mm and in Wexford are 9.8 °C and 840.2 mm (https://www.met.ie/, accessed 26/02/2019).

Twenty-seven farms in each study site were selected and characterised according to farming intensity, in line with the High Nature Value (HNV) categorisation (http://www.high-nature-value-farmland.ie/, accessed 26/02/2019). The nature value score was calculated for each farm using the tool "Is your farm HNV?" (http://www.high-nature-value-farmland.ie/is-your-farm-hnv/), which considers the area owned and farmed, the stocking rate, the proportion of improved grasslands and size of fields and boundaries, based on Boyle et al. (2015). Nature value scores allowed farms to be classified into farming intensity categories: intensive, with scores < 3.5 ($n = 9$ in Sligo, $n = 10$ in Wexford); intermediate, with scores between 3.5 and 5 ($n = 9$ in Sligo, $n = 8$ in Wexford); and extensive, with
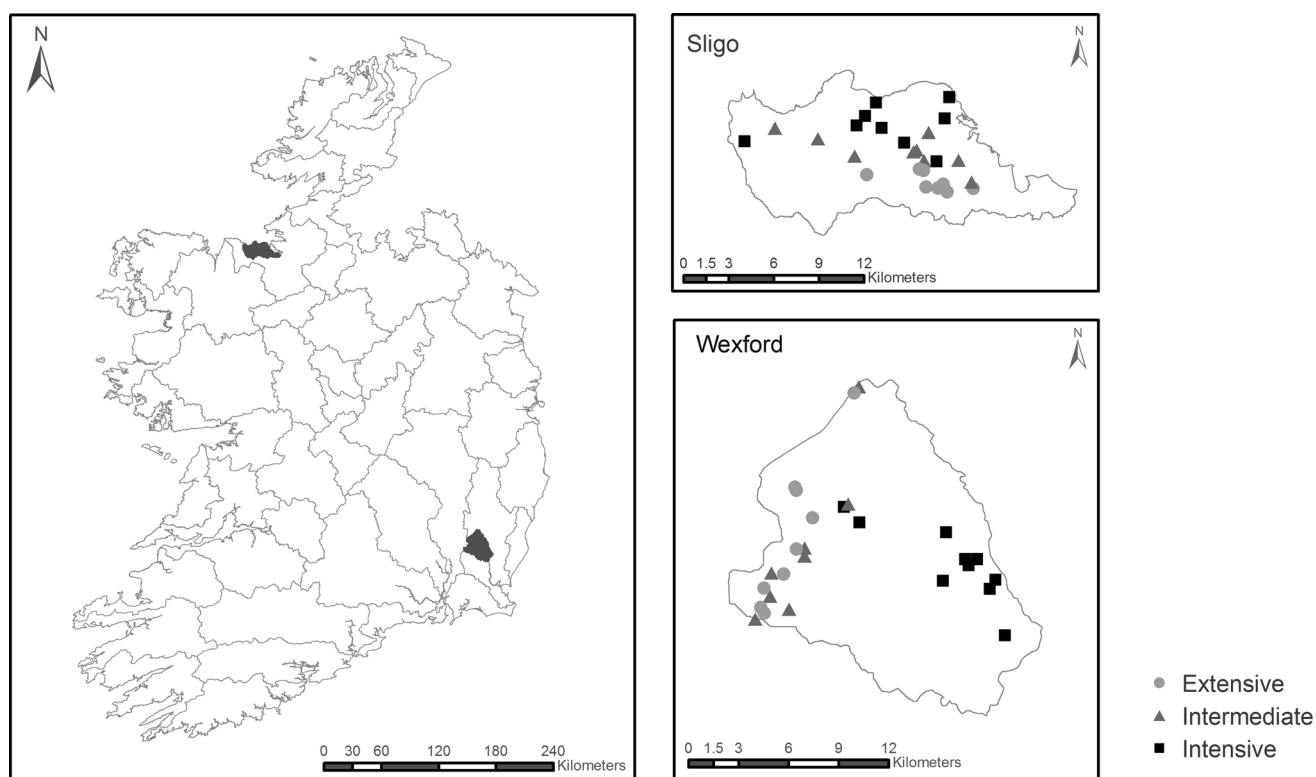
Fig. 1 Location of the study areas (i.e. Sligo and Wexford) and of the farms with different intensity categories

scores > 5 (n = 9 in both Sligo and Wexford) (Table S1 in Supplementary Materials).

Farmland habitat surveys and habitat classification

Habitat surveys were conducted between April and September 2018, following Smith et al. (2011). All habitats on each farm were identified and classified according to the Irish National Habitat Classification Standard level 3 (Fossitt 2000). Infrequently occurring habitats, including different types of woodlands (i.e. riparian woodland, broadleaved woodland, etc.), heaths (i.e. dry calcareous, wet or montane heaths) and peatlands (i.e. raised bog, upland blanket bog, etc.), were grouped together into major classification levels (i.e. woodland, heaths or peatland) to guarantee sufficient replicates for data analysis and interpretation.

All habitats were grouped into high production land, semi-natural habitats or other habitats (Table 1). "High production land" included habitats mainly used for agricultural production, usually requiring intensive management. "Semi-natural habitats" were used for extensive food/fibre production or non-food or fibre producing habitats, with high value for biodiversity. "Other" included built and disturbed land.

Semi-natural habitats were further classified in relation to the level of policy protection. No study farms had land

within Natura 2000 areas (National Parks and Wildlife Service Ireland 2018), therefore, where habitats were afforded policy protection, it was through agricultural policy. Semi-natural habitats groups were:

(a) *Valued habitats* habitats currently protected under national and EU Agricultural Policy (European Commission 2013). They are recognised as eligible habitats under Basic Payment Scheme and farmers are obliged to retain them.

(b) *Optionally valued habitats* habitats that are eligible under Basic Payment Scheme. Farmers are not obliged to retain them, but can be incentivised to do so under optional schemes including Agri-environmental Schemes (AES) or EFAs (DAFM 2018a).

(c) *Undervalued habitats* habitats not fully protected and farmers are not, in general, obliged to retain them. A small number of habitats in this group are referred to in the European Community (Environmental Impact Assessment) (Agriculture) Regulation 2011, whereby their removal is subject to 'screening' by the Department of Agriculture, Food and the Marine (DAFM), if area thresholds are exceeded. These habitats are currently ineligible for agri-environment schemes (DAFM 2016) (Table 1).

Table 1 Mean percentage area (± SE) and number of farms where habitat types occurred across the three intensity categories. Some habitat types group similar habitats with low representation (e.g. different types of woodland are grouped into 'Woodland' category; raised bog and upland blanket bog into 'Peatland' and dry calcareous heath, wet and montane heath into 'Heath'). Different letters indicate significant differences ($p < 0.05$) or marginal differences ($0.1 > p > 0.05$) when ° is accompanying them and 'n.s.' indicates no significant differences in the proportion of habitat area between intensity categories within a certain study site found in the post hoc pairwise comparisons. Consideration of semi-natural habitats under Irish agricultural policy is indicated as: VAL for valued habitats; OPT for valued-optional; and UND for undervalued habitats

| | Sligo | | | | | | Wexford | | | | | |
| | Intensive (n = 9) | | Intermediate (n = 9) | | Extensive (n = 9) | | Intensive (n = 10) | | Intermediate (n = 8) | | Extensive (n = 9) | |
	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms
High production land												
Arable crop	1.77 ± 0.00	1					52.05 ± 9.33	9	6.10 ± 5.36	2	1.23 ± 0.00	1
Horticultural land							1.79 ± 1.21	2	3.28 ± 2.16	2	4.44 ± 6.90	2
Tilled land							0.34 ± 0.00	1	1.55 ± 0.55	2	1.28 ± 0.00	1
Improved grassland	87.05 ± 4.42	9	75.33 ± 3.44	9	50.14 ± 9.09	9	36.05 ± 10.11	9	63.26 ± 7.71	8	65.42 ± 7.79	9
Semi-impr. grassland	2.72 ± 2.73	3	5.33 ± 1.18	7	7.04 ± 3.55	7			1.35 ± 1.45	2	1.67 ± 0.58	2
Bird cover									1.66 ± 1.39	3	0.34 ± 0.00	1
Conifer plantation			1.94 ± 0.00	1					6.20 ± 4.85	3		
Total	91.54 ± 1.13a		82.60 ± 3.29a		57.18 ± 9.41b		90.23 ± 1.99a		83.39 ± 3.91ab		74.39 ± 6.86b	
Semi-natural habitats												
Hedgerow (VAL)	2.35 ± 0.31	9	3.53 ± 0.26	9	2.46 ± 0.60	9	2.96 ± 0.23	10	4.57 ± 0.36	8	4.46 ± 0.66	9
Treeline (VAL)	0.54 ± 0.16	8	0.54 ± 0.11	9	1.09 ± 0.26	9	0.77 ± 0.12	10	0.66 ± 0.12	8	0.52 ± 0.12	8
Drainage ditch (VAL)	0.42 ± 0.18	6	0.67 ± 0.20	8	0.53 ± 0.17	7	0.28 ± 0.05	9	0.42 ± 0.10	8	0.42 ± 0.17	6
Stonewall (OPT)	0.64 ± 0.20	8	0.23 ± 0.06	6	1.08 ± 0.21	9	0.00 ± 0.00	1	0.06 ± 0.04	6	0.82 ± 0.64	8
Semi-nat. grassland (OPT)	0.19 ± 0.00	1	0.15 ± 0.00	1	2.43 ± 2.11	3	0.24 ± 0.00	1	0.26 ± 0.00	1	5.47 ± 6.68	2
Wet grassland (OPT)	0.71 ± 1.01	2	6.05 ± 2.01	6	5.98 ± 2.23	7					0.21 ± 0.00	1
Field copse (OPT)	0.03 ± 0.00	1	0.37 ± 0.25	3	0.61 ± 0.24	6	0.17 ± 0.14	3	0.43 ± 0.13	4	1.54 ± 1.25	6
Earth bank (UND)	0.13 ± 0.05	7	0.05 ± 0.01	7	0.41 ± 0.16	8	0.07 ± 0.03	6	0.07 ± 0.03	5	0.22 ± 0.13	7
Grassy margin (UND)	0.12 ± 0.03	8	0.16 ± 0.04	7	0.05 ± 0.03	5	0.17 ± 0.06	10	0.05 ± 0.03	3	0.03 ± 0.01	2
Dense bracken (UND)					2.55 ± 4.64	2			1.40 ± 0.00	1	0.79 ± 0.26	3
Heath (UND)			1.87 ± 1.49	2	16.85 ± 2.81	4			2.09 ± 0.00	1		
Peatland (UND)			0.00 ± 0.00	0	5.99 ± 5.77	3					3.67 ± 0.00	1
Woodland (UND)	0.41 ± 0.07	2	1.06 ± 0.28	3	0.63 ± 0.39	3	1.42 ± 0.60	5	3.19 ± 1.77	5	2.51 ± 1.10	4
Scrubland (UND)	0.22 ± 0.00	1	0.32 ± 0.15	3	0.41 ± 0.16	3	1.67 ± 1.14	4	1.48 ± 1.60	3	2.38 ± 3.23	3
Pond (UND)	0.01 ± 0.00	1	0.01 ± 0.00	1								
Stream (UND)	0.33 ± 0.11	5	0.55 ± 0.11	8	0.52 ± 0.06	9	0.27 ± 0.04	8	0.23 ± 0.10	6	0.59 ± 0.18	6
Total	6.10 ± 1.13a		15.56 ± 3.41a		41.59 ± 9.63b		8.02 ± 1.92a		14.90 ± 3.64b°		23.63 ± 7.08b	
Other												
Built and artificial	1.45 ± 0.32	9	1.24 ± 0.13	9	0.72 ± 0.24	8	1.08 ± 0.20	9	0.71 ± 0.20	7	0.85 ± 0.28	5
Farm Road	0.40 ± 0.07	7	0.19 ± 0.05	7	0.18 ± 0.08	5	0.34 ± 0.07	8	0.52 ± 0.22	7	0.40 ± 0.11	7

Table 1 continued

| | Sligo | | | | | | Wexford | | | | | |
| | Intensive (n = 9) | | Intermediate (n = 9) | | Extensive (n = 9) | | Intensive (n = 10) | | Intermediate (n = 8) | | Extensive (n = 9) | |
	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms	Mean ± SE	Farms
Amenity grassland	0.37 ± 0.19	6	0.29 ± 0.17	5	0.29 ± 0.24	3	0.11 ± 0.05	4	0.43 ± 0.36	4	0.25 ± 0.17	3
Spoil/bare ground							0.20 ± 0.00	1			0.23 ± 0.00	1
Abandoned field	0.13 ± 0.00	1	0.11 ± 0.15	2							0.23 ± 0.00	1
Fence	0.01 ± 0.01	4	0.00 ± 0.00	3	0.03 ± 0.02	5	0.01 ± 0.01	3	0.04 ± 0.01	5	0.02 ± 0.00	8
Artificial wall	0.01 ± 0.01	4	0.01 ± 0.00	6	0.01 ± 0.01	2	0.00 ± 0.00	4				
Total	2.36 ± 0.47a		1.84 ± 0.24a		1.22 ± 0.42b		1.75 ± 0.10n.s.		1.71 ± 0.16n.s.		1.98 ± 0.19n.s.	

Habitat composition measures

Habitat surveys were digitised using ArcMap (version 10.5) over the World Imagery base map. Habitats were mapped as polygons or as linear habitats if < 4 m width (including hedgerows/treelines, stonewalls, ditches). The area of each habitat was obtained from the polygons and a standard width (see Table S2 in Supplementary Materials) multiplied by their length was used to estimate the area of linear habitats.

The total farm area corresponded to the sum of all habitat areas of a farm and was used to calculate the proportional area of each habitat type per farm (%), and the proportion (%) of each group of habitats per farm (i.e. high production land, semi-natural habitats and other habitats). The overall length of linear habitats per farm was obtained by summing the length of all linear habitats in each farm divided by the overall farm area in hectares. Habitat richness per farm was calculated as the number of different semi-natural habitats, following the classification in Table 2, in each farm. Habitat heterogeneity per farm was calculated as the Shannon's diversity index (H'), calculated as $H' = -\sum[p_i(\ln p_i)]$, where p_i was calculated as the proportion of area of each habitat with regard to the overall area per farm.

Habitat quality surveys

Quality of habitats was assessed by novel Rapid Assessment Cards (RACs) developed by the authors for each main habitat type [i.e. hedgerows/treelines, drainage ditches/streams, stonewalls, earthbanks/grassy margins, grasslands and heathlands). Where previous quality assessment systems existed, these were revised to suit the project needs (e.g. hedgerow and treeline RAC considered most variables from Foulkes et al. (2013); grassland and heath RACs from Maher et al. (2018)]. Where quality assessments did not exist for particular habitats, they were developed by the project team [e.g. RACs for stonewalls were developed following Collier and Feehan (2009) and the description from Fossitt (2000), and for drainage ditches and water courses, following documents from Joint Nature Conservation Committee (2005) and Palmer et al. (2013)]. Information on various descriptors acting as proxies for environmental condition, habitat significance and management pressure was collected with RACs for each habitat type (Appendix S1 of Supplementary Materials). From the RACs, a scoring system was devised to assess the quality of habitats, informed by previously developed Score Cards for habitat quality assessment, e.g. the RBAPS (Maher et al. 2018) or the Hedgerow Appraisal System (Foulkes et al. 2013). The novelty of current RACs and the quality scoring system in this study is that it

Table 2 Average length per hectare (± SE) of linear habitats occurring in each intensity category per study site. Different letters indicate significant differences ($p < 0.05$) between intensity categories within a certain study site found in the post hoc pairwise comparisons. Consideration of semi-natural habitats under Irish agricultural policy is indicated as: VAL for valued habitats; OPT for valued-optional; and UND for undervalued habitats

	Sligo			Wexford		
	Intensive ($n = 9$) Mean ± SE	Intermed ($n = 9$) Mean ± SE	Extensive ($n = 9$) Mean ± SE	Intensive ($n = 10$) Mean ± SE	Intermed ($n = 8$) Mean ± SE	Extensive ($n = 9$) Mean ± SE
Hedgerow (VAL)	103.62 ± 13.78	150.73 ± 11.06	83.52 ± 20.28	112.21 ± 8.53	173.02 ± 13.80	168.83 ± 25.09
Treeline (VAL)	23.73 ± 7.09	23.15 ± 4.59	36.92 ± 8.73	29.05 ± 4.64	25.07 ± 4.65	19.78 ± 4.61
Drainage ditch (VAL)	16.03 ± 6.76	24.78 ± 7.21	28.99 ± 9.28	14.15 ± 2.76	21.66 ± 5.22	16.31 ± 6.73
Stonewall (OPT)	61.62 ± 19.47	22.49 ± 6.16	103.47 ± 20.12	0.11 ± 0.00	5.15 ± 3.11	64.82 ± 50.71
Earth bank (UND)	10.08 ± 3.82	3.93 ± 1.08	31.06 ± 11.96	6.42 ± 3.01	5.79 ± 2.34	19.27 ± 11.03
Grassy margin (UND)	9.15 ± 2.58	12.02 ± 3.43	3.52 ± 2.25	14.80 ± 4.94	4.29 ± 2.41	2.34 ± 1.19
Stream (UND)	12.71 ± 4.23	20.17 ± 4.21	28.02 ± 3.30	13.89 ± 2.13	11.52 ± 5.24	22.90 ± 7.11
Total	236.94 ± 15.23a	257.29 ± 17.50a	315.50 ± 16.39b	190.63 ± a	246.50 ± 22.72b	314.24 ± 29.98c

standardises the scoring methods used in previous quality assessments such that the quality (score) of various different habitats can be compared. Details on the descriptors considered and the scoring system for each habitat can be consulted in Appendix S1. Scores were scaled from 0 to 1 for each habitat, by dividing the maximum achievable score to the score obtained in each assessed feature, to standardise the scoring ranks. Therefore, habitats scored between 0 and 1, being 0 the worst quality habitat and 1 the best quality habitat.

Habitat quality surveys in fields (grasslands and heathlands) were conducted while walking a "W"-shaped route in fields, as recommended in the RBAPS assessment (Maher et al. 2018). For linear features, the quality surveys were conducted along 30 m length. Two surveys were conducted when a linear feature was > 80 m long (Foulkes et al. 2013).

Quality surveys were conducted on all habitats belonging to a selected representative parcel in each farm. Selected parcels consisted of 2 to 5 adjoining fields and all surrounding linear features.

Data analysis

Differences in the share of semi-natural habitats (%), habitat heterogeneity (Shannon's diversity index) and length of semi-natural linear habitats per farm across intensity categories (i.e. intensive, intermediate and extensive) were assessed using linear models. Normality of data was checked visually by QQplots and conducting the Shapiro–Wilk test and homoscedasticity was checked by plotting residuals against fitted values and assumptions were met, in some cases following log-transformation of

data. Generalised linear models with Poisson distribution were used to assess differences in habitat richness (working as counts of different habitats) per farm across intensity categories (i.e. intensive, intermediate and extensive) for each study site.

Post hoc pairwise comparisons were conducted to determine differences among intensity categories and for analysis of the proportion of habitats classified according to the policy protection in Ireland (i.e. valued, optional and undervalued habitats).

Given that parametrical assumptions were not met for habitat quality data, differences in the quality of habitats among intensity categories for each study site were assessed using Kruskal–Wallis rank sum test. To assess whether the quality of semi-natural habitats was related to the habitat quantity descriptiors at farm scale (i.e. % semi-natural habitats, habitat richness, habitat diversity (Shannon) and length of linear habitats), Spearman's rank correlations between the scores of quality and the descriptors of habitat quantity were conducted.

All statistical analyses were conducted using R (R Core Team 2016) and significance was considered with p values < 0.05.

RESULTS

Fifty-four farms, covering 2236 ha (968 ha in intensive, 727 ha in intermediate and 541 ha in extensive farms), were surveyed. The three intensity categories within each study site showed significant differences for nature value indices, but also for the average farm area and stocking rates (Table S1 in Supplementary Materials).

Habitat composition

Intensive farms had significantly greater proportion of farm under high food-fibre production than extensive farms in both study sites (Table 1). Although intensive farms had the smallest proportion of semi-natural habitats, the values always exceeded 5%, the threshold for EFAs (Fig. 2). Intensive farms in Sligo and Wexford showed similar proportions under high food-fibre production, likewise intermediate farms, but extensive farms in Wexford had higher proportion of area under high food-fibre production than extensive farms in Sligo (Table 1; Fig. 2).

The proportion of semi-natural habitats per farm also differed across farming intensities, increasing from intensive to extensive farms (Table 1; Fig. 2). Extensive farms in Sligo had significantly higher proportion of semi-natural habitats than intensive and intermediate farms (Table 3). In Wexford, intermediate and extensive farms had significantly higher proportions of semi-natural habitats than intensive farms (Tables 1, 3).

Similar trends were found for the length of linear habitats across intensity categories (Fig. 2); extensive farms held significantly greater length of linear features per
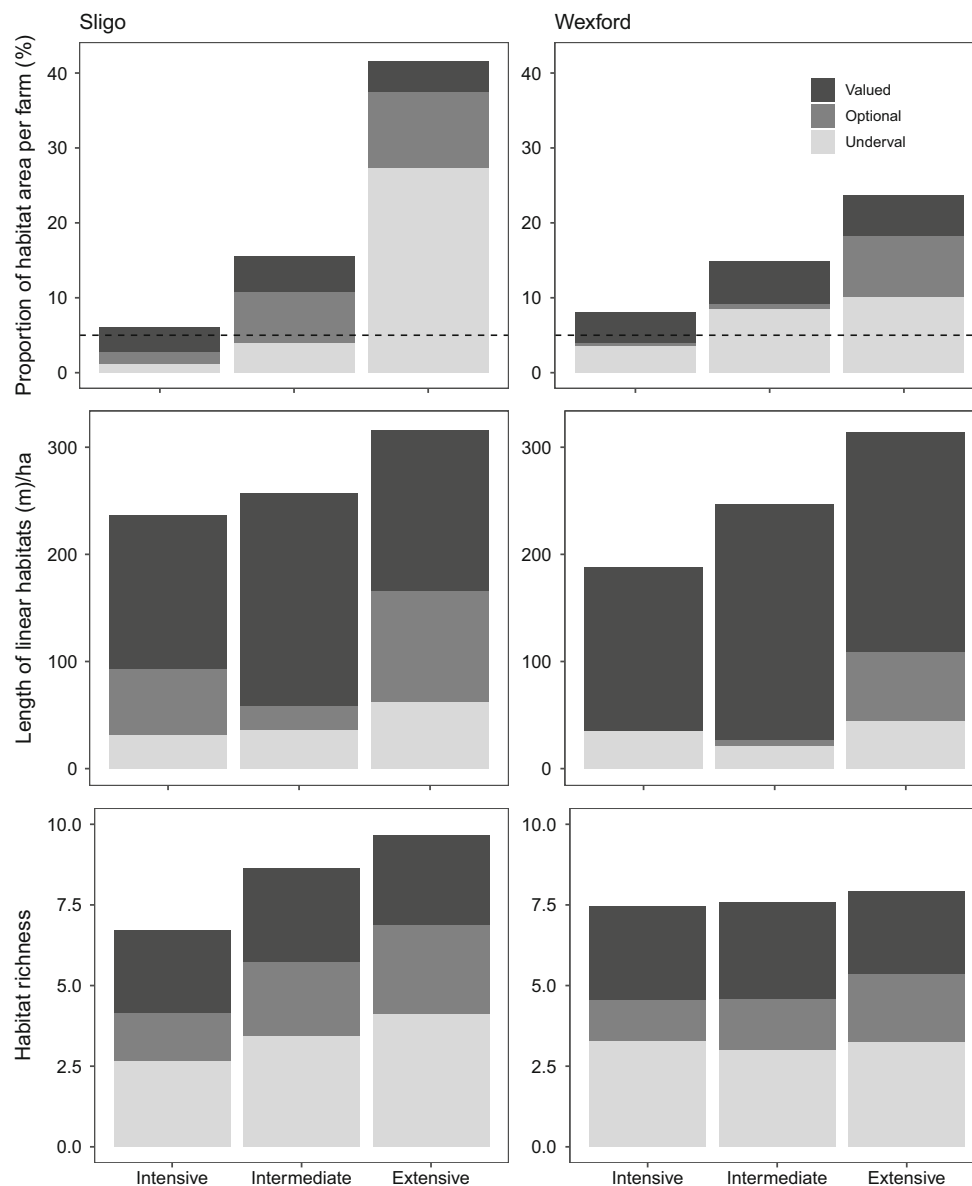
Fig. 2 Proportion of semi-natural habitat area, length of linear habitats and habitat richness per farm among intensity categories, considering the classification of policy protection in Ireland (i.e. valued, optional and undervalued habitats). Dashed line indicates the %-limit (5%) for proportion of semi-natural habitats to qualify as eligible for subsidies

Table 3 Average proportion of semi-natural habitat area per farm and length of linear habitats classified according to the policy protection in valued, valued-optional and undervalued per intensification category and study site. Also, the average habitat richness and habitat diversity (assessed as Shannon diversity index) are presented per intensification category and study site. Different letters indicate significant differences ($p > 0.05$) or marginal differences ($0.1 > p > 0.05$) when accompanied by °, among categories within the study site

	Sligo			Wexford		
	Intensive (n = 9) Mean ±	Intermed (n = 9) Mean ± SE	Extensive (n = 9) Mean ± SE	Intensive (n = 10) Mean ± SE	Intermed (n = 9) Mean ± SE	Extensive (n = 8) Mean ± SE
Proportion of habitat area (%)						
Valued	3.31 ± 0.48a	4.74 ± 0.36b°	4.09 ± 0.80ab	4.01 ± 0.21a	5.65 ± 0.34b	5.40 ± 0.79b°
Optional	1.57 ± 0.56a	6.80 ± 2.14b	10.10 ± 2.17bb	0.40 ± 0.51a	0.75 ± 0.42a	8.04 ± 4.61b°
Undervalued	1.22 ± 0.41a	4.02 ± 1.35a	27.40 ± 10.54bb	3.61 ± 1.54	8.50 ± 3.22	10.19 ± 3.92
Length of linear habitats (m)/ha						
Valued	143.38 ± 20.63a	198.67 ± 14.43b°	149.43 ± 29.41ab	152.71 ± 8.75a	219.75 ± 13.11b	204.92 ± 30.10b°
Optional	61.62 ± 19.47ab	22.49 ± 6.16a	103.47 ± 20.12b	0.11	5.15 ± 3.11	64.82 ± 50.71
Undervalued	31.94 ± 7.37a	36.13 ± 4.74a°	62.60 ± 13.92b	35.11 ± 5.91a°	21.60 ± 7.36a	44.50 ± 11.92b
Habitat richness	6.56 ± 0.63a	8.11 ± 0.95ab	9.67 ± 0.87b	6.70 ± 0.54n.s	7.38 ± 0.56n.s	7.33 ± 0.83n.s
Habitat diversity (Shannon index)	0.25 ± 0.04a	0.48 ± 0.08b°	0.81 ± 0.12c	0.30 ± 0.06a	0.44 ± 0.08a	0.55 ± 0.08b

hectare than intermediate and intensive farms in both sites (Tables 2, 3).

Habitat richness per farm in Sligo followed similar trends to the proportion of semi-natural habitats (Fig. 2): extensive farms had significantly greater habitat richness than intensive farms (Table 3). However, no significant differences were found in habitat richness among intensity categories in Wexford (Table 3). Habitat heterogeneity, assessed as Shannon's diversity index, was significantly greater in extensive farms in both study regions (Table 3). However, Shannon's diversity index values were lower in Wexford, for example, extensive farms of Wexford had equivalent habitat diversity values as intermediate farms in Sligo (Table 3).

Habitats and agricultural policy

Similar proportion of valued habitats was found across intensity categories and study sites. Significant differences were only found between intermediate and intensive farms in Wexford, with higher proportion of valued habitats in intermediate farms (Fig. 2; Table 3). The length of valued linear habitats showed similar results (Table 3).

The proportion of optionally valued habitats increased from intensive to extensive farms, with significant differences between intensive and intermediate/extensive farms in Sligo, and marginal differences between intermediate and extensive farms in Wexford (Fig. 2; Table 3).

Similar trends were found for undervalued habitats, but significant differences occurred when comparing extensive with intensive/intermediate farms in Sligo, with higher

values in extensive farms (Fig. 2; Table 3). Differences were not significant for the share of undervalued habitats in Wexford, although significantly greater lengths of undervalued linear habitats occurred in extensive farms in both study sites (Fig. 2; Table 3).

No significant differences were found for the number of habitats (richness) within valued, optional-valued or undervalued categories either in Sligo or in Wexford (Fig. 2).

Habitat quality on farms

Scores of habitat quality ranged between 0.13 and 0.70 for hedgerows and treelines, between 0 and 0.85 for drainage ditches, between 0.05 and 0.67 for stonewalls, between 0.55 and 1 for semi-natural grasslands, between 0.15 and 0.65 for heaths and between 0 and 0.74 for grassy margins.

No significant differences were found in the average quality of all semi-natural habitats between intensity categories; in either Sligo (K–W $\chi^2 = 1.822$, df = 2, $p = 0.402$) or Wexford (K–W $\chi^2 = 0.645$, df = 2, $p = 0.724$) (Fig. S1 in Supplementary Materials). Significant differences were found among intensity categories for specific habitats, but trends differed among them (Table 4). For instance, habitat quality of hedgerows/treelines in extensive farms of Sligo was significantly higher than in intensive farms, but the opposite happened in hedgerows/treelines of Wexford (Table 4). While habitat quality of drainage ditches in Sligo was lower in extensive farms than in intensive and intermediate, no significant differences

Table 4 Scores of quality obtained for semi-natural habitats for each intensity category per study site. Different letters indicate significant differences ($p < 0.05$), or not (n.s.); between intensity categories within a certain study site per each type of habitat obtained with Kruskal–Wallis rank sum tests. Consideration of semi-natural habitats protection under Irish agricultural policy is indicated as: VAL for valued habitats; OPT for valued-optional habitats; and UND for undervalued habitats

| | Sligo | | | | | | Wexford | | | | | |
| | Intensive | | Intermediate | | Extensive | | Intensive | | Intermediate | | Extensive | |
	Mean ± SE	Freq	Mean ± SE	Freq	Mean ± SE	Freq	Mean ± SE	Freq	Mean ± SE	Freq	Mean ± SE	Freq
Hedgerow/treeline (VAL)	0.45 ± 0.01a	65	0.44 ± 0.01a	90	0.48 ± 0.01b	62	0.49 ± 0.01a	93	0.47 ± 0.01ab	112	0.45 ± 0.01b	78
Drainage ditch (VAL)	0.46 ± 0.03a	8	0.49 ± 0.04a	34	0.25 ± 0.03b	25	0.11 ± 0.02n.s.	4	0.08 ± 0.08n.s.	10	0.19 ± 0.06n.s.	10
Stonewall (OPT)	0.40 ± 0.02a	42	0.27 ± 0.03b	13	0.35 ± 0.02a	52		10	0.34 ± 0.02n.s.	23	0.43 ± 0.03n.s.	23
Semi-natural grassland (OPT)			0.83 ± 0.07n.s.	5	0.70 ± 0.04n.s.	11		1	0.65 ± 0.00	1	0.55 ± 0.00	1
Heath (UND)					0.49 ± 0.11	4			0.17 ± 0.01	3		
Grassy margin (UND)	0.24 ± 0.04a	21	0.34 ± 0.05ab	22	0.44 ± 0.03b	19	0.27 ± 0.05n.s.	8	0.28 ± 0.06n.s.	16	0.15 ± 0.07n.s.	6
VALUED	0.45 ± 0.01ab	73	0.46 ± 0.01a	124	0.42 ± 0.02b	87	0.43 ± 0.02n.s.	97	0.45 ± 0.01n.s.	131	0.42 ± 0.02n.s.	88
OPTIONAL	0.40 ± 0.02n.s.	42	0.42 ± 0.07n.s.	18	0.41 ± 0.02n.s.	63		11	0.37 ± 0.03n.s.	24	0.44 ± 0.03n.s.	24
UNDERVAL/IGNORED	0.24 ± 0.04a	21	0.34 ± 0.05a	22	0.45 ± 0.03b	23	0.27 ± 0.05n.s.	11	0.25 ± 0.05n.s.	16	0.15 ± 0.06n.s.	6

were found in the quality of drainage ditches in Wexford (Table 4).

Overall, for all habitats together, no correlations were found between habitat quantity descriptors (proportion of semi-natural habitats, length of linear habitats, habitat richness and habitat diversity) and habitat quality scores (Fig. 3). For valued habitats, none of the habitat quantity descriptors at the farm scale showed significant correlations with their quality, irrespective of the intensity category (Fig. S2 in Supplementary materials). Quality of optionally valued habitats showed a significant positive association with length of linear habitats, particularly for extensive and intermediate farms, and a negative association with habitat richness, especially for extensive farms (Figs. 3 and S2). While the proportion of semi-natural habitats and the habitat diversity had no significant correlation with the quality of optionally valued habitats in general, these correlations were negatively significant for extensive farms (Fig. 3). The four habitat quantity descriptors showed positive correlations with the quality of undervalued habitats, similarly for all farming intensity categories separately (Fig. 3 and Fig. S2).

DISCUSSION

Habitat quantity and farming intensity

The gradient of farming intensity categories used in this study matched the gradient of the proportion of semi-natural habitats per farm, with more semi-natural habitats on more extensive farming systems. Although intensive farms had similar proportions of semi-natural habitats in Sligo and Wexford, and likewise for intermediate farms, the proportion of semi-natural habitats in extensive farms in Sligo was greater than in Wexford. This might be an indication on farm polarisation of habitats (i.e. high productive land vs. semi-natural landscape elements) in Wexford, whereas semi-natural vegetation is still an integral part of production systems in Sligo (see Sullivan et al. 2017). These results highlight the need to develop a range of policy interventions, adapted to different farm settings and intensities (e.g. intensive, intermediate and extensive farming intensities). Different farmed landscapes with different proportions and types of semi-natural vegetation have the capacity to preserve associated biodiversity and provide different levels of ecosystem services (García-Feced et al. 2014). Consequently, if retention of semi-natural features is restricted to non-productive areas only, farmed semi-natural vegetation (mainly used for extensive pasture) may have little protection, with increased risk of loss due to intensification or land-use change. Therefore, to deliver a broad range of services, policy interventions need to target
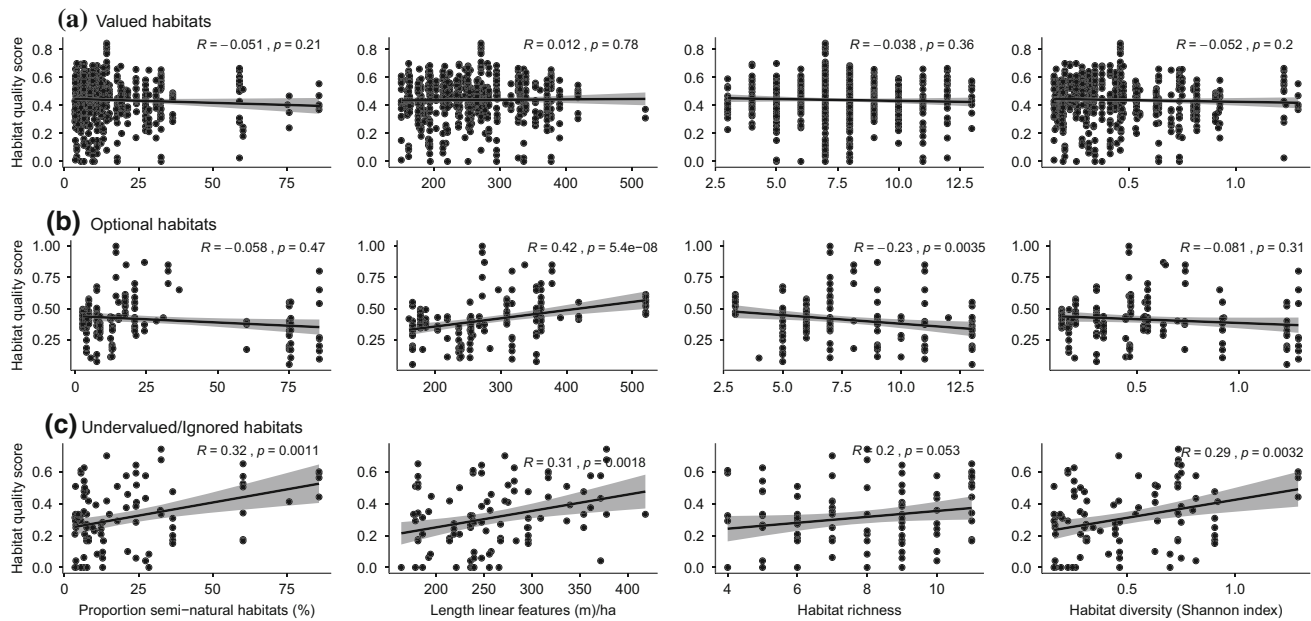
Fig. 3 Correlations (Spearman index) between habitat quality of semi-natural habitats according to their policy protection in Irish agricultural policy: **a** valued, **b** valued-optional and **c** undervalued; and descriptors of habitat composition and configuration at the farm level (i.e. proportion of semi-natural habitats, length of linear features, habitat richness and habitat diversity (Shannon diversity index)

different ecosystem services in specific intensity contexts cognisant of the capacity of particular landscapes.

On average, the share of semi-natural habitats in Irish farms exceeds 5% of the area [the recommended minimum share for EFAs established in current CAP for arable farms (European Commission 2013)]. Note that this is on the assumption that all semi-natural habitats are eligible (which was not the case with EFAs) and that habitat area is actual area without weighting or conversion factors applied (both of which applied in EFAs). From a policy perspective, these findings suggest that if the threshold for the retention of semi-natural features in the upcoming reform of the CAP is, for example, set at 5% (as was the case with EFAs), there is likely to be little additionality for conservation of semi-natural habitats for the majority of Irish farms, or indeed wider European farmland (European Court of Auditors 2017). Habitats already protected under agricultural policy (i.e. valued habitats) constitute on average 3.31% in Sligo and over 4% in Wexford intensive farms. Thus, if a modest threshold of minimum habitat areas is established under future CAP revision, an important opportunity to value and promote retention of semi-natural habitats might be missed. A modest threshold for the share of semi-natural habitats might be detrimental to those extensive farms that already retain larger proportions than the threshold, which may not be rewarded accordingly, endangering the retention of semi-natural habitats. An alternative approach to promote the retention of habitats could be to establish a baseline threshold but provide additional incentives for farms that significantly exceed this threshold. This could be incentivised through the new eco-schemes, which aim to complement the main tools available under CAP to go beyond compensation and conditionality requirements (Dupraz and Guyomard 2019). This type of gradual rewarding could be more cost-effective and represent an appropriate tool to encourage habitat retention of high ecological value (Klimek et al. 2008).

The similarity in the proportion of valued habitats across intensity categories (Table 3) emphasises that policy protection can be successful for the preservation of habitats in farmland, irrespective of farming intensity, i.e. where habitats are protected and valued, they are more likely to be retained within the landscape.

Conversely, differences in valued-optional and undervalued habitats (i.e. habitats not afforded the same protection) among farming intensities highlight that in the absence of policy protection or incentives, these habitats have largely disappeared from more-intensively managed systems, are declining on intermediate farms and their conservation is currently dependent on less intensive management. In these instances there is a danger that should extensive systems intensify, convert to alternative land-use, or be abandoned, these valued-optional or undervalued habitats (and the associated ecosystem services) could disappear (Stoate et al. 2009). The results here provide preliminary evidence of this scenario beginning to occur in intensive areas like Wexford, highlighting the urgency of appropriate habitat protection under agricultural

policy. Most of these habitats (e.g. semi-natural/wet grasslands, heathlands, peatlands, woodlands) are highly valuable for biodiversity and associated ecosystem services (Department of Culture, Heritage and the Gaeltacht 2019). If these habitats are to be retained, their value should be recognised and protected through policy. Future agricultural policy could include them as eligible habitats (e.g. equivalent to 'non-productive' habitats) contributing to minimum threshold requirements for baseline conditionality, and subsequently incentivise their retention (above minimum thresholds) to guarantee their preservation across different farming intensities.

Differences in the length of linear habitats per farm were also significant across farming intensities in both study areas, in line with the proportion of semi-natural habitats. Taken together, these results highlight the importance of extensive farming for the retention of semi-natural habitats, as previously reported in Ireland (Sullivan et al. 2017) and in studies across Europe (García-Feced et al. 2014). Higher abundance of semi-natural vegetation, typically associated with more extensive farming sites, is positively related with biodiversity preservation and ecosystem services supply (Tscharntke et al. 2005; García-Feced et al. 2014; Wezel et al. 2014). Therefore, increasing the local abundance of habitats in more intensive farms, typically within simplified landscapes, might have positive effects on biodiversity and on further ecological processes in these intensive sites (Tscharntke et al. 2005).

Although most of the actions promoted by agricultural policy focus on the share of semi-natural habitats, the structural composition and configuration of habitats on farms should not be measured with one single variable (i.e. proportional area), but could be more adequately assessed by using additional descriptors (Herzog et al. 2017). Habitat heterogeneity represents a significant factor for biodiversity conservation (Benton et al. 2003) and it followed similar trends to the proportion of semi-natural habitats in Sligo and Wexford, being greater in more extensive systems. Habitat richness in Sligo followed the same trend, overall reinforcing the importance of extensive farming for habitat retention, as previously reported (García-Feced et al. 2014). Nevertheless, habitat richness was not related to farming intensity in Wexford, highlighting the need to consider other indicators of habitat composition besides proportion of semi-natural habitats, particularly in more intensive sites, as proposed by Herzog et al. (2017).

Habitat quality, habitat quantity and farming intensity

Assessment of quality (through RACs) allows ecosystem condition to be rated. Focusing on single biodiversity objectives might lead to mismatching and undesired effects on other components of the ecosystem (Keenleyside et al. 2014; Underwood 2014) and, therefore, quality assessment methods may offer a better picture of the conservation status of habitats. Ranges in quality scores of specific habitats achieved consistent variation, which indicate the appropriateness of this method to assess the quality of the corresponding habitats. This methodology provides a suitable foundation for potential methods of habitat quality assessment of different habitats applicable in RBP schemes.

Habitat quality was highly variable within farms and did not show any correlation with farming intensity or habitat quantity at the farm scale. Previous studies reported that local allocation of habitats might have greatest effects on biodiversity and on local quality in simple or more intensive landscapes, but these effects might not be that beneficial in more extensive landscapes (Tscharntke et al. 2005). However, no interactions were found in the current study between local quality and share of habitats at the farm scale, irrespective of the farming intensity, as supported by Dainese et al. (2015). This could be associated with the lack of policy incentives to encourage habitat quality. Retention of habitats in terms of quantity has frequently been the main yardstick for protection of landscape features preservation and biodiversity (e.g. EFAs). Although habitat heterogeneity and landscape complexity are important for biodiversity preservation (Benton et al. 2003; Donald and Evans 2006), retention of habitats alone, with little attention on habitat quality, may not be sufficient to help reverse the decline of farmland biodiversity (Hodgson et al. 2011).

Little correlation was found between habitat quality and the share of semi-natural habitats (or with length of linear semi-natural habitats, habitat richness or habitat diversity). These results reinforce the idea that local management may have a greater impact on habitat quality irrespective of the landscape context, as found by Dainese et al. (2015). Furthermore, a high proportion of semi-natural habitats that rely on extensive farming, with higher proportion of semi-natural habitats, have an unfavourable conservation status (European Environment Agency 2015), even when protected by policy. These results reiterate the importance of policy to provide an added value and promote the quality of habitats. In fact, those valued habitats (i.e. those mandatory to be retained) do not respond to any descriptor of habitat quantity in any of the intensification categories. Thus, to improve the preservation of environmental quality, biodiversity and ecosystem services delivery, habitat quality objectives need to be promoted as opposed to merely relying on retention of habitats (Hodgson et al. 2011). Schemes that incentivise the delivery of environmental quality targets or results, such as RBAPS or Payments for Ecosystem Services (PES) [e.g. Klimek et al. (2008); Reed

et al. ([2014](#)); Maher et al. ([2018](#))], may achieve better results at improving the ecological condition and the preservation of biodiversity in farmland if properly designed, targeted and implemented (Klimek et al. [2008](#); Herzon et al. [2018](#)).

The only habitat category where the assumption of habitat quantity being correlated to habitat quality holds true, in this study, is for undervalued habitats. A stronger dependence of quality of these habitats falls on the conservation of landscape conditions. Therefore if these undervalued habitats (together with other habitats) are retained, they maintain the metacommunity structure and these habitats are of good quality (Diaz et al. [2013](#)). The main threat undervalued habitats are facing is the conversion to more intensive farmland or abandonment and hence the loss of the landscape structure (Diaz et al. [2013](#)). Therefore, these habitats are either there in good quality, or are absent. However, this should be investigated in more detail to fully understand the underlying reasons for this relationship and the parameters for which this is maintained.

CONCLUSIONS

The current study reiterates the importance of extensive farming for the preservation of semi-natural habitats. This is significant for habitats that are currently undervalued under national and international agricultural policy. Reforms of the agricultural policy could focus on some (if not all) of these habitats to support their preservation in farmland.

Establishing a universal minimum share (as proposed under CAP reform) might undervalue farms with higher proportion of semi-natural habitats. It might be worth considering rewarding farms gradually according to proportion of semi-natural habitats. Moreover, promotion of habitat richness and heterogeneity, along with the proportion of semi-natural habitats, especially in more intensive areas and farms, will improve landscape quality and biodiversity preservation.

Enhancing habitat quality has rarely been promoted through agricultural policies. Higher retention of semi-natural habitats per farm does not guarantee higher quality of habitats. Quality of habitats could be incentivised through policy, alongside habitat quantity and the promotion of habitats currently ignored by policy, to ensure their preservation. Results-based approaches or payments for ecosystem services through eco-schemes could be a method of rewarding quality and supporting biodiversity conservation.

REFERENCES

Batáry, P., A. Báldi, D. Kleijn, and T. Tscharntke. 2011. Landscape-moderated biodiversity effects of agri-environmental management: A meta-analysis. *Proceedings of the Royal Society of London B* 278: 1894–1902. https://doi.org/10.1098/rspb.2010.1923.

Batáry, P., L.V. Dicks, D. Kleijn, and W.J. Sutherland. 2015. The role of agri-environment schemes in conservation and environmental management. *Conservation Biology* 29: 1006–1016. https://doi.org/10.1111/cobi.12536.

Benton, T.G., J.A. Vickery, and J.D. Wilson. 2003. Farmland biodiversity: Is habitat heterogeneity the key? *Trends in Ecology & Evolution* 18: 182–188. https://doi.org/10.1016/S0169-5347(03)00011-9.

Boyle, P., M. Hayes, M. Gormally, C. Sullivan, and J. Moran. 2015. Development of a nature value index for pastoral farmland: A rapid farm-level assessment. *Ecological Indicators* 56: 31–40. https://doi.org/10.1016/j.ecolind.2015.03.011.

CBD, UNEP, and United Nations. 2011. *The Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets*. Secretariat of the Convention on Biological Diversity.

Cole, L.J., D. Kleijn, L.V. Dicks, J.C. Stout, S.G. Potts, M. Albrecht, M.V. Balzan, I. Bartomeus, et al. 2020. A critical analysis of the potential for EU Common Agricultural Policy measures to support wild pollinators on farmland. *Journal of Applied Ecology*. https://doi.org/10.1111/1365-2664.13572.

Collier, M., and J. Feehan. 2009. Developing a field boundary evaluation and grading system in Ireland. *Tearmann - the Irish Journal of Agri-Environmental Research* 3: 27–46.

DAFM. 2016. *Terms and Conditions for Tranche 3 of GLAS (Green, Low-Carbon Agri-Environment Scheme)*.

DAFM. 2018a. *2018 EU Basic Payment Scheme (BPS)/Greening Payment - Terms & Conditions*.

DAFM. 2018b. *Fact Sheet on Irish Agriculture - January 2018*.

Dainese, M., D.I. Luna, T. Sitzia, and L. Marini. 2015. Testing scale-dependent effects of seminatural habitats on farmland biodiversity. *Ecological Applications* 25: 1681–1690. https://doi.org/10.1890/14-1321.1.

Department of Culture Heritage and the Gaeltacht. 2019. *Ireland's 6th National Report to the Convention on Biological Diversity*.

Diaz, A., S.A. Keith, J.M. Bullock, D.A.P. Hooftman, and A.C. Newton. 2013. Conservation implications of long-term changes detected in a lowland heath plant metacommunity. *Biological Conservation* 167: 325–333. https://doi.org/10.1016/j.biocon.2013.08.018.

Donald, P.F., and A.D. Evans. 2006. Habitat connectivity and matrix restoration: The wider implications of agri-environment schemes. *Journal of Applied Ecology* 43: 209–218. https://doi.org/10.1111/j.1365-2664.2006.01146.x.

Dupraz, P., and H. Guyomard. 2019. Environment and climate in the common agricultural policy. *EuroChoices* 18: 18–25. https://doi.org/10.1111/1746-692X.12219.

European Commission. 2011. *Our life insurance, our natural capital: an EU biodiversity strategy to 2020. European Commission*.

Commission, European. 2013. Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 december 2013. *Official Journal of the European Union* 2008: 608–670. https://doi.org/10.1017/CBO9781107415324.004.

European Commission. 2016. *CAP in your country: Ireland*. Brussels.

European Commission. 2018. *Proposal for a Regulation of the European Parliament and of the Council establishing rules on support for strategic plans to be drawn up by Member States under the Common Agricultural Policy*. Vol. 2018/0216. Brussels.

European Court of Auditors. 2017. Greening: a more complex income support scheme, not yet environmentally effective 287: 1977–2017.

European Environment Agency. 2015. *State of nature in the EU. Results from reporting under the nature directives 2007–2012*.

Firbank, L.G., S. Petit, S.M. Smart, A. Blain, and R.J. Fuller. 2008. Assessing the impacts of agricultural intensification on biodiversity: A British perspective. *Philosophical Transactions of the Royal Society B* 363: 777–787. https://doi.org/10.1098/rstb.2007.2183ER.

Forest Service, D. 2018. *Ireland's National Forest Inventory 2017-Results*.

Fossitt, J. A. 2000. *A guide to habitats in Ireland*. The Heritage Council.

Foulkes, N., J. Fuller, D. Little, S. McCourt, and P. Murphy. 2013. *Hedgerow Appraisal System-Best Practice Guidance on Hedgerow Survey, Dara Collation and Appraisal*. Edited by Woodlands of Ireland. Dublin.

García-Feced, C., C.J. Weissteiner, A. Baraldi, M.L. Paracchini, J. Maes, G. Zulian, M. Kempen, B. Elbersen, et al. 2014. Seminatural vegetation in agricultural land: European map and links to ecosystem service supply. *Agronomy for Sustainable Development* 35: 273–283. https://doi.org/10.1007/s13593-014-0238-1.

Herzog, F., G. Lüscher, M. Arndorfer, M. Bogers, K. Balázs, R.G.H. Bunce, P. Dennis, E. Falusi, et al. 2017. European farm scale habitat descriptors for the evaluation of biodiversity. *Ecological Indicators* 77: 205–217. https://doi.org/10.1016/j.ecolind.2017.01.010.

Herzon, I., T. Birge, B. Allen, A. Povellato, F. Vanni, K. Hart, G. Radley, G. Tucker, et al. 2018. Time to look for evidence: Results-based approach to biodiversity conservation on farmland in Europe. *Land Use Policy* 71: 347–354. https://doi.org/10.1016/j.landusepol.2017.12.011.

Hodgson, J.A., A. Moilanen, B.A. Wintle, and C.D. Thomas. 2011. Habitat area, quality and connectivity: Striking the balance for efficient conservation. *Journal of Applied Ecology* 48: 148–152. https://doi.org/10.1111/j.1365-2664.2010.01919.x.

IEEP. 2008. *Funding for Farmland Biodiversity in the EU: Gaining Evidence for the EU Budget Review. Case Study Reports. A report for the RSPB*.

Joint Nature Conservation Committee. 2005. *Common Standards Monitoring Guidance for Ditches: Version March 2005*. Vol. 8160.

Keenleyside, C., G. Radley, G. Tucker, E. Underwood, K. Hart, B. Allen, and H. Menadue. 2014. Results-based Payments for Biodiversity Guidance Handbook: Designing and implementing results-based agri-environment schemes 2014–2020: 44.

Kleijn, D., F. Berendse, R. Smit, N. Gilissen, J. Smit, B. Brak, and R. Groeneveld. 2004. Ecological effectiveness of agri-environment schemes in different agricultural landscapes in the Netherlands. *Conservation Biology* 18: 775–786.

Klimek, S., A. Richtergen, H.H. Steinmann, J. Freese, and J. Isselstein. 2008. Rewarding farmers for delivering vascular plant diversity in managed grasslands: A transdisciplinary case-study approach. *Biological Conservation* 141: 2888–2897. https://doi.org/10.1016/j.biocon.2008.08.025.

Maher, C., J. Moran, G. Beaufoy, A. Berastegi Garciandia, A. Bleasdale, D. Byrne, A. Copland, B. Dunford, et al. 2018. *Results-based Agri- environmental Payments General Guidance Handbook*.

Mauchline, A.L., S.R. Mortimer, J.R. Park, J.A. Finn, K. Haysom, D.B. Westbury, G. Purvis, G. Louwagie, et al. 2012. Environmental evaluation of agri-environment schemes using participatory approaches: Experiences of testing the Agri-Environmental Footprint Index. *Land Use Policy* 29: 317–328. https://doi.org/10.1016/j.landusepol.2011.07.002.

Montoya, D., B. Haegeman, S. Gaba, C. de Mazancourt, V. Bretagnolle, and M. Loreau. 2019. Trade-offs in the provisioning and stability of ecosystem services in agroecosystems. *Ecological Applications* 29: 1–12. https://doi.org/10.1002/eap.1853.

National Parks and Wildlife Service Ireland. 2018. Designated sites boundary data in Ireland.

Palmer, M., M. Drake, and N. F. Stewart. 2013. *A Manual for the survey and evaluation of aquatic plant and invertebrate assemblages of grazing marsh ditch systems (Version 6)*.

R Core Team. 2016. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Reed, M.S., A. Moxey, K. Prager, N. Hanley, J. Skates, A. Bonn, C.D. Evans, K. Glenk, et al. 2014. Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services* 9: 44–53. https://doi.org/10.1016/j.ecoser.2014.06.008.

Scheper, J., A. Holzschuh, M. Kuussaari, S.G. Potts, M. Rundlöf, H.G. Smith, and D. Kleijn. 2013. Environmental factors driving the effectiveness of European agri-environmental measures in mitigating pollinator loss: A meta-analysis. *Ecology Letters* 16: 912–920. https://doi.org/10.1111/ele.12128.

Sheridan, H., B. Keogh, A. Anderson, T. Carnus, B.J. Mcmahon, S. Green, and G. Purvis. 2017. Farmland habitat diversity in Ireland. *Land Use Policy* 63: 206–213. https://doi.org/10.1016/j.landusepol.2017.01.031.

Smith, B.G.F., P.O. Donoghue, K.O. Hora, and E. Delaney. 2011. *Best practice guidance for habitat survey and mapping*, vol. 353. Kilkenny: The Heritage Council.

Stoate, C., A. Báldi, P. Beja, N.D. Boatman, I. Herzon, A. van Doorn, G.R. de Snoo, L. Rakosy, et al. 2009. Ecological impacts of early 21st century agricultural change in Europe: A review. *Journal of Environmental Management* 91: 22–46. https://doi.org/10.1016/j.jenvman.2009.07.005.

Sullivan, C.A., J.A. Finn, D.Ó. hÚallacháin, S. Green, S. Matin, D. Meredith, B. Clifford, and J. Moran. 2017. The development of a national typology for High Nature Value farmland in Ireland based on farm-scale characteristics. *Land Use Policy* 67: 401–414. https://doi.org/10.1016/j.landusepol.2017.04.031.

Tscharntke, T., A.M. Klein, A. Kruess, I. Steffan-Dewenter, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity: Ecosystem service management. *Ecology Letters* 8: 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x.

Underwood, E. 2014. *Result indicators used in Europe: Results-based Payments for Biodiversity-Supplement to Guidance Handbook. Prepared for the European Commission, DG Environment, Contract No ENV.B.2/ETU/2013/0046*.

Wezel, A., M. Casagrande, F. Celette, J.F. Vian, A. Ferrer, and J. Peigné. 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development* 34: 1–20. https://doi.org/10.1007/s13593-013-0180-7.

White, P.J.C., M.A. Lee, D.J. Roberts, and L.J. Cole. 2019. Routes to achieving sustainable intensification in simulated dairy farms: The importance of production efficiency and complimentary land uses. *Journal of Applied Ecology* 56: 1128–1139. https://doi.org/10.1111/1365-2664.13347.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

AUTHOR BIOGRAPHIES

Roser Rotchés-Ribalta (✉) is a post-doctoral researcher in the Department of Soils, Environment and Land Use, Johnstown Castle Research Centre, Teagasc. Her research interests include biodiversity conservation, ecosystem functioning and services and landscape ecology in agroecosystems.
Address: Teagasc, Department of Soils, Environment and Land Use, Johnstown Castle Research Centre, Wexford, Ireland.
Present Address: CREAF, 08193 Cerdanyola Del Vallès, Spain.
e-mail: roser.rotches@gmail.com

Sara Ruas is a doctoral candidate in the Department of Natural Sciences at Galway-Mayo Institute of Technology. Her research interests include agro-ecology, ecosystem services and landscape connectivity.
Address: Department of Natural Sciences, Galway-Mayo Institute of Technology, Galway Campus, Galway, Ireland.

Karzan D. Ahmed is a doctoral candidate in the Applied Ecology Unit, at School of Natural Sciences, National University of Ireland. His research interests include invertebrate diversity and their ecosystem functions such as pest-control.
Address: Applied Ecology Unit, School of Natural Sciences, National University of Ireland, Galway, Ireland.

Michael Gormally is Director of the Applied Ecology Unit, Centre for Environmental Science at the National University of Ireland. His research interests include terrestrial invertebrates as bioindicators in agricultural systems and their ecosystem functions.
Address: Applied Ecology Unit, School of Natural Sciences, National University of Ireland, Galway, Ireland.

James Moran is a lecturer in ecology and biology at Galway-Mayo Institute of Technology. His research interests include agro-ecology, development of agri-environment schemes, high nature value farmland, biodiversity and ecosystem services.
Address: Department of Natural Sciences, Galway-Mayo Institute of Technology, Galway Campus, Galway, Ireland.

Jane Stout is a professor in botany at Trinity College Dublin. Her research interests biodiversity conservation, insect diversity and pollination services and ecosystem functioning.
Address: Trinity College Dublin, Dublin, Ireland.

Blánaid White is a professor in School of Chemical Sciences, Dublin City University. Her research interests include the application of analytical techniques for biochemical processes and assessment of soil ecosystem services in agricultural systems.
Address: School of Chemical Sciences, Dublin City University, Dublin, Ireland.

Daire Ó hUallacháin is a researcher in Teagasc, Department of Soils, Environment and Land Use, Johnstown Castle Research Centre. His research interests include agro-ecology, ecosystem services, assessment and development of agro-environment schemes and farmland conservation.
Address: Teagasc, Department of Soils, Environment and Land Use, Johnstown Castle Research Centre, Wexford, Ireland.