Examining the relationship between farmer participation in an agri-environment scheme and the quantity and quality of semi-natural habitats on farms - An Irish case study

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ABSTRACT

Agri-environment schemes (AESs) have been developed by governments to improve biodiversity, reduce pollution from farming and encourage the provision of agriculture's non-market benefits. Despite the substantial amount of money spent on designing, implementing and monitoring AESs, their environmental effectiveness is ambiguous. The objective of this paper is to investigate the relationship between farmer participation in an AES and the quantity and quality of semi-natural habitats found on farms. This study combines farmland habitat data with socio-economic survey data from Irish farms and applies a matching technique to test whether there are differences in quantity and quality of habitats between farms participating in an AES and non-participating farms. Although farmer participation in an AES is found to be positively related to habitat quantity and quality, these relationships are statistically non-significant. However, education, membership of discussion groups, designated land and specific farmer self-identities all positively influence either habitat quantity or quality. From a policy perspective, the shift from action-oriented towards hybrid or results-oriented schemes that incorporate habitat quantity, as well as habitat quality targets, may be a more environmentally- and cost-effective policy alternative to promote grassland biodiversity.

Keywords: Agri-environment schemes · Semi-natural habitats · Self-selection bias · Inverse probability weighting estimator with regression adjustment (IPWRA)

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1. Introduction

It is widely recognized that agricultural expansion and intensification has been associated with reductions in semi-natural grasslands and other types of habitat areas, and decline in farmland biodiversity across north-west Europe and north America (Cerezo et al., 2011). Agri-environment schemes (AESs) and market-based instruments (e.g. taxes, subsidies and tradable permits) have been developed to incentivize environmentally positive practices on farmland. The introduction of AESs in most European countries can be traced back to 'McSharry' reforms of the Common Agricultural Policy (CAP) in 1992. These AESs aimed to compensate farmers for income loss and costs related to certain management actions that farmers perform to mitigate environmental externalities associated with intensive agricultural practices (e.g. increased use of pesticides and other agrochemicals) (Batáry et al., 2015).

In response to the European Union's Agri-environment Regulation 2078/92/EEC, the Irish Government introduced a voluntary action-oriented agri-environment scheme, the Rural Environment Protection Scheme (REPS) in June 1994. REPS operated over four iterations (REPS I to REPS IV) with a significant increase between REPS I and REPS IV in the relative proportion of expenditure on biodiversity-related objectives (Finn and Ó hUallacháin, 2012). A new scheme, namely the Agri-Environment Options Scheme (AEOS) was introduced in 2010, whilst the most recent AES, the Green Low carbon Agri-environment Scheme (GLAS) was launched in 2015 (DAFM, 2012; DAFM, 2021). In addition to action-oriented AESs, results-oriented schemes (e.g. Burren Programme, Hen Harrier Project, Pearl Mussel Project) have been also implemented in Ireland (McLoughlin et al., 2020). In results oriented schemes, farmers are compensated on the basis of delivered ecological improvements instead of costs associated with pre-defined management actions (Vainio et al., 2019).

There has been considerable research interest in evaluating the effect of AESs on farmland use change, biodiversity, soil and water quality (e.g. Bertoni et al., 2021; Boetzl et al., 2021; Concepción et al., 2008; Jones et al., 2016; Zhang et al., 2017). Kleijn and Sutherland (2003) reviewed published peer-reviewed and gray literature on the effectiveness of AES on biodiversity conservation and concluded that only a limited number of studies report positive effects of AESs on species diversity or abundance. In most of these studies, biodiversity in areas under an AES is compared with biodiversity in conventionally managed areas at one point in time. Since the review of Kleijn and Sutherland (2003), various studies and Europe-wide reviews on the environmental effectiveness of AES and measures have been published providing mixed results (Ansell et al., 2016; Batáry et al., 2015; Fuentes-Montemayor et al., 2011; Wrbka et al., 2008).

Considering studies that account for self-selection bias in farmer decision-making, Pufahl and Weiss (2009) and Bertoni et al. (2020) found that farmer participation in AESs had a positive effect on grassland maintenance and the proportion of grassland in farmland in

Germany and Italy respectively. Laukkanen and Nauges (2014) concluded that overall the agri-environmental payments had reduced nutrient pollution from farms in Finland, whilst Kuhfuss and Subervie (2018) showed that the quantity of herbicides used by French winegrowers who participated in an AES in 2011 was by 38-53% below the quantity they would have used without participation in the AES. Zhang et al. (2021) found that an ecological compensation programme (*paddy land-to-dry* programme) in China led to reduced nitrogen use and emissions, whilst Bartolini et al. (2021) found that agri-environment climate scheme (AECS) payments had a positive effect on farm extensification, although environmental performance varied across levels of AECS payments.

As scheme effectiveness depends on sufficient farmer participation levels, researchers have also been interested in identifying the drivers of farmer participation in an AES, by using either data on observed farmer behavior (e.g. Wąs et al., 2021; Wilson and Hart, 2000) or conducting choice experiments (e.g. Espinosa-Goded et al., 2010; McGurk et al., 2020) and meta-analyses (e.g. Lastra-Bravo et al., 2015). As shown in many studies, there is substantial heterogeneity in farmers' preferences towards AESs and the factors influencing farmer uptake of AESs. These factors can be related to physical and agronomic aspects of production (e.g. soil quality, geographic location of production site) (e.g. Dupraz et al., 2003), but also to farmers' self-identity, attitudes towards environment (e.g. Greiner & Gregg, 2011; Herzon & Mikk, 2007; Power et al., 2013), farm economic performance and financial constraints (Mishra and Khanal, 2013), socio-demographic characteristics (e.g. age, level of education, farming experience) and other unobservable factors such as farmer managerial ability or production risk preferences (Lastra-Bravo et al., 2015).

Since farmer participation in an AES is voluntary and depends on various factors, the decision of profit maximizing farmers for instance, to participate in an AES is likely to be based on the comparison of opportunity and scheme compliance costs with the payment offered (Raggi et al., 2015). In other words, farmers may self-select to participate rather than being randomly selected e.g. by government experts to participate in an AES. Hence, *ex-post* evaluations of AESs based on observational and not experimental data are not straightforward. The comparison of performance or other outcomes between farms where farmers participate in an AES and farms where farmers do not participate, without controlling for self-selection, may produce biased estimates of the relationship between participation and outcome variables.

A central question in this paper is: '*Do quantity and quality of on-farm semi-natural habitats differ between farms participating in an AES and non-participating farms*'? Thus, the objective of this study is to examine the relationship between quantity and quality of farmland semi-natural habitats and farmer participation in an AES. The relationship between the ecological status of farmland habitats and farmer participation in AESs accounting for self-selection bias has been analyzed by only a few studies. This study aims to contribute to the AES evaluation literature by combining socio-economic with farm habitat data and employing a non-experimental method that accounts for self-selection bias (inverse probability weighting estimator with regression adjustment) to compare the quantity and quality of farmland habitats across farms participating in an AES and non-participating farms.

2. Data and method

2.1.1 Socio-economic survey

In late 2012, a questionnaire-based survey of 1,000 Irish farms was conducted to gather information on variables including farmers' decisions to participate in AESs, farmer socio-demographic profile, farm location and structural characteristics of farms (e.g. farm size and soil type). A growing literature recognizes the importance of personal factors, such as values, motivations, perceptions and attitudes towards the environment in explaining farmer participation in an AES and farmer intentions in relation to future participation (e.g. Calvet et al., 2019; Greiner, 2015). Building on Cullen et al. (2020), we also considered the additional role of farmer self-identity and perceptions of AESs in understanding farmers' participation in an AES and their environmental performance.

Self-identity mirrors a farmer's personal value system based on farmer's own experiences and moral values determining perceptions of external factors and own preferences (Mills et al., 2017). Central to identity theory (Stryker, 1968) is the view that to understand an action (e.g. participation in an AES), it is essential to conceive of the self and wider social construct as being inextricably linked (Terry et al., 1999). Based on previous studies (Howley et al., 2015; Maybery et al., 2005; Willock et al., 1999), farmers were asked to state how much they agreed with a set of 10 statements related to farmer self-identity (Tables A.1) and a set of 13 statements related to perceptions of AESs (Table A.2). All statements had a 5-point Likert scale ranging from strongly disagree to strongly agree.

A quota-controlled sampling approach was adopted to ensure that the farm sample was nationally representative in terms of farm size and production system. Following the sampling procedures of the Teagasc National Farm Survey (NFS), which is a component of the EU Farm Accountancy Data Network (FADN), farms were classified to production systems based on their Standard Output (SO). Moreover, the target sample of farmers was stratified by electoral divisions (EDs).[1] The survey was conducted through interviewer-led questionnaires.

2.1.2 Habitat survey: Measurement of habitat quantity

Habitat surveys were undertaken on a subset of 130 farms randomly selected from the 1,000 respondents in the original socio-economic survey. All farms were visited between April and August in 2015 and 2016. For each farm, a habitat survey, conducted in line with best practice guidelines (Smith et al., 2011), was undertaken. The participant farms were walked and habitats recorded, quantified and classified according to Fossitt (2000). Survey data (habitats) were digitized onto Ordnance Survey Ireland orthophotographs (2004) using ArcGIS software. This approach facilitated an accurate estimation of length of linear habitats (metres) and the area (ha) (quantity) of all habitats of ecological value on each farm.

[1] Electoral divisions are the smallest legally defined administrative geographical areas in Ireland used as boundaries for political jurisdictions (CSO, 2020)

Areal habitats of ecological value included dry calcareous and neutral grassland, dry meadows and grassy verges, wet grassland, marshes, oak-ash-hazel woodland, riparian woodland, mixed broadleaved woodland, mixed broadleaved/conifer woodland, scattered trees and parkland, immature woodland, exposed siliceous and calcareous rocks, reed and large sedge swamps, tall-herb swamps, lowland blanket bogs, dystrophic lakes, acid oligotrophic lakes and other artificial lakes and ponds.

Linear habitats of ecological value included hedgerows, eroding/upland rivers, stonewalls and other stonework, earth banks, tree lines, linear scrub and riparian margins. The sum of habitat areas (including habitats of low ecological value e.g. improved grassland) within a farm, plus land occupied by buildings make up the surveyed farm area (variable *farm area* in Table 1). It is important to note that a farmer may utilize additional farmland in other geographical locations. Thus, the surveyed farm area may correspond to only a portion of a farm's total agricultural land and cannot be used in this study as an indicator of farm size.

2.1.3 Habitat survey: Measurement of habitat quality

Habitat quality assessments were undertaken on a subset of habitat types. Field boundaries (e.g. hedgerow, stone wall) are ubiquitous on Irish farms (Larkin et al., 2019; Rotchés-Ribalta et al., 2020) and are amongst the most abundant form of semi-natural habitat on many Irish farms (Sheridan et al., 2017, 2011), and were thus selected for assessment of ecological quality. For the purpose of this study, a field boundary was defined as a permanent hedgerow or stonewall with homogeneous management and orientation (Sheridan et al., 2011). The ecological quality of field boundaries was evaluated according to the Field Boundary Evaluation and Grading System (FBEGS) (Collier and Feehan, 2003). FBEGS is a relatively rapid assessment of key indicators related to field boundary quality, including *boundary structure*, *associated features* (e.g. earth banks, drainage ditches), *boundary connectivity*, *botanical diversity* (e.g. shrub species richness), and *boundary type* (e.g. orientation and scope) (Collier and Feehan, 2003). On each farm, three randomly selected field boundaries were walked and assigned component scores in terms of FBEGS variables. The total FBEGS index for each field boundary was derived by pooling the individual FBEGS component scores. The total FBEGS index per farm was derived by averaging the three individual FBEGS scores.

2.1.4 Variable selection

Table 1 describes the variables used in the econometric analysis. The ratio of habitat area (i.e. habitats of ecological value) over surveyed farm area was employed as the outcome variable for habitat quantity. For robustness checking, the length of linear habitats was also used as an additional descriptor of habitat quantity (Rotchés-Ribalta et al., 2020). The total FBEGS index of farms was used to indicate the quality of field boundary habitats. To identity farms participating in an AES in 2012, a dummy variable was constructed. Given that REPS IV ran until 2013 and due to the considerable overlap between REPS and AEOS measures (Finn and Ó hUallacháin, 2012), participants in an AES in 2012 are considered as farmers who participated in AEOS or who participated in all REPS (REPS I-IV). The dummy variable is set to zero for farmers who were not enrolled in AEOS or all REPS in 2012.

Table 1. Definition of variables used in analysis

Variable	**Description**
Participation in an AES	Dummy variable indicating farmer participation in all REPS (I-IV) or AEOS in 2012 (yes =1; non-participation in any AES = 0)
Share of habitat area	Ratio of habitat area of ecological benefit over surveyed farm area (see sub-section 2.1.2)
Length of linear habitats (metres/ha)	See text (sub-section 2.1.2)
Quality of boundary habitats	Total Field Boundary Evaluation and Grading System (FBEGS) index (see sub-section 2.1.3)
Farmer age	Farmer age in years
Agricultural education	Dummy variable (farmer has agricultural education =1; 0 otherwise)
Discussion group membership	Dummy variable (yes =1; 0 otherwise)
Off-farm employment	Dummy variable (yes =1; 0 otherwise)
Farm area	Surveyed area including land occupied by buildings (ha). See text (sub-section 2.2.1)
Farm system	Categorical variable on a scale of 1 to 6 (Dairy =1; Cattle rearing =2; Cattle other =3; Sheep =4; Other =5)*
Designated land	Dummy variable indicating if farm encompasses designated land e.g. Special Area of Conservation or Special Protection Area (yes =1; 0 otherwise)
Scheme benefits conscious	Factor variable measuring farmer perceptions of AESs
Positive environmental farming	Factor variable measuring farmers' views on farming and the environment
Innovative orientation	Factor variable measuring farmers' views on farming and the environment
Productivist orientation	Factor variable measuring farmers' views on farming and the environment
Conservative orientation	Factor variable measuring farmers' views on farming and the environment
Soil type	Categorical variable on a scale of 1 to 3 (farms with suitable soil for a wide range of agricultural uses =1; farms with somewhat limited agricultural uses -either poor drainage or altitude =2; farms with very limited soil for agriculture e.g. mountain areas =3)
Region**	Categorical variable on a scale of 1 to 8 (Border =1; Dublin =2; East =3; Midlands =4; Southwest =5; Southeast =6; South =7; West=8)

Notes: * The *other* system covers mixed livestock and tillage systems. ** The variable region is expected to account for geographical differences in terms of environmental conditions (e.g. geology, climate), and cultural and socio-economic factors.

2.2 Factor analysis

As per Cullen et al. (2020), attitudinal variables related to AESs and a typology of farmers' self-identity was generated by using data on farmers' level of agreement with selected statements and factor analysis. Two factor analyses were performed to reduce the dimensionality of data by examining the correlations among variables, and identify the optimal number of factors that explain most of variation in farmers' ratings of statements related to AESs and views on farming and environment (Howley, 2011). The derived factor scores were ready to be used as explanatory variables in subsequent regression analyses.[2] The factor loadings are presented in Tables A.1 and A.2 (Appendix A).

A factor analysis of farmers' views on farming and the environment resulted in four self-identity factors which we have named *Positive Environmental Farming*, *Innovative Orientation*, *Productivist Orientation*, and *Conservative Orientation* due to the type of statements strongly loading on each factor.[3] The factor loadings in Table A.1 are correlations between all farmers' ratings for each statement related to farming and environment and the derived factors.

The first factor has high factor loadings on the statements about farmers taking good care of the countryside, enjoying farming as a job, and the positive role of farmers in protecting the environment. As such, this factor was labelled *Positive Environmental Farming*. The second factor, *Innovative Orientation*, has high factor loadings on statements related to the adoption of new technologies ('*to be successful in farming it is important for me to adapt and use new technologies*'), the use of different types of information ('*I am good at finding different types of information to help me run my business*'), and keeping the farm running into the future.

The statements unravelling business related possibilities, such as '*farmers should be allowed to maximize their income irrespective of the environmental consequences*' and '*we need to produce more food even if some damage is caused to the environment*' are highly loaded on the factor *Productivist Orientation*. The *Conservative Orientation* factor is mainly related to statements implying risk-averse farm business behaviour and cautiousness about adopting new ideas and technology.

The factor analysis on farmer perceptions of AESs identified the *Scheme Benefits Conscious* and the *Scheme Drawbacks Conscious* factors.[4] As expected, positive statements relating to AESs, such as '*countryside looks better*' or *'REPS/AEOS payments are a valuable income source*' load highly on the *Scheme Benefits Conscious* factor,

[2] More precise guidance on the methods applied to derive factor scores is provided by Cullen et al. (2020).
[3] The *Positive Environmental Farming*, *Innovative Orientation*, *Productivist Orientation* and *Conservative Orientation* factors correspond to *Optimistic Caretaker*, *Forward Looking*, *Productivist* and *Conservative* constructs respectively in Cullen et al. (2020).
[4] The *Scheme Benefits Conscious* and *Scheme Drawbacks Conscious* factors correspond to *Benefits Conscious* and *Drawbacks Conscious* constructs respectively in Cullen et al. (2020).

whereas negative statements load highly on the *Scheme Drawback Conscious* factor. The derived factors from the two factor analyses were used further as explanatory variables in regression analysis to examine if farmer self-identity and perceptions of AESs, among other variables, are related to farmer participation in an AES and the quantity and quality of farmland habitats.

2.3 Descriptive statistics

Table 2 provides descriptive statistics for the full sample of farmers, plus descriptive statistics of the variables classified by participation status. These indicate that 45% of farms have participated in all REPS or AEOS in 2012. Moreover, 18% of the land on the surveyed farms was categorized as semi-natural habitats, a higher proportion than was reported by Sheridan et al. (2011) for 50 grass-based farms in south-east Ireland. In another study, Rotchés-Ribalta et al. (2020) found that the average habitat area on farms ranged from an average of approximately 6% on intensive farms to an average of 42% on extensive farms in County Sligo (Ireland). Table 2 also shows that 28% of farms in the sample had designated land in accordance with the provisions of the 1992 EU Habitats Directive (Council Directive 92/43/EEC).

Table 2. Descriptive statistics

	Full sample (*n* = 130)	**Participants in an AES (*n* = 58)**	**Non-participants (*n* = 72)**	**Differences**
Variable	**Mean (Standard deviation)**	**Mean (Standard deviation)**	**Mean (Standard deviation)**	**Test statistic**
Participation in an AES	0.446 (0.499)			
Share of habitat area	0.182 (0.224)	0.199 (0.238)	0.168 (0.213)	t = -0.786
Length of linear habitats	147.320 (58.737)	152.537 (61.136)	143.118 (56.812)	t = -0.908
Quality of boundary habitats	40.507 (7.561)	41.648 (7.591)	39.588 (7.463)	t = -1.552
Farmer age	53.496 (11.208)	54.387 (12.040)	52.777 (10.521)	t = -0.813
Agricultural education	0.707 (0.456)	0.793 (0.408)	0.638 (0.483)	$X^2 = 3.770^{*}$
Discussion group membership	0.376 (0.486)	0.482 (0.504)	0.291 (0.457)	$X^2 = 4.999^{**}$
Off-farm employment	0.153 (0.362)	0.206 (0.408)	0.111 (0.316)	X^2 = 2.253
Farm area	28.476 (16.405)	24.482 (11.788)	31.693 (18.812)	$t = 2.543^{**}$
Farm system	2.384 (1.235)	2.310 (1.157)	2.444 (1.298)	X^2 = 1.607
Designated land	0.276 (0.449)	0.327 (0.473)	0.236 (0.427)	X^2 = 1.337

Scheme benefits conscious	0.131 (0.983)	0.502 (0.850)	-0.167 (0.986)	t = -4.091***
Positive environmental farming	0.061 (0.923)	-0.067 (1.027)	0.165 (0.824)	t = 1.431
Innovative orientation	0.105 (0.921)	0.183 (0.924)	0.042 (0.921)	t = -0.869
Productivist orientation	-0.149 (1.093)	-0.244 (1.044)	-0.072 (1.132)	t = 0.891
Conservative orientation	0.039 (0.884)	0.079 (0.873)	0.006 (0.898)	t = -0.461
Soil type	1.461 (0.558)	1.500 (0.599)	1.430 (0.526)	X^2 = 1.585
Region	5.161 (2.439)	5.103 (2.538)	5.208 (2.373)	X^2 = 11.306*
Notes: Significance levels: ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$; t-tests are two-sided tests.				

The average differences in the characteristics of participants and non-participants are also presented in Table 2. Statistical tests show that the two groups differ in terms of agricultural education, membership in farmer discussion groups, farm area, awareness of agri-environment scheme benefits and farm location. The average size of farm area is smaller in participating farms with participants being, on average, more aware of the environmental and financial benefits of AESs than non-participants. Almost half of participants (48.2%) are members of a discussion group and 79% that have obtained an agricultural qualification. As regards, non-participants, 64% stated that they have obtained an agricultural qualification whereas 29% of non-participants are members of a discussion group.

2.4 Data analysis

Ideally, the effect of farmer participation in an AES (on habitat quantity and quality) would be assessed by calculating the difference Δ in outcome variables (habitat quantity, habitat quality) at time t between what is empirically observable after participation (treatment) and what one would have observed in the same period and for the same farmers, in the case of non-participation. However, calculating Δ is not feasible as farmers can only be observed in one state (i.e. as participants or non-participants) (Balaine et al., 2020). In a randomized experimental setting where participation in an AES would be randomly assigned to farmers, the effect of participation in an AES on habitat quantity or quality could be calculated as follows:

$$ATT = E[Y^1 \mid T = 1] - E[Y^0 \mid T = 1] \quad (1)$$

where T is the treatment indicator and ATT is the Average Treatment Effect on the Treated (ATT) i.e., in a counterfactual framework, ATT is the difference between the expected average effect of participation on e.g. habitat quantity Y^1 for the group of AES participants and its counterfactual (expected average effect of non-participation on habitat quantity Y^0 for the group of AES participants). Solving Eq. (1) the researcher answers the question: '*How much did the quantity (or quality) of habitats on a randomly selected farm participating in an AES improve compared with what habitat quantity (or quality) would be if the farm would not have participated in an AES*'?

Policy impact evaluation is often based on observational data in which the assignment of treatment is not random, i.e. farmers can only be observed in one of the two states (participants or not participants) and farmers usually self-select into treatment (participants in an AES) or control (non-participants) groups. Consequently, the use of the ordinary least squares (OLS) estimator to calculate treatment effect as the difference of mean outcomes between the two groups (participants or not participants) may generate biased results due to endogeneity related to self-selection bias. This study is based on data generated by *ex post* cross-sectional farm household and habitat surveys. Moreover, participation in an AES is voluntary and not randomly assigned. Thus, a farmer's decision to participate in an AES could be influenced by observed and unobserved unmeasured characteristics.

In the absence of longitudinal data and valid instruments, the propensity score matching (PSM) has emerged as a popular non-experimental method of evaluation (e.g. D'Alberto et al., 2018; Kuhfuss & Subervie, 2018; Pufahl & Weiss, 2009). Matching aims to isolate the effect of treatment (participation in an AES) by finding for each treated subject (e.g. a participant in an AES) an untreated counterpart (a non-participant) that has the most similar (ideally identical) observable characteristics. If all characteristics that explain the outcome variable(s), except for treatment, are equal, the difference in average outcomes across the treated group and control groups is attributable to the treatment (Jusys, 2016). The identifying assumption in matching is that selection bias between treated and control groups can be controlled for with these observable characteristics.

In the context of farmer participation in an AES, PSM compares the outcomes (habitat quantity and quality) of scheme participants ($T = 1$) with those of matched non-participants where matched farmers are chosen on the basis of similarity in observed characteristics (covariates X) and the associated probability p of participating in an AES. Assuming that selection occurs only on observables, the within-matched-pair differences in outcomes is then attributable to the impact of scheme and treatment effects are estimated by averaging within-matched pair differences in outcome variables (Balaine et al., 2020; Imbens and Wooldridge, 2009; Jusys, 2016). However, PSM can be sensitive to bias due to unobservable factors and misspecification in the treatment model. Furthermore, PSM may not perform well in small samples in comparison with other estimators (Kebebe, 2017). Given the relatively small size of the sample in this study, the inverse probability weighting estimator with regression adjustment (IPWRA) was employed to control for potential selection bias related to farmer participation in an AES (Cattaneo, 2010).

The IPWRA estimator involves the estimation of a discrete choice model (treatment model) that predicts the probability of farmer participation in an AES (propensity score), and the subsequent computation of inverse probability weights. The estimation of propensity scores can be expressed as:

$$p(X) = Pr(T_i = 1| X) = F\{h(X)\} = E(T_i|X) \quad (2)$$

where the vector X contains observed pre-treatment covariates based on observed characteristics (e.g. farmer age, agricultural education and other characteristics) and F is a cumulative distribution function. The estimated propensity scores are used to create an artificial sample in which the distribution of baseline covariates is independent of treatment assignment (participation in an AES). Assigning inverse probability weights equal to unity for participants and $\frac{\widehat{p(x)}}{1-\widehat{p(X)}}$ for non-participants, propensity weights are defined as:

$$w_i = T_i + (1 - T_i)\frac{\widehat{p(x)}}{1-\widehat{p(X)}} \quad (3)$$

where $\widehat{p(x)}$s are the estimated propensity scores. The computed probability weights are used as weights in separate regression models for participants and non-participants (habitat quantity and quality), whilst the estimated weighted regression models (outcome models) yield treatment-specific predicted outcomes adjusted for observables for each farmer. Averages of the treatment-specific predicted outcomes (e.g. ATT) can be further computed (Long et al., 2020) as:

$$ATT_{IPWRA} = n_A^{-1}\sum_{i=1}^{n} T_i[r_A^*(X, \delta_A^*) - r_N^*(X, \delta_N^*)] \quad (4)$$

where n_A is the number of participants in an AES, r_i(X) is the regression model of participants A and non-participants N regressed on variables X. The parameters δ_A^* and $\delta_N^*$are obtained from the weighted regressions for participants and non-participants respectively. The property of using weighted regression coefficients to compute treatment effects renders the IPWRA estimator 'doubly-robust' to the violation of the conditional independence and overlap assumptions, and more efficient than regression adjustment and PSM estimators when the outcome or treatment model (but not both) are mis-specified (Wooldridge, 2010).

Researchers often make causal claims when using matching models that satisfy the overlap and covariate balance assumptions (Caliendo and Kopeinig, 2008). The overlap assumption requires that a match with similar propensity score value must be found for each participant in an AES, whilst the covariate balance assumption requires that pre-treatment (i.e. before participation) farmer characteristics (covariates) have been equalized across participants and non-participants after matching (Balaine et al., 2020; Flaster, 2018).

In this study, over-identification tests were performed to verify the assumption of covariate balance. Moreover, the density distributions of the estimated probabilities for participants and non-participants in an AES were plotted to infer if the overlap assumption is satisfied. Although the overlap and covariate balance assumptions are satisfied by the specified IPWRA model used in this study, results are presented from a correlational and not causal perspective, due to potential bias induced by remaining unobservable characteristics underlying a farmer's decision to participate in an AES (Franke and Bicknell, 2019).

3. Results and discussion

3.1 Factors influencing participation

Before estimates of the relationship between participation in an AES and habitat quantity and quality are presented, we first discuss the factors affecting participation as shown in Table 3. Results from the probit model used in IPWRA to derive inverse probability weights show that there is a positive relationship between farmer age and the likelihood of participation in an AES. Older farmers, everything else being equal, are more likely to participate in an AES. Although studies have shown that younger farmers are more likely to participate e.g. due to (on average) higher level of education and possibly better understanding of the environmental benefits of AESs, there is also evidence that younger farmers are more production and profit-oriented, hence they may be more reluctant to participate (McGurk et al., 2020).

Studies have found that education can increase the likelihood of farmer participation in AESs, as more educated farmers might combine information more effectively (Giovanopoulou et al., 2011). Furthermore, knowledge transfer and exchange initiatives aiming to encourage farmer engagement with new technologies and management practices through agricultural training, national advisory services, farmer discussion groups, open days and farm walks, have also been found to increase the likelihood of adoption of management practices (Daxini et al., 2018). This study also finds positive and statistically significant relationships of agricultural education and discussion group membership with higher rates of farmer participation in an AES.

Table 3. Estimated coefficients of probit (treatment) model on farmer participation in an AES

Variables	**Coefficients**	**z-statistic**
Farmer age	0.026**	2.06
Agricultural education	0.805***	2.63
Discussion group membership	0.550*	1.77
Off-farm employment	0.132	0.31
Farm area	-0.035***	-3.41
Farm system: Cattle rearing (base: Dairy)	0.265	0.76
Farm system: Cattle other (base: Dairy)	-0.041	-0.09
Farm system: Sheep farm (base: Dairy)	0.100	0.20
Farm system: Other (base: Dairy)	0.339	0.64
Designated land	0.429	1.21

Scheme benefits conscious	0.582^{***}	3.24
Positive environmental farming	-0.400^{**}	-2.54
Innovative orientation	-0.272^{*}	-1.67
Productivist orientation	0.027	0.21
Conservative orientation	-0.027	-0.19
Soil type 2 (somewhat limited land use potential; base: Soil type 1)	-0.190	-0.65
Soil type 3 (limited land use potential; base: Soil type 1)	-0.243	-0.27
Region-East (base: Border)	0.826	1.13
Region-Midlands (base: Border)	0.092	0.15
Region-Southwest (base: Border)	0.823	1.56
Region-Southeast (base: Border)	-0.701^{*}	-1.74
Region-South (base: Border)	-0.042	-0.09
Region-West (base: Border)	-0.335	-0.74
Constant	-1.458	-1.50
Number of observations: 130		
Notes: Significance levels: $^{***}P < 0.01$, $^{**}P < 0.05$, $^{*}P < 0.1$		

The present study found that farms with less *farm area* are more likely to participate in AESs. The negative relationship between farm area and participation could indicate that Irish farmers perceive AESs as an income supplement rather than a policy instrument that aims to enhance farmers' environmental performance (Emerson and Gillmor, 1999; Hynes et al., 2008). In other words, farmers' participation in AESs could be primarily driven by the financial rather than the environmental benefits of AESs. However, such an inference may not hold across the population of farms as the surveyed area may not necessarily reflect total farm size for all farms. Surprisingly, the type of farm system does not affect the likelihood of farmer participation in an AES. The statistically non-significant effect of farm system could be related to the small number of mixed livestock and tillage farms in the sample.

The latent factor being *Scheme Benefits Conscious* increases the likelihood of participation. This finding implies that participation in an AES is more likely amongst farmers who better understand the environmental and financial benefits of participation. The negative effect of the *Positive Environmental Farming* factor on the likelihood of farmer participation could be linked with the view that farmers' perceived contribution to the environment is already positive with or without their participation in an AES (Cullen et al., 2020).

Results from a number of past studies support the argument that innovative farmers are more likely to adopt conservation practices and participate in an AES, as well as having higher potential to achieve better environmental outcomes (e.g. Herzon and Mikk, 2007; Schmitzberger et al., 2005). Given that innovation adoption often occurs when farmers perceive that the innovation in question will help them achieve their goals (including economic, social and environmental goals) (Pannell et al., 2006), the negative association between participation and the *Innovative Orientation* factor implies that REPS and AEOS, similar to other action-based AESs, failed to attract innovative farmers, probably due to the limited scope for innovation or due to a mismatch between target habitat types and farms with innovative orientation.

3.2 Impact of scheme participation on habitat quantity and quality

Conditional on cross-section data availability, we examine the relationship between farmer participation in an AES on habitat quantity and quality. Table 4 displays the expected average effects of farmer participation in AESs on habitat quality and quantity compared with the alternative of non-participation (*ATT*s) from the doubly robust IPWRA estimator. The plot of density distributions of the estimated probabilities for participants and non-participants in an AES show that there is considerable overlap between participants' and non-participants' scores (Fig. B.1). Non-significant X^2 test statistics in Table 5 suggest that the covariate balance condition is satisfied.

Table 4. Estimated average treatment effects (*ATT*) on participants in an AES

Outcome variable	**Coefficient**	**z-statistic**
Share of habitat area	0.008	0.24
Length of linear habitats	6.864	0.58
FBEGS index	0.760	0.58
Notes: Number of observations: 130		

As regards the estimated *ATT*s of participation in an AES on habitat quantity, findings suggest that participant farms are expected to have on average, a higher share of habitat area by approximately 1% ($P < 0.1$) and higher length of linear habitats by seven metres per hectare, had these farms not participated in an AES. However, the estimated *ATT*s for habitat quantity are statistically non-significant at conventional levels of statistical significance. We also examined the relationship between farmer participation in an AES and boundary habitat quality. As shown in Table 4, participating farms in an AES have higher, on average, expected FBEGS index score than for non-participation. Nevertheless, the estimated *ATT* for habitat quality is also statistically non-significant at the 10% level. This result supports the argument that EU agri-environment measures have paid little attention to the improvement of farmland habitat quality (Rotchés-Ribalta et al., 2020).

Table 5. Parameter estimates of outcome models for participants

Explanatory variables	Outcome variables		
	Share of habitat area	**Length of linear habitats**	**Quality of boundary habitats**
Farmer age	-0.000 (-0.05)	-0.681 (-1.30)	-0.024 (-0.50)
Agricultural education	0.006 (0.08)	12.439 (0.59)	6.379** (2.29)
Discussion group membership	0.160*** (2.94)	-16.205 (-1.28)	-1.503 (-0.90)
Off-farm employment	0.126* (1.83)	27.612 (1.55)	2.488 (1.36)
Farm area	0.002 (1.00)	-1.725*** (-3.63)	-0.165** (-2.28)
Farm system: Cattle rearing (base: Dairy)	0.104* (1.88)	-8.888 (-0.76)	1.458 (0.76)
Farm system: Cattle other (base: Dairy)	0.088 (1.37)	-28.773 (-1.18)	4.112* (1.66)
Farm system: Sheep farm (base: Dairy)	-0.125 (-1.12)	-19.090 (-1.06)	-4.912* (-1.86)
Farm system: Other (base: Dairy)	0.011 (0.17)	-12.551 (-0.67)	0.281 (0.09)
Designated land	0.006 (0.12)	14.247 (1.07)	4.278** (2.25)
Scheme benefits conscious	0.078** (2.06)	-24.798*** (-2.89)	-2.028** (-2.01)
Positive environmental farming	-0.012 (-0.46)	11.392** (2.24)	0.211 (0.34)
Innovative orientation	-0.027 (-1.04)	11.385 (1.55)	-1.893 (-1.56)
Productivist orientation	-0.006 (-0.24)	11.692** (2.47)	1.632** (2.50)
Conservative orientation	0.043* (1.65)	2.325 (0.41)	-0.928 (-1.30)
Soil type 2 (somewhat limited land use potential; base: Soil type 1)	0.060 (1.15)	-13.742 (-1.03)	1.393 (0.96)
Soil type 3 (limited land use potential; base: Soil type 1)	0.370*** (3.14)	-33.740** (-2.05)	3.110* (1.76)
Region-East (base: Border region)	-0.179* (-1.76)	-40.436 (-1.49)	7.975* (1.89)
Region-Midlands (base: Border)	-0.246*** (-2.70)	-4.399 (-0.19)	4.706 (1.37)
Region-Southwest (base: Border)	-0.038 (-0.30)	-5.086 (-0.16)	11.520*** (2.98)
Region-Southeast (base: Border)	-0.174** (-1.97)	7.363 (0.37)	-0.938 (-0.34)

Region-South (base: Border)	-0.196** (-2.23)	-32.309 (-1.32)	12.849*** (6.13)
Region-West (base: Border)	-0.031 (-0.42)	-55.817*** (-3.16)	-0.402 (-0.20)
Constant	0.014 (0.15)	271.683*** (5.50)	37.771*** (8.37)
Balancing test after propensity score reweighting: Over identification test for covariate balance X^2 test statistics X^2 (24) = 15.54; $P > X^2 = 0.90$			
Notes: Significance levels: $^{***}P < 0.01$, $^{**}P < 0.05$, $^{*}P < 0.1$. z-statistics in parentheses. Number of observations: 130			

3.3 Determinants of habitat quantity and quality

Although the main objective of this study is to examine the relationship between farmers' participation in an AES and the quantity and quality of semi-natural habitats found on farms, we also discuss briefly the drivers of habitat quantity and quality for participants (Table 5). Agricultural education is found to be positively associated with the quality of boundary habitats. This result suggests that improvements in habitat quality may require more educated members of the farming community to be involved. Membership in a farmer discussion groups has a positive effect on share of habitats.[5] Thus, a different form of agricultural extension or specific training may be required to improve outcomes related to the management of linear habitats and habitat quality.

We also found that designated land is a strong predictor for habitat quality. The relationship between farmer perceptions of AESs and habitat quantity and quality varies across environmental outcomes. For example, the relationship between *Schemes Benefits Conscious* farmers and the share of habitat area is positive, but the relationship is negative with the length of linear habitats and habitat quality. As regards farmer self-identities, *Positive Environmental Farming* was found to be positively related with greater length of linear habitats, whilst farmers with *Productuvist Orientation* are positively related to the length of linear habitats and habitat quality. Farms on soils with limited land use potential have on average, a higher proportion of semi-natural habitats but smaller length of linear habitats than farms with high land quality.

4. Conclusions and policy implications

The sustainable management of natural resources and the provision of public goods such as biodiversity, nature-based cultural values and climate stability are key deliverables for modern agricultural production systems. Since the 1990s, AESs became an important mechanism to safeguard a wide range of environmental and aesthetic functions in European farmed landscapes. Although, AESs have evolved and adapted over the years to changing

[5] Farmer discussion groups typically refer to groups of farmers who meet regularly on farms to share ideas, discuss and learn about farm practices and technologies that may be applied on their own farms. In Ireland, discussion groups are often facilitated by a farm advisor whose main role is to create the right learning environment within the group. Discussion groups are widely used as a participatory extension activity (Hennessy and Heanue, 2012).

policy priorities and public awareness, the success of many AESs in terms of conservation is mixed (Mewes et al., 2015).

The aim of this *ex post* analysis is to examine the relationships between farmer participation in an AES and farmland habitat quantity and quality. A major contribution of this study is the combined use of socio-economic and habitat survey data and their econometric analysis through the employment of a 'doubly robust' estimator which corrects for potential self-selection bias. Results suggest that although farmer participation in an AES is positively related to habitat quantity and quality, these relationships are statistically non-significant at the 5% level. However, education, membership of discussion groups, designated land and specific farmer self-identities all positively influence either habitat quantity or quality. From a policy perspective and given that higher proportion of semi-natural habitats does not necessarily guarantee higher habitat quality, the shift from action-oriented towards hybrid or results-oriented schemes that incorporate habitat quantity, as well as habitat quality targets, may be a more environmentally- and cost-effective policy alternative to promote grassland biodiversity.

The analysis also highlights that the impacts of socio-economic and farm structure characteristics on habitat quantity and quality can differ. Moreover, the varying role of agro-climatic differences across regions on farm environmental performance possibly advocates for the development of spatially-targeted payment mechanisms. It is also important to understand farmer attitudes towards the environment and farmer perceptions of AESs. This study shows that there is a rich variety of links between farmer self-identities and habitat quantity and quality. The engagement of psychologists and other social scientists in the conservation process could be critical for the effective communication of nature values, shaping new forms of social capital and understanding barriers and new opportunities for the adoption of AESs by farmers.

The main limitation of this study is inherent in the limitations of using cross-section data as they do not allow the identification and control of unobservable farm characteristics that may influence a farmer's participation in an AES and the status of habitat ecological conditions (habitat quality or quantity). As regards future research, the evaluation of AESs should be validated, not only in terms of environmental effectiveness but also in terms of their cost-effectiveness. The identification of cost-effectiveness conservation measures in follow-up studies could be insightful and helpful for the design of new, more innovative agri-environmental policies.

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Appendix A. Factor analysis. *Source*: Cullen et al. (2020)

Table A.1. Factor loadings related to farmer self-identity

	Positive Environmental Farming	**Innovative Orientation**	**Productivist Orientation**	**Conservative Orientation**
Farmers are good caretakers of the countryside	**0.79**	0.03	0.05	0.01
I enjoy farming much more than I would other potential sources of employment	**0.55**	0.07	-0.05	0.09
Farmers have a strong positive role to play in protecting the environment	**0.46**	0.26	-0.13	0.14
To be successful in farming it is important for me to adapt and use new technologies	0.02	**0.74**	0.04	-0.09
I have to keep my farm running to ensure I have something to pass on to my children	0.05	**0.61**	-0.04	0.17
I am good at finding different types of information to help me run my business	0.24	**0.58**	0.07	-0.05
We need to produce more food even if some damage	-0.16	0.22	**0.72**	0.07

is caused to the environment				
Farmers should be allowed to maximize their income irrespective of the environmental consequences	0.18	-0.15	**0.73**	-0.01
I don't think it is a good idea to take too many risks when it comes to farming	0.04	0.06	-0.02	**0.71**
I am cautious about adopting new ideas and farm practices	0.03	-0.22	0.14	**0.55**
Eigenvalue	0.37	0.92	2.71	1.25

Table A.2. Factor loadings related to farmer perceptions of agri-environment schemes.

	Scheme Benefits Conscious	**Scheme Drawbacks Conscious**
Countryside looks better	**0.81**	-0.01
Better management of slurry	**0.83**	-0.10
Environmental knowledge gained from agri-environment courses	**0.82**	0.02
REPS/AEOS payments are a valuable income source	**0.74**	-0.02
More areas for wildlife on farms	**0.77**	0.07
Farmyards look much better	**0.89**	0.04
Limitations on stocking and nutrient management make it difficult to farm profitably	-0.03	**0.75**
Lack of continuity between schemes	0.14	**0.71**
High adviser/consultant cost to enter schemes	0.02	**0.74**
Lose too much productive land to hedgerows, wildlife corridors, habitats etc.	-0.14	**0.68**
Greater risk of inspection/penalty	0.09	**0.69**

Payment doesn't cover all the costs of participation	0.02	**0.73**
Too much hassle with forms, record-keeping, etc	-0.10	**0.74**
Eigenvalue	4.05	3.60

Appendix B. Overlap assumption

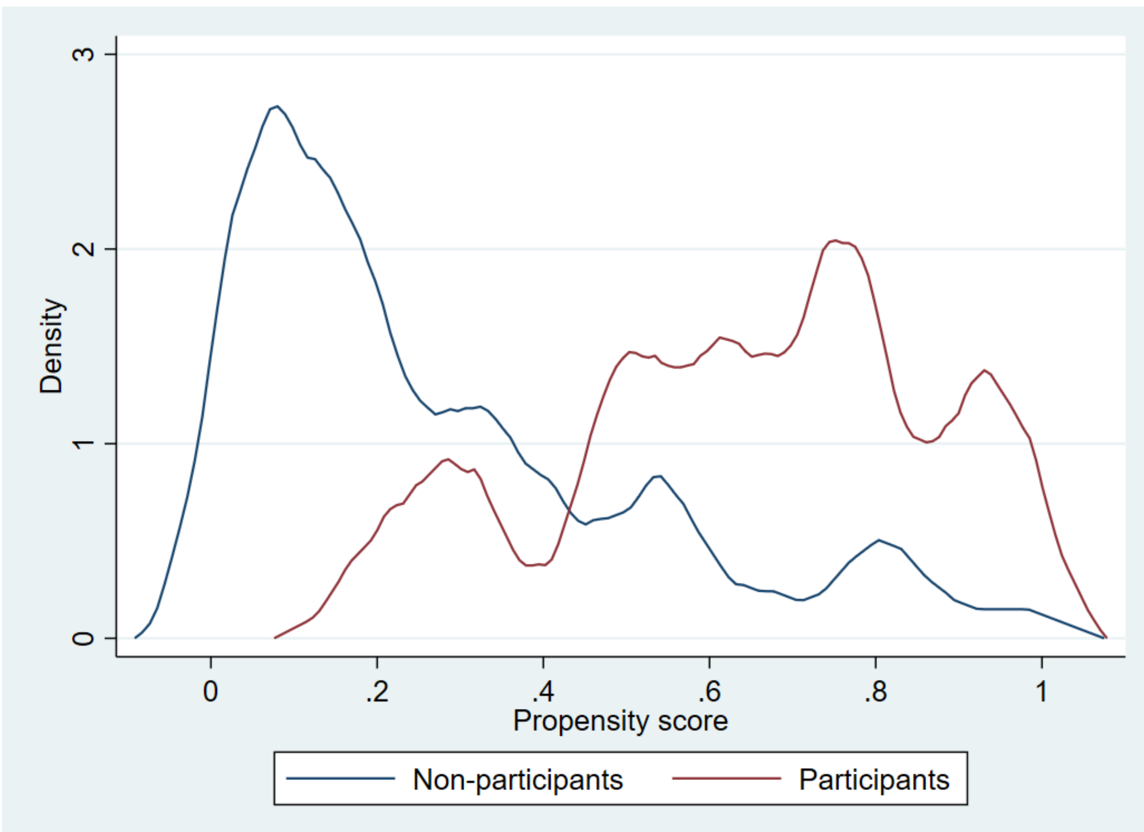

Fig. B.1. Density distribution of propensity score by participation in AES status.