Evaluation of the GLAS
Phase 1 – Literature Review (Final)

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Submitted to: Michael Gleeson, DAFM
Prepared by: Michael Image
Checked by: John Elliott

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Contents

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DAFM	Michael G. Gleeson, Jerome Walsh, Patricia Kelly, Damien Flynn, Patricia Torpey John Muldowney
Teagasc	Daire Ó hUallacháin, Cathal Buckley
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Birdwatch Ireland	Alex Copland
IT Sligo	James Moran
UCD	Mary Kelly-Quinn
TCD	Ainhoa González
ADAS	Nigel Critchley, Chris Forster-Brown, Dave Skirvin, Ellie Wright, Yiying Cao, John Elliott

2 Executive Summary

Introduction, Scope and Method

The agri-food and fisheries sector is Ireland's most important indigenous industry, and represents a significant land use at approximately 72% of the national territory. Because of the relative lack of heavy industry in comparison to other Member States, agricultural activities have had a more noticeable environmental footprint in particular on greenhouse gas (GHG) emissions, water quality, and biodiversity. Improvements have been made over past decade that reflect both the mandatory requirements of Pillar I and voluntary measures offered under Pillar II of the CAP. However, the sustainability of these improvements may be challenged by potential increases in national livestock numbers, crop areas, and fertiliser use required to meet the value targets of Food Wise 2025.

The Rural Environment Protection Scheme (REPS) was Ireland's first major agri-environment scheme and operated from 1994. The scheme had a horizontal whole-farm focus and evolved through four iterations which gradually added more complexity, such as additional biodiversity options. It was succeeded in 2010 by a smaller Agri-Environment Options Scheme (AEOS) which took a more targeted approach, focussing on part-farm actions. The current scheme is the Green Low-carbon Agri-environment Scheme (GLAS) which has a tiered approach and a much stronger biodiversity focus, but also contains targeted actions for climate and water quality. Other measures have been established outside the Rural Development Programme (RDP) that sought to target specific Natura 2000 features. These include the Burren Farming for Conservation Programme (BFCP), which adopted a results-based remuneration approach, and the Farm Plan Scheme (FPS) operated by the National Parks and Wildlife Service (NPWS) to target certain birds listed in the Birds Directive.

A previous review of REPS by Finn & Ó hUallacháin (the REPS Review) and the mid-term evaluation of the 2007-2013 RDP brought together a considerable volume of information about the effectiveness of REPS. However, these studies also raised a number of issues such as the need to demonstrate national scale effectiveness in addressing GHG abatement and water quality over the long term, the need for further and more consistent work to investigate biodiversity effects, and the need for more studies on socioeconomic aspects of schemes. This review has sought to capture and synthesise work on agri-environment measures in Ireland produced subsequent to these reviews (i.e. since 2010). It has focussed on REPS and AEOS but has also considered the FPS, the BFCP and other LIFE projects, as well as other relevant research projects or national reports on biodiversity, climate and water quality. Adopting a similar analytical framework to the previous REPS review, it breaks down the research into thematic topics. In particular, the review asked a number of specific questions of the literature captured.

In what way does the literature change or confirm the previous understanding of the measure(s) in question?

REPS and AEOS

The previous review of REPS identified some evidence from life cycle assessments that emissions from dairy and suckler beef farms in the REPS scheme were lower than non-REPS farms, though results were not scalable to national level. The literature captured in this review has mainly focussed on quantifying the carbon abatement potential of individual management actions which were funded under REPS and AEOS. Cover crops have been shown to be more effective at lowering emissions (37% reduction) than minimum tillage (9% reduction). Using a trailing shoe injector for slurry application could also be effective at mitigating emissions, though all three measures have cost implications which make them expensive relative to the prevailing traded price of carbon. The abatement potential of clover swards

(20-23% reductions) and the carbon sequestration achieved by hedgerows planted (0.66 $tCO_2ha^{-1}yr^{-1}$) under REPS have also been evaluated, suggesting that these had contributed to emission reductions. The extent of any resilience to climate change effects achieved through REPS actions remains unclear.

Strong evidence has emerged to suggest a significantly lower nitrate leaching rate in REPS (losses of less than 20 kg $ha^{-1}yr^{-1}$) versus non-REPS (losses exceeding 50 kg $ha^{-1}yr^{-1}$) intensive beef suckler systems. REPS uptake may also explain the decrease in phosphorus enrichment observed in some catchments over the previous decade, though this does not appear to have been fully investigated through a longitudinal counterfactual study. Indeed, these declines may have had more to do with the implementation of the Nitrates Action Programme which made certain nutrient management measures mandatory nationwide, and have been shown to decrease phosphorus surplus by 74% and increase efficiency by 48%. A considerable volume of work has been carried out as part of the Agricultural Catchments Programme (ACP) to investigate the effectiveness of these measures with important implications for the evaluation of actions funded under agri-environment schemes.

Few studies could be identified that evaluate REPS or AEOS effect on Natura 2000 features. This does not mean that REPS itself was not having some positive effect, but because work has measured changes in actions (e.g. lower stocking density) rather than results (changes in conservation status) it is not possible to draw any firm conclusions. There is a more extensive body of work on non-designated features (in particular field margins, riparian margins, and hedgerows), though few studies have baseline information from the pre-REPS era, making a complete assessment difficult. Notwithstanding this limitation, higher level indicators of biodiversity (bird abundances, bird species richness and vegetation species richness) generally show little or no difference between REPS and non-REPS measures. However, functional indicators of biodiversity such as invertebrate and below-ground species richness, generally show that REPS had a positive effect. Other studies identified in this review on the management regimes for field margins, riparian margins and hedgerows have proposed refinements which would have helped improve REPS effectiveness on the higher level indicators.

There have been comparatively few studies on landscape and archaeology objectives of agri-environment schemes, though previous evaluations suggest that REPS was achieving broader environmental objectives. The REPS Review also highlighted two projects which made a holistic assessment of REPS overall environmental footprint by scoring performance across multiple objectives. However, this work has not been repeated on AEOS.

Socioeconomic factors associated with environmental actions have been more widely studied in recent years, although this is generally about the characteristics associated with scheme uptake rather than impact studies. A major regression analysis of the National Farm Survey (NFS) dataset over all four iterations of REPS has identified commonalities in farmers participating in the scheme. Less intensive farms with lower incomes dominate these statistics, including many farms that would be otherwise non-viable. Intensive dairy farms generally took a more opportunistic approach, choosing only to participate when the limits on organic nitrogen were removed, or to smooth incomes during more difficult times. Attitudinal survey work on REPS and AEOS has been more limited and a national scale study could not be identified; however, work done in other Member States reveals similar findings to the regression analysis. At individual measure level farmers with stewardship, environmental conservation, or productivist objectives are more likely to adopt nutrient management best practice over those who prioritise human needs. Lower than expected uptake rates of riparian buffers in AEOS can also be attributed to the funding available (€0.74 $m^{-1}yr^{-1}$ for a 10.5m wide strip) being only about half the average farmer's actual costs.

Other Agri-environment Measures and Research Programmes

Of the projects originally funded by LIFE, the BFCP has been the most extensively developed and studied. A simple numerical scoring system has been developed to assess the quality of habitat on participating farms which in turn determines the amount of funding a farmer receives. Scores (and therefore compensation) have consistently increased over the past 10 years. Cost efficiency studies suggests it delivers annual public goods of €2.3 million against annual costs of €1.4 million, and that its administration costs are relatively low compared to the EU average for agri-environment schemes (12% vs 15% of total costs). The scheme has received consistent praise from farming and environmental communities. The other LIFE schemes are still largely in their initial research phases.

The hen harrier FPS was the most popular in terms of numbers and funding. The initiative has been carried through to GLAS, with refinements informed by NPWS and others' research into the bird's ecology. Lower grazing intensities (down to 0.15 LU ha^{-1}) can now be accommodated but more work is needed to incorporate predator control and provision of winter resources. A future Locally-Led agri-environment scheme will also seek to address the conflict between the needs of the hen harrier and other farm diversification measures such as forestry and wind farms. NPWS and partner organisations have also provided input for the new measures in GLAS to target certain species, for example breeding waders, twite, and grey partridge. Extensive monitoring on the FPS and other efforts to stimulate the recovery of the corncrake suggest that Ireland-wide targets for population whole have not been met, though this reflected more climatic events outside the scheme's control. The outcome for the chough has been better, with breeding productivity increasing from 1.08 to 2.50 young per attempt between 2008 and 2014. Notably, this scheme set out broad prescriptions but allowed farmers flexibility in shaping grazing and silage regimes, an approach which has been praised by the participants.

Does the literature help address any of the issues raised in the REPS Review or formal evaluations?

The majority of new papers are focussed on assessing the effectiveness of a particular measure or facet within a given catchment or in a small sample of farms, so the spatial scale issue remains. The temporal scale situation has improved with some nutrient leaching and socioeconomic studies considering data going back to the initial scheme. However, interpreting work on REPS biodiversity effects has suffered from a lack of pre-scheme data against which to derive a baseline comparison.

Farmer behaviour has been more extensively studied, and has provided insight into uptake, participation and attitude. No studies investigating REPS exit and AEOS participation specifically could be identified, though evidence from other Member States suggests that mandatory measures are having a more dominant effect in terms of nutrient management, hence highlighting the challenge of identifying the net impact of additional agri-environmental measures on certain parameters.

Much of the research that was identified in the REPS Review had not been published in peer-reviewed journals; but since then a good number of these have been able to pass through this process. The proportion of peer-reviewed articles identified in this review (27%) is lower than the REPS Review (45%), and there is considerably more reliance to preliminary results (37% vs 5%) as opposed to published reports (27% vs 49%).

What are the implications for the evaluation of GLAS?

The GLAS evaluation will take on board the broad methodological concerns raised, and will seek to carry out a national scale and longitudinal study across the scheme as a whole. It will also seek to establish baseline information (pre-scheme) so that any changes in the monitored variables can be more clearly attributed to the scheme itself. A counterfactual scenario (non-uptake) will also be investigated as part of the attitudinal component of the evaluation.

The research gathered in this review will also be considered as part of the calibration of models, fieldwork protocols and other aspects of the GLAS evaluation. The socioeconomic studies in particular will provide useful information about farm structural and attitudinal typology that will inform the analysis of the GLAS and broader NFS datasets, as well as the development and targeting of questionnaires to elicit relevant information. Results from ongoing programmes of work, such as the COSAINT project, the ACP, NPWS research, the BFCP and LIFE schemes will also be taken on board as they become available.

What are the implications for future agri-environment measure design?

Much of the research evaluated has already been factored into the design of GLAS and the wider RDP, either as part of the consultation on the RDP and its Strategic Environmental Assessment, or because the work has explicitly led to the inclusion of a new measure (for example the Burren Programme as a Locally-Led and the various bird measures now within GLAS itself). For water quality, the ACP in particular is likely to provide a more refined understanding of pathways and critical source areas. Other ACP research into nutrient and sediment attenuation capacity of specific features (riparian buffers, field margins, drainage ditches, and hedgerows) can also help improve their design and maintenance.

The success of results-based and bottom-up schemes has led to a broader call for more of these to be incorporated into agri-environment scheme design more broadly. There are a number of challenges to be overcome, but these are not insurmountable. The Results-Based Agri-Environment Payment Scheme (RBAPS) project is investigating solutions for Natura and non-Natura areas with work underway in two locations in Ireland. Developing a results-driven approach for water quality is more challenging but will be informed by Teagasc's work on critical source areas, connectivity, and storm events.

Identification and conservation of high nature value farmland (HNV) is a priority of the RDP and was not sufficiently addressed in previous schemes. The Ideal-HNV has so far mapped potential HNV farmland at national level and developed a typology of Irish farmland which can be used to classify farms as whole, partial, or non-HNV. The project has also developed a 'nature value index' on which individual farms could be assessed for performance, should measures be developed with an HNV focus. Along with RBAPS and the scoring approaches used in the Burren, these will help construct a consistent approach to metrics for future agri-environment measure design and evaluation.

Future schemes could be informed by the work on functional land management which seeks to identify how farmland can be managed to meet the multiple objectives of food production, carbon sequestration, water purification, nutrient cycling and habitat provision. The other socioeconomic studies can provide guidance for future scheme design by revealing more about Irish farmers' underlying attitudes and responses to the incentives offered. Research in other Member States is currently exploring the viability of auction or other approaches to help improve value for money.

Conclusion

This study has uncovered literature suggesting that past agri-environment schemes have had a positive impact on water quality and GHG abatement, though this still needs to be verified at national level. The evidence for their effect on biodiversity is less strong, though they may have still played an important role. Participation in REPS was mainly attractive to lower income, extensive farmers; but for a brief time it was able to attract the more intensive dairy farms. The approach taken in the Burren and the FPS to deal with the unique issues of SAC and SPA management has been more extensively studied, and has generally led to positive outcomes for these features. The applicability of this approach to a national-level scheme still needs to be established, but ongoing initiatives are investigating. Adapting a results-driven approach to water quality will be more challenging, but the knowledge gained from the ACP research, COSAINT and other projects will help devise more precise and cost-effective measures.

3 Introduction

3.1 The Irish Agri-Environment

The agri-food and fisheries sector is Ireland's most important indigenous industry, contributing a gross annual output of €26 billion and directly employing around 170,000 people. The sector's proportion of national Gross Value Add (GVA) was around 7.6% in 2014, though primary production component is only 2.5%. Agriculture remains a significant land use, with the utilisable agricultural area (UAA) representing approximately 72% of Ireland's territory (DAFM 2014). As such, agricultural activities have had a significant environment footprint, especially in terms of climate change, water quality, and biodiversity.

The EPA has estimated Ireland's total national greenhouse gas (GHG) emissions at 58,205 $kTCO_2e\ yr^{-1}$ in 2014 (EPA 2015b). These have been on a reducing trend, with declines noted in 8 of the previous 9 years. Emissions from sectors outside the Emissions Trading Scheme (ETS) were 42,242 $kTCO_2e\ yr^{-1}$, which is ahead of the target under the EU Effort Sharing Decision. The agriculture sector has been Ireland's primary source of GHG emissions since the early 1990's, though this reflects a relative lack of heavy industry in comparison to other industrialised nations. The EPA report also shows that levels peaked in 1998 at 22,609 $kTCO_2e\ yr^{-1}$ but have since reduced to 19,400 $kTCO_2e\ yr^{-1}$ in 2014, though this still represents 33.3% of total emissions. The main drivers for this decline have been reduced CO_2 emissions from liming on soils, and a reduction in nitrogenous fertiliser use which has brought down N_2O losses from soils. However, these were counterbalanced by expected emissions due to higher livestock numbers, in particular from the dairy cow population which rose by 4.8% in 2014. On a relative basis, a Life Cycle Analysis (LCA) carried out in 2004 has shown that Ireland's livestock sector has a favourable GHG footprint with emissions per kg of cow milk at 1.0 $kgCO_2e$ compared to the EU average of 1.4 $kgCO_2e$ (Leip et al. 2010).

The most recent "Water Quality in Ireland" report indicates that 53% of rivers, 43% of lakes, 45% of transitional, 93% of coastal waters and 99% of groundwater are at high or good status (EPA 2015c). Although these statistics compare favourably with many EU-15 nations, there still remain challenges in achieving Water Framework Directive (WFD) targets: many rivers, lakes, and transitional waters still require improvement. The report identifies eutrophication from nutrient enrichment as the main issue facing Irish waters. However, it also acknowledges that there has been considerable progress in dealing with the problem. In the previous decade Ireland had one of Europe's highest nitrogen stocks and lowest nitrogen efficiencies (Kuosmanen 2014). The nitrogen surplus has since declined considerably, last registering at 22 kg N ha^{-1} in 2011, which is considerably lower than the EU-15 average of 57 kg N ha^{-1} (EC 2014). Nutrient inputs to rivers, particularly from the agriculture sector, have seen 18.7% and 37.7% reductions against 2007 values in nitrogen and phosphorus sources respectively.

Much of this improvement reflects Ireland's implementation of the Nitrates Directive on a whole territory basis, which is included in the cross-compliance process under the Common Agricultural Policy. These regulatory measures implemented by the Irish Government as part of its Nitrates Action Programme (NAP) ensure that all farmers in Ireland are contributing to mitigating the impact of agriculture on water quality (EPA 2015a). The EPA has linked the observed declines in nutrient inputs mentioned above to the introduction of the NAP (EPA 2015c). However, stakeholders acknowledge that this regulatory baseline will not provide sufficient mitigation in sensitive/vulnerable areas and necessitates additional targeting of measures funded under the Rural Development Programme (RDP) (DAFM 2014). These additional measures, which include agri-environment schemes, knowledge transfer schemes, and targeted agricultural modernisation schemes build on the protection provided by the regulatory baseline.

The National Parks and Wildlife Service (NPWS) in its last Article 17 report concluded that 9% of habitats and 52% of species listed under the Habitats Directive were considered to be in a favourable state (NPWS 2013). The report also identifies agricultural practices as the main category of threat or pressure for the decline in habitats' conservation status and as a major contributor towards declines in those of protected species. Ecologically unsuitable grazing regimes, land abandonment, and pollution of waters as a result of agricultural activities are the most prominent actual threats and pressures. Features particularly affected include: peatland and grassland habitats; *Vertigo* and pearl mussel species and marsh fritillary; and farmland birds such as corncrake, curlew, lapwing, grey partridge, and twite (NPWS 2012; NPWS 2013; Copland 2015). Ireland has also faced a series of cases in the European Court of Justice (ECJ) in relation to its failure to adequately implement the Habitats Directive and the Birds Directive (ECJ 2007).

Ireland's agricultural production strategies are set out in Food Wise 2025 (DAFM 2015) . Amongst other general objectives, Ireland is seeking to increase the value of primary production to almost €10 billion by 2025. There are also objectives for each sector, including actions for the dairy sector to develop strategies to increase fertility and utilisation of grassland. The strategy acknowledges the potential for these objectives to increase environmental challenges and sets out how processes and technologies will be developed to address these.

A Strategic Environment Assessment (SEA) and Appropriate Assessment (AA) of Food Wise 2025 have been carried out (Philip Farrelly & Co Ltd 2015a; Philip Farrelly & Co Ltd 2015b). Although these studies found there to be no likely significant adverse environmental effects after safeguards and mitigation was put in place, they did acknowledge potential uncertainty in assessing this, as the strategy does not specify biophysical targets for the growth in primary production. Teagasc has produced estimates for the proposed size of the national herd, crop areas, and fertiliser use required to deliver the Food Wise 2025 targets, which the EPA have incorporated into their GHG emissions projections (EPA 2016). The implications are that emissions from agriculture will increase by 7% from 2014 to 2020, meaning that Ireland's emissions profile will start to exceed its Effort Sharing Decision target from 2016 or 2017 onwards. The consequences for water quality and biodiversity are harder to predict though the Teagasc analysis suggests that nitrogen fertiliser use is projected to increase by 21% from 2014 to 2020.

3.2 Agri-Environment Schemes

3.2.1 Rural Environment Protection Scheme (REPS)

Publicly funded measures to address issues in the Irish agri-environment began in in 1994 with the Rural Environment Protection Scheme (REPS). This was the Irish government's response to Council Regulation 2078/92 requiring the development of such a policy. Prior to this date, there had been little in the way of agri-environmental policy in Ireland save for some grants given to farmers towards the cost of waste facilities and farmyard buildings aimed at reducing pollution, and a short-lived Environmentally Sensitive Area scheme in the midlands and Galway (Emerson & Gillmor 1999).

The stated objectives of the first REPS scheme (REPS1) were:

- To establish farming practices and controlled production methods which reflect the increasing concern for conservation, landscape protection and wider environmental problems.
- To protect wildlife habitats and endangered species of flora and fauna
- To produce quality food in an extensive and environmentally friendly manner.

Farmers who signed up for REPS1 were obliged to comply with 11 basic measures for a 5 year period, which included requirements to protect watercourses and limit use of herbicides, pesticides and

fertilisers. In exchange for this, farmers received an annual payment of €151/ha/annum to a maximum of 40 ha (i.e. €6,040). Farmers were able to get additional funding for one of six supplementary measures. Two of these measures (Natural Heritage Areas (NHA) and Rejuvenation of Degraded Areas) were obligatory in areas falling under these designations.

Although each farm was required to produce an individually tailored agri-environmental plan, REPS1 was very much a comprehensive scheme with the 11 basic measures covering virtually all aspects of agricultural practice and land management. It was also largely spatially untargeted, with relatively little uptake of the supplementary measures in the designated areas. REPS1 was also a whole-farm scheme, with participants required to implement the measures across their entire holding. Analysis of the scheme (Hynes & Murphy 2002; Emerson & Gillmor 1999) shows that uptake was initially slow but by the end of the funding period 44,769 farms (approx. 32% of the total) had entered the scheme and nearly €800 million[1] had been paid out. Participants were mostly (70%) less intensive cattle and sheep farmers in the west and north-west of the country. By contrast intensive dairy and tillage farms found it impractical to comply with the organic and inorganic input restrictions, and the REPS1 income did not provide a sufficient economic incentive.

REPS2 was introduced in 2000 as part of the Rural Development Programme (RDP) covering the period from 2000 to 2006. It was a successor to REPS1 with essentially the same objectives and measures though with a key condition that their plan would go above and beyond usual good farming practice. Similar payment rates were offered, though an additional 10% was given to smaller farms (less than 20ha). The main structural difference with the original REPS specification was that the two supplementary measures aimed at designated areas were combined into a single "Measure A" targeting actual or proposed NHA, Natura 2000, and Commonage land[2]. A further element was also added where farmers who had land in one of these areas, but chose not to participate in the general REPS, could take up Measure A specifically.

REPS3 was introduced in 2004 after the 2003 amendment to support for European Agricultural Guidance and Guarantee Fund. The same basic 11 measures were retained, but farmers were then obliged to choose two additional options which were generally aimed at biodiversity. Measure A (target areas) was largely the same, but was brought into the core REPS section to emphasise its mandatory status. Additional supplementary measures were added to the menu, including Traditional Irish Orchards, LINNET (Land Invested in Nature, Natural Eco Tillage), and a specific action to target Corncrake habitats. Core payment levels were boosted, and the threshold for payments was increased to 55ha albeit with a tapered rate.

The final iteration of the REPS scheme was REPS4, which was introduced in 2007 to reflect the new RDP period. By this stage the objectives of the scheme had changed somewhat and were as follows:

- To promote
    - Ways of using agricultural land which are compatible with the protection and improvement of the environment, biodiversity, the landscape and its features, climate change, natural resources, water quality, the soil and genetic diversity.
    - Environmentally-favourable farming systems.
    - The conservation of high nature-value farmed environments which are under threat.
    - The upkeep of historical features on agricultural land.
    - The use of environmental planning in farming practice.

[1] REPS1 predated the introduction of the EUR. The amount paid out was IEP 626,588,463.

[2] The consolidation of Supplementary Measures 1 and 2 into Measure A actually took place in the final year of REPS1.

- To protect against land abandonment.
- To sustain the social fabric in rural communities.
- To contribute to positive environmental management of Natura 2000 sites.

The 11 basic measures were retained, but with some changes to their specification. Intensive farmers (>170kg OrgN/ha) were required to have a valid Nitrates Derogation and choose one additional option. More supplementary options were added including Traditional Sustainable Grazing, Low Input Tillage, Minimum Tillage, Lake Catchment, and Clover Sward measures and changes were made to how they could be claimed. The Organic Farming supplementary measure was taken out of REPS and became a standalone measure in the RDP. Payment rates for the core payment were further increased (to €234/ha/annum for the first 20 ha) and adjustments were made to funding for Measure A and supplementary measures.

3.2.2 Agri-Environment Options Scheme (AEOS)

REPS itself finally closed to new applicants in 2009, at which point it had over 60,000 farms receiving payments, representing 45% of farms in the country and had paid out over €3.1 billion to Irish farmers since 1994 (Finn & Ó hUallacháin 2012). In part this reflected the challenging economic conditions that Ireland faced in the aftermath of the financial crisis. However, there was also a desire that the next generation of agri-environment scheme should be more targeted, rather than the horizontal approach applied in REPS (OECD 2009). Its successor, the Agri-Environment Options Scheme (AEOS) was initiated in 2010 and ran for three annual funding cycles until the end of the RDP 2007-2013 programming period. Its stated objectives were:

- To promote biodiversity, encourage water management/quality and combat climate change.
- To contribute to positive environmental management of farmed Natura 2000 sites and river catchments in the implementation of the Birds Directive, Habitats Directive and Water Framework Directive.

AEOS had a much smaller budget (€146.3 million), was considerably more targeted focusing on part-farm actions as opposed to whole farm approach, and was also a competitive scheme. The scheme was not open to those already in REPS, but previous participation in REPS was a criteria to determine access. Natura and commonage farmers were required to manage their land in a specified manner, but otherwise applicants could choose from a list of options including grassland field margins, arable field margins, tree planting/management, traditional hay meadows, species rich grassland, rare breeds, traditional orchards, wild bird cover, hedgerows, dry stone walls, riparian margins, preventing bovine access to watercourses, trailing shoe slurry spreading, and minimum tillage.

3.2.3 LIFE Schemes

During the period that the REPS programme was in operation, there had been considerable research into the effectiveness of European agri-environment schemes. A common conclusion was that the broad-based non-targeted agri-environment schemes were not adequately conserving biodiversity (Kleijn & Sutherland 2003; Feehan et al. 2005). At the same time Ireland also faced a series of cases in the European Court of Justice (ECJ) in relation to its failure to adequately implement the Habitats Directive and the Birds Directive (ECJ 2007). This resulted in it needing to implement a series of actions including number of additional sites becoming designated as Special Area of Conservation (SAC) or a Special Protection Area (SPA), as well as placing additional restrictions on farmers. These changes posed considerable challenges for farmers, and despite the increasing focus on these areas in REPS2 to REPS4, many felt that the broad-based provisions and support in the scheme were inadequate (Dunford 2015). These challenges have led to a different type of agri-environment scheme emerging in Ireland where

public funds outside the scope of the RDP were channelled towards areas with biodiversity designations to assist farmers to meet the very specific and localised challenges.

The first of these was the BFCP, which began as a €2.5 million EU funded "LIFE" project from 2005-2010, and continued as a €5 million DAFM/NPWS joint-exercise from 2010-2015. 20 farms were involved in the LIFE phase, and 160 farms in the subsequent "Burren Farming Conservation Programme" (BFCP) (Dunford 2015). The scheme covers the Burren SAC, a unique karst limestone habitat in Clare and Galway, and was designed by Teagasc, NPWS, and the local farmers themselves represented by the Irish Farmers Association (IFA). The structural approach was very different from the REPS approach. Management regimes were designed by the farmers and their advisors, and were allowed to be flexible to adapt to changing individual needs. Moreover, payments to farmers are based not just on actions implemented, but also on the conservation results achieved. This additional payment was based on a scoring approach where individual eligible fields of grassland or heath are rated on a 1-10 scale, with higher scores obtaining higher payments subject to a minimum threshold. Unlike REPS, each farmer is paid according to his individual costs, subject to standard costings for certain investments. The BFCP, rebranded as the Burren Programme, is now subsumed within the RDP 2014-2020 as a "Locally-Led" agri-environment scheme.

The Burren was not the only Natura 2000 area to benefit from EU funding aimed at developing novel approaches to agri-environment schemes. Other LIFE projects have been established in Kerry, the Aran Islands, and Duhallow with a similar purpose though aligned to different habitat requirements.

KerryLIFE focusses on two freshwater pearl mussel (FPM) catchments in South Kerry which represent 46% of the total Irish population for the critically endangered species, which is protected under Annex II of the Habitats Directive and is currently in poor conservation status throughout Ireland (NPWS 2013). The FPM is sensitive to high sediment and nutrient input, as well as changes in habitat hydrology. The KerryLIFE project began in 2014 and is currently trialling conservation measures aimed at reducing these problems in the catchment through a mixture of agriculture and forestry actions including drainage management, nutrient reduction, buffer strips, protection of water courses from livestock, broadleaf tree planting in riparian zones, and restructuring of commercial forests (NPWS 2015c). In total €5 million will be invested into the project. The Kerry LIFE project will feed into the development and establishment of an FPM scheme in nine priority FPM catchments identified by NPWS, as part of a commitment made in the RDP 2014-2020.

DuhallowLIFE began in 2010 and is also looking at FPM amongst other species and birds linked to water quality issues in River Blackwater SAC, including otter, atlantic salmon, kingfisher, and dipper. Project actions have included tree planting, protection of riparian zones, placement of nest boxes and otter holts, as well as a considerable public education effort.

The AranLIFE project began in 2014 and is seeking to develop the most appropriate conservation management practices for orchid-rich calcareous grassland, machair, and limestone pavement Annex I habitats in the Aran Islands. It aims in particular to research the impacts on habitats of grazing regimes and removal methods for scrub and bracken, as well as to develop new approaches to these. There will also be an assessment of the socioeconomic impact on local communities that will form part of a PhD project (AranLIFE 2015).

3.2.4 NPWS Schemes

Another scheme that emerged with a more targeted approach was the Farm Plan Scheme (FPS), which was launched in 2006. The FPS was administered by NPWS and has distributed €25 million since inception covering around 685 plans (Bleasdale & O'Donoghue 2015). The FPS intended to assist farmers in designated areas (in particular Natura 2000 sites) for additional costs and income foregone in relation

to managing that land for conservation objectives. Rather than following a prescribed set of measures as in REPS in return for a fixed payment, bespoke farm plans were prepared on an individual level with a maximum level of funding per holding. Farm plans focussed on certain protected species and habitats, in particular those which were the subject of the European Court of Justice cases brought against Ireland in relation to implementation of the Birds Directive (DAHG 2015). In addition to the FPS, NPWS has also run a number of separate voluntary grant schemes have been established targeting specific species or groups such as corncrake and breeding waders.

The FPS scheme closed to new applicants in 2010 though fresh funding was made available after this to support some farmers to continue for a second phase, and to support some new species specific plans. Many of the FPS measures developed have been subsumed within Pillar II funding. Despite this, the FPS has continued albeit on a reduced scale with a main objective being to trial novel approaches to farming for environmental benefits, such as very specific measures to farm plots for corncrake conservation (NPWS 2014a).

3.2.5 Green Low-carbon Agri-environment Scheme (GLAS)

Food Wise 2025 recognises that the growth of the agriculture sector must be realised in an environmentally efficient and sustainable manner. It also states that "*A guiding principle to meet these sustainability goals will be that environmental protection and economic competiveness will be considered as equal and complementary, one will not be achieved at the expense of the other*." (DAFM 2015).

The latest RDP 2014-2020 has been designed with this in mind and aims to ensure that growth of the sector will be compatible with European legislation and targets on climate change, water quality, and biodiversity. The RDP introduces a new agri-environment scheme, GLAS (Green Low-carbon Agri-environment Scheme). The scheme aims to support cross-cutting goals for biodiversity, climate change and water quality as well as actions to help preserve archaeological heritage. Like its predecessors it contains a range of actions, which involve either direct support for environmental intervention or promotion of more sustainable agricultural practices. Core GLAS requirements include, preparation of the application by an approved agricultural planner, a nutrient management plan, knowledge transfer and record keeping of actions taken. However, GLAS's design also reflects the need for agri-environment schemes to become more targeted, and to have a greater focus on biodiversity features. Hence, it also has a tiered structure which prioritises farmers whose land features "priority environmental assets". Furthermore, additional financial assistance is available to farmers through GLAS+ who undertake more challenging actions or have a high number of compulsory actions.

The top tier of GLAS (Tier 1) targets climate change mitigation, water quality (high status water areas) and farmland birds on farms and include vulnerable landscapes, organic farmers and farmers who have a priority environmental asset. Tier 2 focuses on Vulnerable Water Areas and other farmers who would like to target climate change and mitigation and support farmland birds. Tier 3 invites applications for other complementary environmental actions. DAFM's aim is that 60-70% of applications will be in the top two tiers. Maximum packages are an annual grant of €5,000 (€7,000 in GLAS+) and are expected to attract approximately 25,000- 30,000 farmers in 2015 and up to 50,000 farmers in total (approx. 36% of all farms in Ireland).

3.3 Previous Evaluation of Agri-environment Schemes in Ireland

Formal evaluation of Irish agri-environment schemes has taken place within the context of EC requirements and protocols for RDP evaluation[3]. The most recent to take place was the mid-term evaluation of the RDP 2007-2013 (Indecon 2010). With respect to the REPS scheme, this concluded that:

- REPS had improved knowledge and awareness amongst farmers of the environmental impact of farming systems and processes;
- REPS had contributed significantly to improving the soil and water quality in rural Ireland through control of chemical usage, soil testing, and waste storage regulation;
- REPS had contributed to an increase in production of renewable energy from agriculture and forestry, making a small contribution to emissions abatement;
- There was little evidence to suggest that the scheme had contributed to any increase in biodiversity and other initiatives would be required, including more training.
- Focus had been on quantity of feature delivered (such as area of hedgerow) rather than the quality of that feature.

The last academic synthesis on Irish agri-environment schemes was conducted during 2009-2010 and published in 2012. This study (hereafter the "REPS Review") was titled "*A review of evidence on the environmental impact of Ireland's Rural Environment Protection Scheme (REPS)*" and was a thorough and exhaustive review of the subject matter (Finn & Ó hUallacháin 2012). It assessed a full range of published and some unpublished information covering material produced up to 2010.

On an overall basis Finn and Ó hUallacháin were unable to draw any firm conclusions about the environmental effectiveness of REPS. The reasons for this were given as follows.

- There were a lack of studies at a sufficient spatial and temporal scale to provide an effective evaluation of the national-level and long term impacts of REPS.
- Despite a large number of biodiversity studies, there was little coordination in the objectives, methods, and scales used. As such, it was not possible to synthesise the individual findings into an aggregate meta-analysis.
- Although the available evidence points to REPS having beneficial effects on nutrient management and water quality, relatively few studies had actually assessed this topic.
- Although not stated in their conclusion, a position on GHG emissions could not be drawn due to the lack of a national level sample.
- Much of the evidence available was not published in peer-reviewed journals

At best, conclusions could only be drawn about specific aspects of certain REPS measures in certain geographies only, in particular on "core" measures that had been part of REPS since inception. These will be discussed in more detail in the next section. By contrast, many of the supplementary measures and options introduced from REPS3 onwards lacked empirical studies on environmental effectiveness.

Finn and Ó hUallacháin also raised a series of important points around the impact of future scheme design and funding on environmental effectiveness. At the time, little was known about the impact of REPS on farmer behaviour, and they raised the following questions:

- Will the conditions of re-entry to a new scheme with limited budget and restrictive participation, successfully target the farms offering the greatest environmental benefit?

[3] The previous evaluation requirements for RDPs were set out in Council Regulation (EC) No. 1698/2005 which has, *inter alia*, established a Common Monitoring and Evaluation Framework (CMEF) in view of guiding Member States towards a more effective system for assessing progress towards Community and national objectives, ensuring the accountability of public spending through RDPs, and improving programme performance.

- For farmers who no longer participate in an agri-environment scheme, to what extent will they retain elements of farming practice that were learned in REPS and go beyond the requirements of cross-compliance?
- What will be the fate of environmental benefits that have been gained?
- Will the management of farmland habitats change, and what will the consequences be for habitat quality and biodiversity?

3.4 The need for this study

In the REPS Review, the principle criticism was the lack of a long-term, national scale evaluation of agri-environment measures. A specification for what this evaluation might look like for REPS was devised (Finn 2010) has informed the GLAS evaluation project under the monitoring and evaluation programme for the RDP 2014-2020. A key recommendation was that the design and evaluation of new agri-environment measures should be evidence-led and informed by research carried out in Ireland and elsewhere. The REPS Review brought together and analysed that information up to 2010, but work carried out subsequently has not as yet been synthesised. As such, there is a need for an updated exercise to inform this particular project, other evaluations and ultimately subsequent policy design.

4 Scope

4.1 Overall aim

The overall objective is to prepare a detailed literature review and synthesis of research on agri-environment measures in Ireland to include: relevant published and unpublished work; any preliminary results from current research projects; consideration of any relevant planned research, including LIFE projects or other relevant research projects; any relevant national reports or available data on biodiversity, climate, and water quality.

As the history of agri-environment schemes in Ireland goes back to 1994, this review could potentially capture a very large quantity of material. In order for it to become more focussed and relevant to the evaluation of the GLAS, the aim has been refined as follows.

- The desire for a broad synthesis will be respected, but the state of the evaluation of Irish agri-environment schemes as provided in the REPS Review (covering the period up to 2010) will be used as a "baseline". This literature review will then focus on material produced subsequent to that document.
- It will assess material according to a similar analytical framework, with a relatively high-level approach.
- It will also seek to establish the extent to which points raised in the REPS review have been addressed in the subsequent literature, and to what extent the new information can inform subsequent stages of GLAS evaluation, and future agri-environment scheme design.
- Other schemes outside the previous RDPs that are in effect agri-environment measures will be in scope, in particular the BFCP and the FPS. However, organic farming measures will not be evaluated.
- Although the focus will be on Republic of Ireland schemes, literature on similar measures applied in comparable geographies (e.g. UK) and broad studies at EU level will also be considered as evidence.

4.2 Specific objectives

Within each section of the analytical framework we will ask specific questions. Most of these are derived from the points raised in the REPS Review, but others have also been suggested as result of discussions within the project team, with DAFM, and with external stakeholders that occurred during the information gathering phase of this review.

Specific questions will be asked as follows:

- In what way does the literature change or confirm the previous understanding of the measure(s) in question?
- Does the literature help address any of the issues raised in the REPS Review or formal evaluations?
    - Do the papers provide adequate spatial and temporal information, and do they use consistent methodologies?
    - What do they indicate about farmer behaviour such as uptake, participation, and attitude (including those exiting schemes and not re-entering)?
    - Have the results been published in peer-reviewed journals?
- What are the implications for the evaluation of GLAS?
- What are the implications for future agri-environment measure design?

-

5 Method

To avoid bias within the literature review and ensure an efficient assessment within the specified timescales a "Rapid Evidence Assessment" (REA) approach was taken. REAs use the principles of systematic reviews to search and critically appraise existing research on a topic area. They are rigorous and explicit in their approach but limit certain aspects of a full Systematic Review in order to comply with a shorter timeframe (Miler et al. 2013).

As the main objective of this assessment was to build on literature assessed in the REPS Review, the first step of the assessment was to thoroughly review this document and establish a "baseline" 2011 position on each of the thematic sub-topics.

- Gaseous emissions / Climate Change[4]
- Nutrient management
- Designated farmland biodiversity
- Non-designated farmland biodiversity
- Other environmental objectives
- Multiple environmental objectives
- Socioeconomics

New material was then sourced as follows:

- Peer-reviewed journal articles and publically available grey literature were identified by means of targeted queries of search engines and databases including Web of Science™, Science Direct, JSTOR, Google Scholar and Google. Searches were initially carried out using two keywords "Agri-environment AND Ireland" with a published date of 2010 onwards[5]. The first 100 results were extracted and analysed. Literature which was clearly not relevant to the study topic was marked as RED and discarded, as were papers already identified in the Finn & Ó hUallacháin paper; other documents were added to a Mendeley[6] database.
- The process was then repeated with alternative search terms "Agri-environment AND Irish", "REPS AND Ireland"; "AEOS AND Ireland", "REPS AND Irish"; "AEOS AND Irish". Duplicate entries already captured in previous searches were removed, as were other RED-marked articles. The remaining documents were added to the database.
- Further grey literature was obtained from an exhaustive search of the Teagasc, EPA, NPWS, and DAFM websites, and by inspecting the websites of national organisations operating in the fields of farming and conservation such as the Irish Farmers' Association, The Environment Pillar and its constituent bodies (e.g. Birdwatch Ireland, An Taisce), the Sustainable Water Network Ireland, Climate Ireland, Climate Action Ireland Platform, Heritage Council, Geological Survey of Ireland, the Tree Council of Ireland, Herpetological Society of Ireland and Butterflies of Ireland. Where possible, these were investigated using the websites own search facilities and the keywords mentioned above.

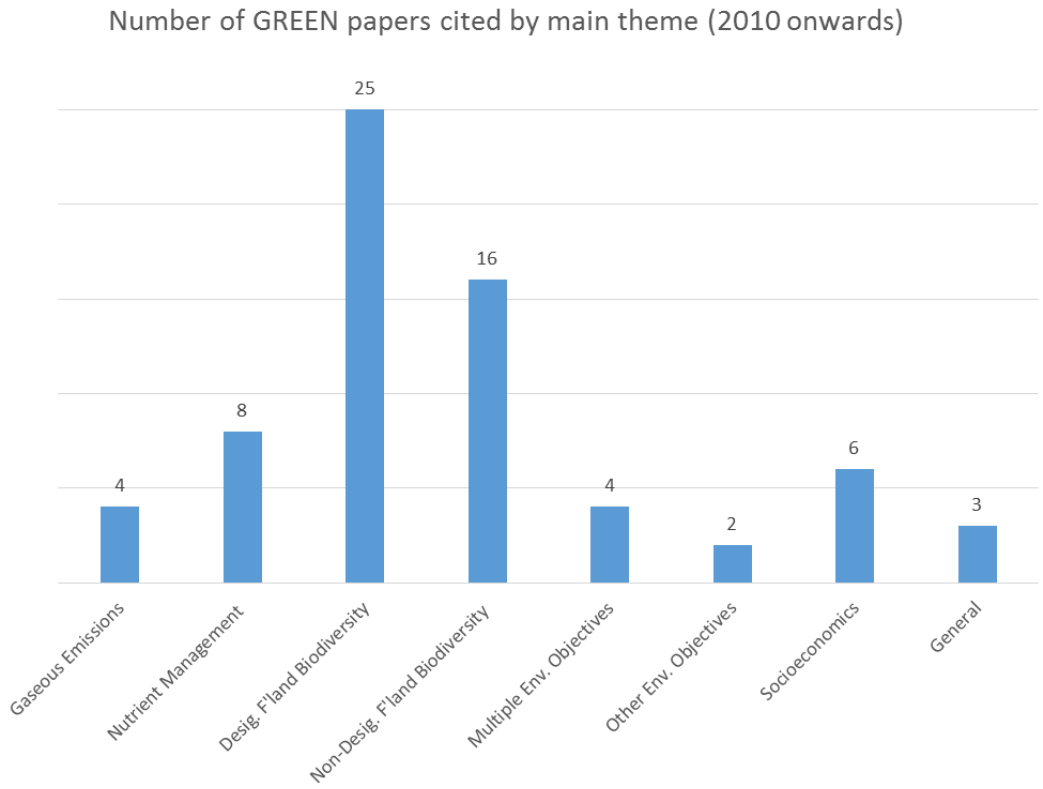
[4] The REPS Review only considered Gaseous Emissions. This literature search looked at climate change more broadly, including adaptation and resilience aspects as well as mitigation.
[5] Although the Finn & Ó hUallacháin study was published in 2012, their literature search was actually completed in 2009. As such the date range of this review was extended to include 2010.
[6] https://www.mendeley.com/

- Information about unpublished or other material was obtained by attending the Teagasc Agri-Environment Conference 2015 and through semi-structured interviews with personnel from government departments, agencies, universities, farm bodies, and environmental NGOs. The interviewees were chosen either because they were members of the RDP Monitoring Committee, or because they had been identified as a key author in the literature search, or because they had been recommended by DAFM or another interviewee. A number of additional articles were also suggested by ADAS's own internal reviewers.
- The review also considered submissions made by the above bodies and the general public to the three consultation stages of the 2014-2020 RDP formulation (Scoping, Draft RDP and Draft SEA).

Material which had passed the RED filter was then categorised as GREEN or YELLOW. Papers falling into the GREEN category were ones whose abstracts seemed entirely relevant. Those falling into the YELLOW category were ones where it was not possible at first inspection to decide and where a second opinion was necessary. The YELLOW list was then reviewed by other members of the project team who re-categorised as RED, GREEN or BLUE. The latter category (BLUE) represented material with indirect relevance that could provide some contextual information that would assist the evaluation.

Information in the GREEN and BLUE sections of the database were then extracted to an Excel spreadsheet where papers were then read in full to identify which particular sub-topical sections they would inform. Of the total of 84 GREEN papers identified in the initial review, 68 of these were deemed to be entirely relevant and have been included in this paper. A total of 123 BLUE papers were identified in the initial search, of which 50 have been cited in this paper because they provide useful context from other countries or other research themes.

Information on the thematic breakdown of GREEN papers identified is presented in the chart below. The majority of directly relevant papers address biodiversity themes. The majority of the literature on designated biodiversity relates to Irish schemes outside the RDP. However, much of the literature on other topics is directly relevant to REPS or AEOS.



6 REPS and AEOS

The literature assessed by Finn and Ó hUallacháin was broken down into a set of thematic topics linked to the environmental objectives of the REPS scheme and other relevant matters, including: nutrient management, gaseous emissions, archaeology, designated farmland habitats, non-designated farmland habitats (including field margins and hedgerows), multiple environmental objectives, financial effects, and others. The main findings of their review are summarised by theme below, accompanied with descriptions of subsequent research on REPS identified in the literature search. The section on gaseous emissions has been expanded to include any literature addressing REPS broader relationship with climate change, in particular whether any evidence could be found to demonstrate improved resilience across Irish landscapes.

The previous review pre-dated the AEOS scheme. However, as it was a much smaller and shorter-lasting scheme and as such it has not been the subject of very much research. As such, the few studies that have considered AEOS have also been included here.

6.1 Gaseous Emissions / Climate Change

The broad evidence base for impacts of extensification on net greenhouse gas (GHG) emissions is rather uncertain (Horrocks et al. 2014). Nevertheless, the previous review of REPS identified some evidence from life cycle assessments that emissions from dairy and suckler beef farms in the REPS scheme were lower than non-REPS farms (Casey & Holden 2005; Casey & Holden 2006). However, the sample set in both studies cited was too small to be considered representative at a national level. Indeed Finn and Ó hUallacháin stress the need for a study which consider effects on emissions broken down into a more granular farm typology that would be more reflective of the diversity in Irish agriculture, and with a sufficient statistical sample that it could be extrapolated to provide national level figures.

This does not appear to have occurred in the intervening years, at least not in the context of agri-environment schemes. Instead there have been efforts to better understand the carbon footprints of individual management actions and land uses, some of which have featured in previous or currently active agri-environment schemes. Much of this work has been carried out by Teagasc's working group on GHG emissions and has been driven by the agricultural intensification set out in Food Harvest 2020 and the implications this has had for Ireland's net GHG trajectory (Donnellan et al. 2014).

A major output from this has been the production of marginal abatement cost curves (MACC) which seek to quantify measures that could be implemented to abate emissions from agriculture to 2020 to develop (Schulte et al. 2012). Ten measures were selected in the first phase of the study, of which four have featured in past or current Irish agri-environment schemes: Manure Management, Other gains in nitrogen efficiency, Minimum tillage techniques, and Use of cover crops. "Manure management" considered a scenario where trailing shoe technology was adopted instead of bandspreader with total abatement potential to 2020 of 0.041 Mt CO_2e (using IPCC methodology) or 0.065 Mt CO_2e (using a global Life-Cycle Analysis approach). "Other gains in nitrogen efficiency" included use of clover, nutrient management planning, and changes to timing/application of fertiliser with a total abatement potential of 0.08 MtCO_2e (IPCC) or 0.065 Mt CO_2e (Global LCA). "Minimum tillage" had a total abatement potential of -0.02 MtCO_2e (IPCC) or 0.148 Mt CO_2e (Global LCA), whilst "Cover Crops" were 0.08 MtCO_2e (IPCC) and 0.24 Mt CO_2e (Global LCA). The lower values of the IPCC methodology reflected only the abatement that could be recognised in Ireland's GHG accounts, either because the benefits were realised in another country, or because (in the case of min tillage and cover crops) Ireland's accounting methodology could not include changes in soil organic carbon.

Interpreting these results in the context of Irish agri-environment schemes is challenging as it is not clear to what extent the measures evaluated in the MACC study exactly reflect how these approaches have been implemented in REPS or AEOS. Nevertheless they do provide a useful comparison between approaches, as well as an idea of the relative cost-efficiency. The manure management, min tillage, and cover crops are all at the far end of the MACC curve meaning that they cost money to implement, and may not necessarily be net cost-beneficial based on the traded price of carbon. By contrast the nitrogen efficiency measures save farmers money, and as such there is no net cost making them hard to justify in terms of EU rules for Pillar II funding (Murphy et al. 2015). Indeed, this may explain why clover swards, which were previously a supplementary measure in REPS4, have not been included within GLAS.

That being said, at the time of its inclusion in REPS, there was still some uncertainty as to the effectiveness of white clover (Metz et al. 2007). A subsequent study at Teagasc's Solohead Research Farm in County Tipperary has shown that N_2O emissions in clover-based systems are much lower (20-23%) than in conventional fertilised nitrogen systems and also indicated that emissions due to biological fixation should not be included as an N_2O source in IPCC methodology (Li et al. 2011; Humphreys 2012). A further phase of the study looked at carbon footprints of 18 Irish dairy farms employing different management tactics. A few of these farms which had employed effective management of clover swards were able to reduce emissions, though required greater land use to produce milk (Yan et al. 2013).

One piece of work on arable systems has investigated the impact of minimum tillage, straw incorporation, and the use of winter cover crops on GHG emissions and soil organic carbon, as compared to conventional inversion ploughing (Lanigan 2012). The research, carried out at Teagasc's Oak Park Research Station in County Carlow included a life-cycle analysis up to the farm gate and found that all three strategies reduced emissions, but some were more effective than others. Minimum tillage reduced emissions (measured in kg CO_2e kg^{-1} grain) by approximately 9% mainly through reduction in fuel use, whilst straw incorporation and cover crops reduced by 30% and 37% respectively, mainly by reducing soil organic carbon loss. Combining the minimum tillage and cover crop methods was the most effective approach with a reduction in emissions of over 50%. Combining all three was less effective (47%) as higher N_2O emissions offset other benefits.

An EPA funded report by FERS Ltd investigated carbon sequestration by hedgerows, non-forest woodland and scrub at a study site in Frenchpark, County Roscommon (Black et al. 2014). A LIDAR technique was used to estimate the biomass of these features in the study area. The potential for biomass gains assuming no management was estimated, and from there an annual above-ground carbon sequestration figure was inferred using a model. The results suggested a mean sequestration potential of 0.66 t CO_2 ha^{-1} yr^{-1} for the study area for the hedgerows, and 2.4 t CO_2 ha^{-1} yr^{-1} for the woodland and scrub features. The authors acknowledged that the biomass growth figures would need to be ground-truthed, and recognised that the hedgerow numbers in particular may be overstated, especially as they do not allow for losses due to ongoing management (cutting and removal). Using the range of sequestration potential estimated in their study, and allowing for management losses, the authors then estimate that the increase in hedgerow and non-forest woodland between 2000 and 2007, much of which was incentivised by REPS. Net sequestration was between 3,087.02 and 17,465.94 t CO_2 over the period.

Extended grazing was one of the scenarios considered in the Irish MACC study and was an increase to the season by 21 days was estimated to have a mitigation potential of 0.264 Mt CO_2e. However, a recent study of the Irish dairy sector indicated that those who had participated in REPS were 24% less likely to adopt this approach (O'Shea et al. 2015). This finding is not exactly surprising, as the priorities of REPS have been primarily water quality and ecology, both of which can be compromised by extended grazing. This finding does not necessarily mean that REPS may have underperformed its potential in terms of

GHG abatement. However, it does serve to illustrate that where trade-offs exist between different environmental priorities it will not always be possible for agri-environment schemes to meet all needs.

The focus of research into REPS and AEOS measures has focussed on how they have helped abate GHG emissions or to mitigate them through additional sequestration. However, the response of the agricultural sector is broader than this and also includes production of renewable energy. Incentives to grow bioenergy crops and to produce renewable energy have been provided in the current and previous RDP as well as in the Forestry Programme. As these were not funded under explicit agri-environment measures (REPS or AEOS) their efficacy has not been evaluated in this review.

Studies from other countries, such as the UK, have demonstrated that many agri-environment measures also have the potential to provide adaptation to the adverse effects of climate change, in particular flood risk management (Wilkinson et al. 2010; Firbank et al. 2013). Reduced stocking densities can reduce runoff from fields through better soil infiltration capacity; whilst vegetated buffer strips, tree shelterbelts and hedgerows can trap, retain or slow down flows (Posthumus et al. 2008). However, this facet has not been a primary focus of past agri-environment schemes and has generally been addressed through catchment-specific project work (Posthumus & Morris 2010).

Climate change adaptation does not appear to have been a focus of research into previous Irish agri-environment schemes, and was not considered in the evaluation framework of the REPS Review and the Mid-Term Evaluation of the 2007-2013 RDP. This does not mean that the considerable quantity of field margins, buffer strips, and hedgerows created under REPS and any reduction in stocking density it achieved have not had a positive effect in terms of building landscape resilience. However, no evidence is available on which to provide an informed opinion, and drawing inferences from other geographical contexts is inappropriate given that spatial location of these is a critical factor in determining their effectiveness. Given that climate change adaptation is a cross-cutting objective in the current RDP 2014-2020, and many of the GLAS actions are expected to contribute, it is an area that may warrant further investigation.

6.2 Nutrient Management

Pre-2010 studies included two investigations of National Farm Survey (NFS) data to either directly calculate or indirectly estimate the extent to which REPS participation reduced chemical use in Irish farms over a number of years (McEvoy 1999; Hynes et al. 2008). Both studies showed reductions against the counterfactual, with the more recent study estimating that REPS resulted in an annual decrease of 29 kg $ha^{-1}yr^{-1}$ in nitrogen and 8.3 kg $ha^{-1}yr^{-1}$ in phosphorus.

These findings have been corroborated by a recent economic regression study at the EU level which sought to see if there was any relationship between agri-environment spending between 2001 and 2009 and the reduction in the nitrogen surplus over a similar time period (Reinhard & Linderhof 2015). The findings do indicate a significant negative relationship between agri-environment spending and nitrogen surplus, suggesting that such schemes are having a desired effect. The effects are most pronounced where countries started with a higher nitrogen surplus, as was the case with Ireland. However, the study also noted that agri-environment expenditure was less effective at reducing nitrogen surplus in countries which went through a period of agricultural expansion over the time period considered.

Finn and Ó hUallacháin called for more work to investigate whether nutrient input reduction from REPS was actually having an effect on water quality itself. However, the timescale on which measures to improve water quality take effect can be quite long, and can vary considerably depending on local catchment circumstances (Fenton et al. 2009). Indeed, decades may need to pass before high phosphorus and nitrate levels in soils and groundwater reduce to acceptable levels (Shortle 2014;

Horrocks et al. 2014). With REPS having run since 1994, some longitudinal studies at farm level have assessed whether the reductions in nitrogen and phosphorus usage are having the desired effect. The results of these studies are encouraging and reveal a significant decrease in nitrate leaching levels between REPS (losses of less than 20 kg $ha^{-1}yr^{-1}$) and intensive beef suckler systems (losses exceeding 50 kg $ha^{-1}yr^{-1}$) studied, with little consequence for overall animal performance (Richards et al. 2015; Drennan & McGee 2009). Another study has looked at sediment cores from Namachree Lough, County Monaghan, as a way of establishing historical water quality conditions (O'Dwyer et al. 2013). This has revealed that the lake was previously eutrophic but that phosphorus enrichment began to decline in the 2000's. The authors note the uptake of REPS participation in the catchment (from 6% in 1995 to 48% in 2010) as a possible influence, but the study's methodology is not able to test this hypothesis.

However, another longitudinal study focussed on Lough Sheelin did not find that the decrease in phosphorus loading observed in the catchment between 1990 and 2008 translated to an equivalent decrease in the actual concentrations observed in the lake over the same period (Greene et al. 2014). This non-correspondence was linked to an external factor, the presence of the invasive zebra mussel in the lake, which increased the amount of phosphorus being released from the lake's sediment and offset the reduced external loading. This does not of course imply that nutrient reduction activity was ineffective, but simply illustrates that there are ecological limitations to what can be achieved through reductions of agricultural loadings alone.

The evidence for the uptake and implementation of REPS nutrient management measures was less encouraging. An extensive study of the Lough Melvin catchment showed lower than expected participation rates in REPS as a whole; and of those participating, none had taken up the supplementary measure for riparian zones (Doody et al. 2009). The same project also found that REPS did not offer the two most cost-effectiveness and popular measures for farmers in the catchment to reduce phosphorus loading (feeding of concentrates with low phosphorus concentration, and non-replacement of phosphorus on Index 4 silage areas). Although nutrient management planning and advice (available in REPS) did also prove popular and cost-effective, there was evidence that farmers were not receiving adequate levels of support at the implementation stage (Schulte et al. 2009). The development of an online tool for nutrient management planning to assist farmers and advisors participating in GLAS is therefore seen a positive development (Murphy 2015). However, it is important that advice also reflects guidance on timing of nutrient application: a recent study in Wales has attributed local eutrophication events not to over-application of nutrients, but rather to poor timing of application where farmers had not made use of appropriate decision-making tools (Gibbons et al. 2014).

Subsequent to 2010, there literature search found relatively little research on the nutrient management implications of REPS or AEOS. In part this may simply reflect that the REPS scheme closed in 2009 and nutrient management planning did not feature as a requirement of the AEOS scheme. However, it may also reflect the shift in focus of nutrient management towards mandatory measures implemented by the Irish Government under the NAP (EPA 2015a). As such there has been a greater research focus on assessing the effectiveness of these measures (Baily et al. 2011; Huebsch et al. 2013). In addition, a multi-million euro research project called the Agricultural Catchments Programme (ACP) was set up by DAFM and run by Teagasc to evaluate the effectiveness of these measures (Teagasc 2013).

Although not focussed on agri-environment schemes, much of the research carried out under the ACP has nonetheless been of relevance to their study and development. Many of factors identified as relevant to the evaluation of the NAP measures would apply equally to the assessment of agri-environment schemes, such as: the source to impact concept, catchment scale and selection, nutrient source and mobilisation potential, nutrient delivery, nutrient transport pathways, nutrient impacts, and socioeconomic factors (Wall et al. 2011). The ACP has also revealed the greater importance of

mobilisation and hydrological transfer potential as contributing factors to delivery of phosphorus into receiving watercourses, as compared to source risk, something which is not currently reflected in agri-environment or NAP policy (Jordan et al. 2012). Other ACP work has also shed light on the role that surface ditches or streams play in phosphorus transfer, and has suggested periodic removal of fine sediment and maintenance of channel bank vegetation as management solutions (Shore et al. 2015). The ACP has also investigated how critical source areas in Ireland could be identified with a longer view of developing better targeted agri-environment measures (Doody et al. 2012; Thomas et al. 2015).

Both NAP and agri-environment measures have been in place over the past few years, so it is valid to ask to what extent each is contributing to improvements in water quality. Recent work in Italy has indicated that reductions in inorganic nitrogen use are more strongly associated with constraints arising from the Nitrates Directive (presence of a Nitrate Vulnerable Zone) than they are with agri-environment measures (Marconi et al. 2015). However, an equivalent study does not appear to have taken place in Ireland. There has been work on the effectiveness of Ireland's Good Agricultural Practice (GAP) regulations with respect to phosphorus balance and use efficiency, which found significant improvements in performance on 21 intensive Irish dairy farms with up to a 74% decrease in phosphorus surplus on a per hectare basis and a 48% increase in use efficiency relative to the pre-GAP period (Mihailescu et al. 2014). These reductions were primarily attributed to lower stocking ratios, lower chemical fertiliser application to land, and changes in the timing of organic fertiliser application. In this study, 17 of the 21 farms surveyed were participating in the REPS scheme and limitations on stocking ratio and nutrient management plans were already part of the REPS provisions. However, the study does not establish whether the REPS measures were in some way influencing these results.

With nutrient management a more explicit objective within GLAS, research has begun to focus on elements of this scheme which go above and beyond the cross-compliance and legal minima. A recently commissioned project entitled "Cattle Exclusion from Watercourses: Environmental and Socio-economic implications" (COSAINT) seeks to assess the environmental effect of and farmer attitudes towards measures intended to restrict cattle access to watercourses (O'Callaghan et al. 2015). These featured in REPS and AEOS with incentives for fencing to prevent animal access, as well as incentives to provide alternative sources of drinking water away from the watercourse (e.g. water troughs and associated piping). GLAS also includes an explicit measure to install a fence at least 1.5m from the watercourse to exclude bovines, which is mandatory for high status or vulnerable water sites (outside of commonages). Riparian margin measures also require the installation of fencing to protect the area. Until now, little was known in a RoI context about the efficacy of these approaches in terms of reducing faecal coliform count, nutrient and sediment input, and temperature effects. Work elsewhere suggests that such measures can be effective at reducing sediment input as long as cattle are completely excluded (Evans et al. 2006; Collins et al. 2010), but only have a very small impact on overall faecal indicator organism loads from farms (ADAS 2011). It is hoped that the COSAINT project will shed further light on this topic and thus inform future RDP development.

6.3 Designated Farmland Biodiversity

REPS provided additional funding for farmers in designated areas (SPA, SAC, NHA, and commonages) through "Measure A". Despite this, very few studies could be found which have actually investigated the direct impact on designated features of the management changes proposed in agri-environment schemes. The REPS Review was only able to identify three studies which explicitly investigated linkage between REPS participation and designated habitats. These include two survey studies of REPS and non-REPS control farms: management changes did occur in turlough and commonage areas (fertiliser reduction, lower stocking density, shorter grazing periods, cessation in silage cutting) that could be

inferred to have a beneficial effect on the habitat (Moran et al. 2008; Van Rensburg et al. 2009). However, it is not possible to confirm if these measures were making any actual difference to the conservation status of the designated feature. Moreover, the other study indicated little attitudinal difference between REPS and non-REPS farmers towards the value of the turloughs, suggesting that the farmers taking part in the scheme were doing so primarily to benefit from the financial incentive (Visser et al. 2007).

A study commissioned by the EPA to investigate the state of peatland management, utilisation and conservation in Ireland ("BOGLAND") has suggested that lower stocking densities encouraged by REPS may have somewhat addressed the issue of overgrazing as a threat to these habitats, though not to the most severely degraded sites (Renou-Wilson et al. 2011). However, the authors also point out that the sustainable stocking density for sheep grazing can be highly dependent on the specific vegetation composition and its seasonal dynamics, and therefore management plans must assess and accommodate this. Another issue raised in this report is whether farmers in REPS or other schemes will continue to remain in them, or whether economic incentives from peat cutting will encourage them to leave.

Subsequent to this there appear to be few studies assessing the linkage between REPS and designated biodiversity. Only one study could be identified: this considered the management practice and attitude of 80 farmers in the Iveragh Peninsula, County Kerry, a region containing a large proportion of SAC and commonage (O'Rourke et al. 2012). The majority of farmers surveyed were participating in REPS, but very few indicated that REPS had had any material effect on how they managed their land. This does not necessarily mean that REPS was ineffective, as it may have led to implicit changes in behaviour that the farmers had not noticed and which were not investigated in the study.

Another interesting observation from this paper was the wide range of farmer attitudes and management practices and the bearing this had on adoption of the most suitable grazing intensity and pattern to suit the ecological needs of the SAC. Only 40% of farmers could be described as "environmental stewards", a group that showed the strongest commitment to ecologically sustainable farm practice and reported the lowest incidence of scrub encroachment and overgrazing. The others were categorised as those farming mainly for the subsidies, those with a traditional farming outlook, and those with more commercial objectives. These groups were all associated with less desirable grazing regimes and scrub outcomes. This suggests that the effectiveness of the scheme on biodiversity may actually depend on the motivational and attitudinal type of the farms involved, and indeed the authors conclude that a more targeted bottom-up approach to agri-environment schemes which reflects these differences could be more effective than the non-targeted approach.

No studies could be identified which have investigated the effects of REPS measures specifically on individual protected species. This may of course simply reflect that prior to the RDP 2014-2020, most of the voluntary incentives offered to farmers to manage land explicitly for certain species have been funded outside the scope of Pillar II. The evidence base underpinning the effectiveness of these schemes, which include the NPWS Grant Schemes, the NPWS Farm Plan Scheme, the BFCP, and other EU LIFE programmes will be assessed in the next section. This evidence also includes work on the corncrake within these other schemes, and may have some implications for REPS and AEOS, which did have a measure targeting this bird.

6.4 Non-Designated Farmland Biodiversity

Non-designated biodiversity was an important aspect of the REPS programme with many core measures having a direct or indirect relevance. Because the previous review found a lot more studies in this

section than any other, they broke down the analysis into papers that assessed more general aspects, and papers that covered the effectiveness of field margin and field boundary measures. A critique of all the work was that a diversity of methods had been used which made it difficult to synthesise an overall conclusion. This section will briefly summarise the work from the previous review, and update it with subsequent studies addressing general, field margin, and field boundary features in turn.

6.4.1 General

A number of researchers had studied the presence or absence of wildlife habitats on farms as required in the core REPS specification. Earlier studies show relatively low numbers of habitats/farm (approx. 1.6) in REPS with many farms (40-70%) showing none at all (Curtin & Whelan 1998; Clarke 1998; DAF 1999). Later studies of REPS farms show much higher numbers (over 2.5 habitats/farm) and very few absences (less than 10%) recorded (Gabbett & Finn 2005; Sullivan et al. 2011). It is not clear if this temporal difference reflects an actual improvement in the REPS programme over time or is simply reflective of non-standard methodology of habitat type definition in the earlier papers.

When studies actually assessed whether REPS participation was having an effect on farmland biodiversity, the evidence was not strong. The Ag-Biota project found REPS participation not to be significantly associated with many farmland biodiversity descriptors, with the exception of field margins (Purvis, Anderson, et al. 2009). Meanwhile, the Farmland Birds Project also found no significant difference in bird diversity or abundance between REPS and non-REPS farms, though it did identify a greater density of hedgerow and a greater number of other habitats in REPS farms (Copland & O'Halloran 2010). Indeed, a synthesis of expert opinion on REPS4 concluded that several of the measures would have little or no benefit to biodiversity (Carlin et al. 2010).

Subsequent work investigated the link between REPS and farmland biodiversity as measured by abundance and richness of indicator farmland birds comprising both designated and non-designated species (McMahon, Sheridan, et al. 2013). The study covered 120 farms across three distinct geographic regions of the country and involved the collection of primary data on bird presence and abundance from field surveys during the winter and breeding seasons over two annual cycles. The results showed no significant difference in indicator values collected at REPS farms versus non-REPS farms. Whilst this is not encouraging in terms of its effect on biodiversity, the authors acknowledged that it is hard to draw any firm conclusions about REPS effectiveness due to the lack of baseline data from the pre-REPS period. An interesting finding from the study was that general bird numbers were actually higher on more nutrient intensive farms (i.e. dairy), though this was not true of endangered species such as skylark (McMahon, Carnus, et al. 2013). The implications from this work are that agri-environment measures design may need to differ depending on whether the objectives are to enhance designated or non-designated biodiversity, and should also be reflective of the nutrient intensity of the receiving farm system.

New information is also known about the impact of REPS on habitat diversity. Surveys were undertaken of 50 farms in southeast Ireland to collect information on habitats, watercourses, and field boundaries, which were subsequently digitised to calculate area. The information was then regressed against a series of variables including REPS participation (Sheridan et al. 2011). The habitat composition of the REPS farms was quantifiably different from the non-participants which was attributed in part to the higher proportion of field boundary present. The regression also revealed a lower proportion of intensively managed grassland habitat on REPS farms though it is not clear if this difference was statistically significant. However, as information was not available on the habitat composition of farms prior to the establishment of REPS, the study was unable to make a fully objective assessment of its impact.

As the REPS specification evolved from the first to the fourth iteration, the complexity of the scheme increased. From REPS3 onwards a suite of supplementary measures were added, many of which were aimed at addressing biodiversity issues not specifically addressed in the core 11 requirements. Farmers were obliged to take up at least two of these as part of their management plan[7]. Although some restrictions were made in terms of the choice, farmers still had considerable flexibility as to which options they were allowed to select. An interesting study looked at the link between the expected choices made by farmers subscribing to REPS4 and the likely ecological benefit that these combinations would achieve (Murphy et al. 2011). The expected choices for REPS4 were inferred from the 2007 NFS data which included information about the choices they had made in REPS3. The ecological effects were established based on the habitat of each participating farm and expert opinion on the impact of each particular option. The results suggest that farmers with wetland and reclaimed peatland habitats were likely to choose suitable options for their land, but those with peatland and marginal grassland were more likely to choose an unsuitable option (*set aside*) as opposed to the more suitable *maintain and enhance grazing areas* option.

In one of the very few studies to consider AEOS, the management options "Species Rich Grassland", "Traditional Hay Meadow" and "Species Rich Grassland in Natura 2000" were trialled by the researchers on 20 sites each at drystock farms in the Irish Midlands to assess effect on species richness (Ó hUallacháin et al. 2015). Greatest species richness was recorded in the Natura 2000 trial fields and least in the Traditional Hay Meadow. The species compositions relating to each management option were also assessed, with the Natura 2000 swards being generally considered to be diverse and indicative of semi-natural habitat. However, the other two regimes did not generally yield vegetation of a high nature value, suggesting that improvements could be made to the design or targeting of these measures. Another conclusion might be that simply more time may be required to assess the measure - restoration of these habitats can take up to 20 years (Smith et al. 2008).

6.4.2 Field Margins

Field margins were a specific focus of the REPS scheme, and the creation of them as a consequence was expected to lead to greater farmland biodiversity. However, the link between field margins as created in REPS and species biodiversity was not borne out at the time of the previous REPS review, with no evidence of increase in species richness or abundance (Feehan et al. 2005; Sheridan et al. 2009). The reason suggested for this was the management prescription for grassland field margins set out in REPS (cessation of nutrient inputs) was insufficient to promote plant and insect diversity – reseeding with grass and wildflower mixes and reasonable sward height are also necessary (Sheridan et al. 2008; Fritch et al. 2011).

Another possible reason could simply be the need for a longer period of time to allow fertility to decline. Indeed, the apparent poor performance of REPS field margins noted in the REPS Review is surprising in the context of general research on non-productive areas (Batáry et al. 2015). However, subsequent research on grassland field margins in Ireland does now suggest they can still be effective. A study investigated arthropod biodiversity in margins given different treatments: fencing only, rotovation, and reseeding with a grass/wildflower mix (Anderson et al. 2013). A primary finding was that taxon richness and abundance was greater in the protected margins than the grazed areas of the field itself irrespective of management regime. The finding that fencing alone can be effective does run contrary to the earlier research on REPS. However, this study did note that fencing alone had a lower magnitude of effect on taxon richness and abundance than the rotovated and reseeded treatments.

[7] This increased to three in the case of Nitrates Derogation farmers from REPS4 onwards.

The earlier Irish findings regarding arable field margins are also somewhat contrary to results found in England where the creation of a 4-6m grassy margin under the Entry Level Stewardship (ELS) specification did lead to higher invertebrate abundances (Hof & Bright 2010). This has subsequently been corroborated by a study of five fields across central and southeast Ireland that found higher earthworm abundance, biomass, and species richness in grassy margins than in the adjacent fields (Roarty & Schmidt 2013). The difference between this result and the earlier findings may of course reflect the focus on below-ground biodiversity, rather than above-ground features.

A PhD study established a typology of field margin types within Northern Ireland with some showing greater plant diversity than others. However, all were found to have less species richness than most semi-natural grasslands (Spratt 2012). The four categories developed reflect the dominant vegetation composition observed from the author's fieldwork and compare with certain UK National Vegetation Classification types and also with Irish grassland classifications. The author also set out a management regime that may be of relevance to future agri-environment scheme design. This includes a generic approach for all four types, which was broadly reflective of existing UK and Ireland field margin specifications and academic knowledge. On top of this are some specific management requirements for each field margin group in her typology. The highest biodiversity group (1) would require only reduction of inputs to the main field and controlled grazing as further management. In addition to these, the intermediate biodiversity group (2) would also require retention of ditches and encouragement of wet habitat plant species. The lowest biodiversity groups (3 and 4) would also require hedgerow maintenance to prevent scrub encroachment and shading out of ground flora as well as the introduction of seed mixtures.

A study carried out in County Wexford investigated the effectiveness of riparian margin measures as specified in REPS and AEOS in terms of their benefit to small mammal populations (Ó hUallacháin & Madden 2011). Margins were categorised as grassy, scrubby, or woody depending on the dominant vegetation type and revealed interesting findings in terms of abundance and diversity found in each category. Although woody margins had the highest abundances, this was almost entirely accounted for by one species alone (wood mouse) with 98%. In contrast, grassy margins at least contained material proportions of pygmy shrew (19%) and house mouse (3%), as well as the wood mouse (78%). The implications of this distinction are important as they imply that woody margins would be more effective if the objective of an agri-environment measure was to provide prey for other target animals, whilst grassy margins would be more effective if the objective was to target the pygmy shrew (protected under the Irish Wildlife Act).

6.4.3 Field Boundaries

Schemes which include field boundaries are generally associated with broad biodiversity benefits (Batáry et al. 2015). However, at the time of the review there was no published study investigating the biodiversity value of the REPS field boundary features, and thus no judgement could be made on their effectiveness in Ireland specifically. This omission has been addressed to an extent by a survey of 286km of features across six sites in County Galway (Sullivan et al. 2013). Field boundary density was high (exceeding 200m ha^{-1} on most farms) but the quality of features was lacking: 68.5% of the hedgerows surveyed were not species rich and 44.2% were not in favourable condition for wildlife. This echoes the "quantity over quality" criticism raised in the mid-term review, but it would be instructive to understand what factors were inhibiting the development of species richness and favourable condition in the REPS prescription. Recent studies of the English ELS scheme point to the need for an appropriate cutting regime, with less frequent hedgerow cuts (every 2-3yrs) improving invertebrate abundance over the annual cycle prescribed in the agri-environment measure (Facey et al. 2014).

The authors also point out the diversity of field boundaries, with the average farm having four different features (hedgerow, drainage ditch, stone wall, treeline, earth bank or wire fencing). Yet Irish agri-environment management prescriptions for field boundaries are limited to hedgerows and stone walls, despite evidence that drainage ditches can be important for biodiversity (van Dijk et al. 2013). A greater focus on ditches in agri-environment specifications would also be welcome in the context of water quality: channel management regimes that can promote nutrient attenuation such as periodic removal of sediment and vegetation may not necessarily correspond with ecological needs and would need to be confined to summer months only (Shore et al. 2015).

6.5 Other Environmental Objectives

REPS had a particular focus on archaeology, with a core measure (Measure 7) requiring the establishment and maintenance of buffer strips around historic environment features. As a consequence, the evidence suggests that the scheme did have a positive effect, with a study finding that no features on the Sites and Monuments Record and recorded in REPS plans were destroyed compared to a background destruction rate of 1.3% over the same period (Sullivan 2006).

Landscape protection was an explicit environmental objective within REPS, and many of the measures in it would be recognised as mechanisms for improving or preserving landscape character (e.g. dry stonewalls, visual appearance of farmyard/farm buildings, orchards, tree planting, farm woodland). The review did not discuss this facet of environment effectiveness in any detail, but did identify a series of papers by the Teagasc Rural Economy Research Centre which evaluate the public response to this, both in terms of attitude and economic benefit. These indicate generally positive public opinion towards landscape improvements that have occurred as result of the REPS scheme (Campbell et al. 2006). However, criticism has been made of the incoherent approach to the manner in which “landscape” is defined in REPS documentation (Whelan et al. 2010). Although references to landscape became more common and expansive in successive REPS schemes, the documentation would have benefited from a more coherent set of landscape category definitions accompanied by a set of specific landscape undertakings linked to distinct character of each of the landscapes covered by the scheme. This would have given better and more locally specific guidance to farmers and planners and would have therefore strengthened the quality of the local landscape character developed.

6.6 Multiple Environmental Objectives

Two studies identified in the previous review in particular deal with multiple objectives. Both were funded under the EU’s Research and Innovation 6th Framework Programme (FP6). The first of these “Integrated Tools to design and implement Agro Environmental Schemes” (ITAES) used a multi-criteria approach based to develop indicators for performance across different objectives, and score measures accordingly (Finn et al. 2007). Due to the lack of quantitative data, the scoring was largely done using expert opinion. The overall assessment suggested that REPS would have contributed to improvements in nutrient management and water quality, but effects on farmland biodiversity would have been more mixed.

The second FP6 project led to the development of the “Agri-environment Footprint Index” (AFI), a tool designed to assess farm performance against agri-environmental objectives on a common 0-10 indicator scale (Purvis, Louwagie, et al. 2009). The index itself is comprised of a number of sub-indicators which were customised to the Irish context using a multi-criteria approach based on stakeholder judgements. A small sample of farms in Sligo, Leitrim, Cork, and Tipperary were assessed with a particular focus on organic nutrient management, organic nutrient storage, biodiversity value, and landscape value. Mean

scores on REPS farms significantly higher than non-REPS (Finn et al. 2010; Louwagie et al. 2012). Improved performance on the AFI for agri-environment participants was noted across all thirteen national case studies in the EU were the AFI was trialled, with significant differences noted in ten cases (Mauchline et al. 2012). The AFI was never applied to perform a complete assessment of REPS or AEOS at a national scale. However, some of the sub-indicators developed such as change in gross nutrient balance and farmland bird species population did subsequently feature in the mid-term evaluation of the RDP 2007-2013.

The literature search could not find any studies subsequent to this that have explicitly considered multiple objectives. Indeed a criticism of REPS schemes is that they were never subjected to the process of Strategic Environmental Assessment (SEA), which would have taken this multi-faceted approach (Whelan & Fry 2010). It is not possible to objectively say what impact this omission has had on scheme design, though a key point is that the SEA process would have mandated a monitoring regime, a critique echoed in the previous review of REPS. This omission has been rectified in the development of the RDP 2014-2020 with an SEA taking place.

6.7 Socioeconomics

The REPS Review was mainly focused on environmental effectiveness, so studies investigating socioeconomic factors such impact on farm incomes or farmer attitude towards the scheme were not examined explicitly. However, the review did recognise the importance that REPS income plays to farmers overall, and to particular farming groups. REPS farms represented 45% of the national total and these farms earned on average 15.5% higher incomes than non-REPS farms, with cattle and sheep farms in REPS being particularly dependent on this income source (Connolly et al. 2009).

A subsequent study has used NFS data to establish the relationship between farm socioeconomic variables and REPS participation throughout all four iterations of the scheme (Murphy, Hynes, et al. 2014). The key findings were that REPS farmers tended to have lower incomes (not including REPS payments), work longer hours, and have higher productivity levels than their non-REPS equivalents. In addition, REPS farmers were more likely to be young and married. The change in demographics and farm type over the duration of the four phases largely reflects the relative payment levels offered, with the most common farm size grouping reflecting the most generous per hectare payment rate. External variables also played a part, with participation in REPS2 attributed to the need for additional income support and uncertainty caused by the foot-and-mouth outbreak. Participation in earlier iterations of the scheme was also strongly linked to continued participation in later schemes. This may simply reflect the fact that much of the REPS structure remained similar across the years, but may also reflect that high levels of trust had built up in the scheme (IFA 2014). These findings are broadly representative of other Member States' agri-environment schemes as studied in a recently published qualitative meta-analysis of work across the EU (Lastra-Bravo et al. 2015).

The same NFS study also revealed that restrictions on organic nitrogen had a material effect on participating farm typology with intensive farmers being less likely to be in the scheme during the first three phases. Only when the 170 $kgha^{-1}$ limit was removed at the REPS4 stage do the data suggest an increased participation from intensive farms. The authors suggest that an opportunity for REPS to have had an earlier impact on nutrient loading at REPS3 may have been missed. This bias towards less intensive farms has also been reflected in a study of all EU agri-environment schemes, especially where committed per hectare premiums are low (Zimmermann & Britz 2016). However, the removal of the limit on organic nitrogen at the REPS4 stage was criticised by the Irish Cattle and Sheep Farmers Association (ICSA) as having diluted the overall funding available to cattle and sheep farmers whose livelihoods were more dependent on agri-environment scheme income (ICSA 2013).

Other analysis of the NFS dataset has looked more closely at what variables drove the decision-making to enter the REPS scheme (Murphy, Donoghue, et al. 2014). The participation model associated with non-viable farmers was very different from the one associated with viable farmers because they have different fundamental motivations. The former group are more likely to be engaged in farming as a way of life than for the purpose of maximising returns, and thus respond differently to the incentives offered. Being a non-targeted scheme with fixed per hectare payments, REPS design therefore could not reflect their different opportunity costs. The authors suggest it could potentially be improved through a reverse auction mechanism where farmers would bid at their minimum opportunity cost, thus allowing the scheme operator to distribute payments according to value for money. Evidence from modelling work suggests that this may be an effective way of maximising the environmental benefit and cost effectiveness of an agri-environment scheme, though there are a number of associated practical and structural challenges (ADAS et al. 2015). The NFS study also found soil type and region were linked to participation preference, though these variables are strongly associated with incomes and viability of the core farming business.

Another study looked more explicitly at Irish dairy farms to get a better understanding of their decision-making process when it came to REPS participation (Vollenweider et al. 2011). The results suggest that participation in REPS by intensive farmers is used as a risk management tool. The study also concludes that the attractiveness of REPS depends greatly on its ability to smooth income over time. On average, a 1% increase in a farmer's relative risk premium increased his probability to join REPS by 0.4%. The authors also suggest that reforms to the Pillar I of the Common Agricultural Policy (CAP) were likely to increase farmers' exposure to risk and hence a positive dynamic would establish in terms of the uptake of the voluntary agri-environmental scheme of Pillar II.

Only one attitudinal study on REPS participation could be identified. One example cited earlier on the Iveragh peninsula (O'Rourke et al. 2012) does break down farmers into similar groups (environmental stewards, traditionalists, productivists, and support optimisers). Although all farmers reported REPS participation having no or little impact on their actual management approach, the study does not explicitly ask what would happen in the absence of the scheme. Nor does it explore whether REPS participation has had any impact on their attitudinal typology.

The REPS review also did not consider the societal benefits (i.e. "ecosystem services") of the REPS scheme. This may have been because the concept was still relatively new in an Irish context at the time of the review. As such, there were relatively few papers evaluating this aspect, and consequentially it did not feature within the review's analytical framework. Nevertheless some work was done pre-2010 to assess the societal value of certain environmental benefits of REPS using stated preference ("willingness to pay") methods. One paper suggests that the monetary value of the landscape benefits alone of the REPS1 and REPS2 schemes exceeded €150 million, almost 80% of the total public expenditure (Campbell et al. 2006). Another study found in aggregate that farmers would be willing to allocate a far greater amount of their budget (over €1.5 million yr^{-1}) on corncrake conservation in Ireland compared to the actual amount of public expenditure (€264,530 yr^{-1}) for this measure in REPS (Hynes & Hanley 2009). Interestingly, this study also shows that REPS farmers are willing to allocate a larger budget than non-REPS farmers, suggesting a greater empathy with corncrake conservation.

The ACP has also carried out socioeconomic studies which are of relevance to agri-environment scheme design. One paper has assessed farmers' willingness to adopt 10m riparian buffers in the context of the funding needed to persuade them to proceed (Buckley et al. 2012). The result indicates that the average farmer would require €1.51 $m^{-1}yr^{-1}$ to go ahead with the measure, though this figure would be higher for specialist dairy and lower for sheep farms. The study compares the result to the funding available in AEOS of €0.74 $m^{-1}yr^{-1}$ for a 10.5m wide strip and concludes that this may explain the undersubscription

of this measure within the scheme. This emphasises again the problems of adverse selection in Member State agri-environment scheme design and its need for mitigation (Fraser 2009).

Another ACP study looks at nutrient management best practice adoption on farms within the ACP catchments against control sites outside (Buckley et al. 2015). The work was commissioned to understand reasons for lower than expected uptake rates, and sought to understand if there was a link between this and farmer attitude. Questionnaire analysis revealed four distinct groups in the sample population representing those with different motivation for farming, and found that this was strongly related to uptake. Farmers with stewardship, environmental conservation, or productivist objectives are more likely to adopt best practice (though perhaps for different reasons), whilst those who view human needs as being more important are less likely to do so. Uptake of the options was also more likely for younger farmers and those who have an advisor.

Socioeconomic research on agri-environment measures outside Ireland could also be of relevance to this review. A major study of "entry-level" EU agri-environment schemes has come to the following conclusions regarding factors which influence uptake (Keenleyside et al. 2011). The 10 case studies investigated do not include Ireland, but the REPS scheme could be considered in many ways to be representative of the other entry-level schemes. Better levels of uptake were associated with requirements that fit well with the existing farming system, targeted towards less productive areas of the farm, synergised well with other farm objectives such as soil protection, and where the absence of payments would otherwise risk abandonment due to lack of economic viability. Poorer levels of uptake were associated with lack of capacity or technical knowledge, concerns about the effect of the scheme on yields, insufficient payment rates (especially on small farms), lack of institutional capacity and problems with processing of applications or payment.

Structured interviews carried out in Wales on the uptake of the Tir Gofal scheme has found that farmers with stewardship motivations were generally agreement holders whilst those with productivist motivations were all outside the scheme (Ingram et al. 2013). The outcomes of the interviews are interesting in the context of the Irish research above. The majority of Tir Gofal participants confirmed that their decision to be in the scheme reflected an opportunity to support an approach to farming that made less demands on their resources and time, though some also saw it as a risk management solution to stabilise incomes especially during periods of uncertainty. Meanwhile non-intensive farmers that chose not to participate were older farmers whose children were not ready to manage the land in that way. The interviews with commercial farmers (all outside the scheme) also revealed long term motivations for the farm to continue to produce food and generate income through subsequent generations, and therefore indicate a low desire to participate in subsequent schemes in their current guise. The observations of scheme participants with respect to succession planning are interesting, as this is generally associated with lower uptake at an EU level (Lastra-Bravo et al. 2015).

6.8 Overall Evaluation

The REPS Review raised the issue of a lack of studies at a sufficient spatial and temporal scale to provide an effective evaluation of the national-level and long term impacts of REPS. There is now more information known about longer term effects on nutrient balance, but certainly not at national level. More work has also been done on some of the biodiversity issues and has raised some pertinent points around the design of certain measures such as traditional hay meadows, species rich grassland, field margins, and field boundaries. However, the studies identified have been carried out at relatively localised scales. In addition they do not appear to have addressed the effects on designated features, although the general picture is that non-targeted schemes like REPS may not be best suited to that purpose. More information is certainly known about the emissions profile of certain measures, but no

study was identified which scales those up to infer an overall impact for the entire scheme. No studies could be found that provide evidence of a climate adaptation benefit, although this has been demonstrated in UK schemes. On a more positive note, much of the work which Finn and Ó hUallacháin cited in their review as preliminary findings has now been published in peer-reviewed journals.

Knowledge of socioeconomic factors driving participation at national scale has certainly improved, in particular in terms of the balance of uptake of REPS between more and less intensive farmers, in relation to the premiums offered. However, the farmer dynamics surrounding AEOS uptake do not appear to have been investigated, meaning that the likely environmental implications of the switch from broad based to more restricted schemes with tighter budgets can only be inferred. These implications for this will be discussed below.

None of the new studies identified in this review of REPS or AEOS have been able to address one of the key issues raised in the original review, namely the lack of initial and ongoing monitoring data against which to establish a baseline and counterfactual. However, this issue is not unique to Ireland: an assessment of the cost-effectiveness of biodiversity conservation programmes in Scotland suggests that there is a need to focus not only on improving the cost-effectiveness of biodiversity conservation programmes, but also to improve the robustness of cost-effectiveness assessments, in terms of data availability and accuracy and improved monitoring of the outcomes of interventions (Austin et al. 2015). The European Court of Auditors' report on the EU agri-environment support echoed the same message that the Common Monitoring and Evaluation Framework (CMEF) produces little information on the environmental benefits achieved (ECA 2013).

7 Other Agri-Environment Schemes and Research Themes

This section will investigate research and evaluation into *de facto* agri-environment schemes where public funds outside the scope of the RDP were channelled towards areas with biodiversity designations to assist farmers to meet the very specific and localised challenges. Many of these schemes have been the subject of research or have indeed begun their life as research initiatives. In addition it will consider other research that has either directly informed the development of novel measures in GLAS, or will inform the development of the next generation of agri-environment schemes.

7.1 The Burren Measures

The impacts of farm practice on biodiversity of the BFCP have been extensively examined. Undergrazing and hazel scrub encroachment were identified as two main threats to habitat quality and a considerable programme of works was put in place to address these issues (Parr et al. 2009). There is evidence to suggest that these issues were dealt with successfully during the Burren LIFE phase (Walsh 2009). Improvement in biodiversity has continued to be observed and this has continued to be the case during the BFCP phase: the proportion of fields scoring 7 or less has consistently decreased whilst the proportion scoring 8 or more has consistently increased, meaning that average payments to farmers have correspondingly increased (BLP 2015). A key point to note here is the development of a simple monitoring and scoring method that has enabled performance to be easily monitored.

A report has considered the cost efficiency of the scheme (McGurn & Moran 2013). This identifies public administration costs at 12% of total costs comparing favourably to the EU average of 15% for agri-environment schemes. This report also makes some explicit comparisons of with REPS suggesting the Burren's greater environmental output was being delivered at a relative cost saving of €8.3 million. The cost efficiency has also been the subject of an independent, peer-reviewed paper that constructed a theoretical model to assess the environmental value for money of the scheme (Kelley et al. 2013). The results suggest a conservative estimate of annual public good delivered by the scheme of €2.3 million as compared to the annual direct and indirect costs of €1.4 million. Interestingly the cost of implementing the measures for three quarters of the farms exceeds the actual payment received. The model also simulated changes in REPS and BFCP funding rates, and found that the former was more effective at maintaining the number of agricultural producers but that the latter was more effective at delivering environmental goods. This comparison should be taken with some caution, as the scale of both schemes are very different, and it does not necessarily mean that the Burren model would be as effective if it had to be delivered across the entire country .

Nevertheless, the scheme receives consistent praise from all aspects of the farming and environmental communities as a role model example of what an agri-environment scheme should look like (IFA 2014; An Taisce 2014) and has received awards as a consequence. This can been attributed in part to its bottom-up and results-orientated approach which has cemented strong and trusting relationships between farmers and management agencies. However, it also reflects a considerable time investment – the original research to derive the first management prescription for the LIFE programme began in the late 1990s.

7.2 Other EU LIFE Projects

Initial results from KerryLIFE presented so far only include the characterisation of the project area and the species population status (Phelan et al. 2015). However, future work will consider sediment transfer and flux in the catchments and will use source apportionment techniques to identify and evaluate likely root causes such as overgrazing (O'Neill et al. 2015).

One of the interesting outcomes of the Duhallow LIFE project was that it became apparent that the scale of catchment management required on the River Allow exceeded the scope of the LIFE funding, and it was necessary to combine efforts with a separately funded catchment management project. By forming this partnership the project was able to operate at a larger scale and engage more effectively with multiple stakeholders. Although the project has been successful in terms of completing the management prescriptions, it is not clear yet from the limited reports that are publically available to what extent farm-directed actions have been effective at improving conservation status or water quality (IRD Duhallow Ltd 2011; Igoe et al. 2015).

Initial results from AranLIFE include a characterisation of the vegetation types present within the SACs to classify them according to how representative they are of the ideal habitat. This has yielded five distinct groups rated I to V in descending order of quality which would also reflect the proposed "payment by results" approach with highest payment going to farmers delivering group I habitat (Browne et al. 2015). In a similar way to the Burren LIFE programme, the AranLIFE researchers have also investigated the forage quality of the semi-natural grasslands to identify differences in nutrient availability of the various plant communities over the annual cycle. The information gathered will inform what annual grazing pattern would be required to maintain livestock production viability, and will help develop a regime that is compatible with habitat and economic needs (Duignan et al. 2015).

7.3 NPWS Schemes

One of the birds targeted in the FPS was the corncrake, though it has also been the subject of a long-running Species Action Plan to stimulate its recovery in Ireland which has also included measures in REPS, AEOS, and a separate Corncrake Grant Scheme also established by NPWS (DEHLG & EHS 2005). The targets of this Plan were to maintain the existing number and range of corncrakes in Ireland, to maintain the population in three core areas above 2003 levels and to increase the population in these sites by 2010. Targets were also set to establish new populations at Rathlin Island by 2010 and in other suitable areas of the RoI and Northern Ireland by 2015. However, after a decade of effort, none of these targets have actually been met and a new Framework for Corncrake Conservation to 2022 has been established with GLAS at its core (NPWS 2015a). The failure has not been attributed to the inadequacy of the corncrake measures in previous agri-environment schemes. Indeed, the populations in Donegal and West Connacht have increased, and the overall targets might have been met if climatic events outside the schemes' control had not compromised the viability of the Shannon Callows SPA (O'Donoghue & Bleasdale 2015).

Work to improve the status of the chough focussed on the Seven Heads SPA in County Cork. The FPS set out certain prescriptions for land management aimed at improving habitat quality, with flexibility given to farm planners on the exact grazing and silage regimes used as well as capital works undertaken. During the period that the FPS was in place, the breeding productivity of chough surveyed at the increased from 1.08 young per attempt in 2008 to 2.50 young per attempt in 2014 (O'Donoghue et al. 2015). The authors do acknowledge that the low productivity at inception may also have been reflective of weather condition. The report makes no mention of any increase in recorded population at expected locations though it does mention that the birds were regularly seen using the fields included within the

FPS. The report also revealed some interesting attitudinal findings: farmers showed a positive change in attitude towards the chough and the effect of the SPA designation on farming practice from inception to maturity. In addition, all the farmers concerned agreed that a flexible results-based approach was a good idea, and indeed most suggested improvements they could deliver which would further improve habitat quality.

In the 10 years prior to GLAS, support for breeding waders was delivered through the voluntary NPWS Breeding Wader Grant Scheme. An area of particular focus for this was the Shannon Callows which contain nationally significant proportions of Ireland's redshank, lapwing, snipe, and curlew populations. Since 2006 BirdWatch Ireland have been running a research project to study the birds' ecology *in situ*, with findings from the project informing the development of management options (Birdwatch Ireland 2016).

Outside the Republic of Ireland there have been studies of the effectiveness of other agri-environment schemes with respect to breeding waders. A 5 year study of features targeting lapwing and other breeding waders in agri-environment schemes in England, Wales, and Northern Ireland has made some interesting findings that may be of relevance to the Irish schemes (Smart et al. 2013). The UK measures did have a positive impact on habitat suitability and made some improvement breeding productivity, but did not manage to achieve any significant change in the population trend when compared to land outside the scheme. The authors attribute this to the effects of predation from crows and foxes, and also the need for general improvements to habitat delivery that were not adequately addressed in the scheme.

The FPS for the hen harrier was the most popular NPWS schemes, with 378 plans approved and over €13 million distributed. The exact regime used varied from farm to farm, but the overall prescription aimed to provide suitable nest sites and improve the value of the farm as a foraging location (DEHLG 2010). These two core objectives have been taken through to the GLAS hen harrier specification. Knowledge gained from the NPWS's research into the bird and from schemes elsewhere will add value to scheme design (SNH 2003; O'Donoghue 2011; O'Donoghue et al. 2011). For example, in terms of minimum grazing intensity, the previous FPS recommendation of 0.6 LU ha^{-1} has been revised to allow for less intensive regimes (0.15 – 0.60 LU ha^{-1} on specific plots[8]). Research in the Netherlands in an arable setting has shown that it is possible to encourage the abundance and accessibility of prey for the Montagu's harrier whilst maintaining some agricultural productivity using alternating strips of set aside and alfalfa (Schlaich et al. 2015). A similar approach with a different crop is currently being trialled in the Slieve Blooms with hen harriers[9].

The focus of the FPS and GLAS is mainly on the breeding season, and NPWS has acknowledged that a more holistic approach to hen harrier conservation is necessary (NPWS 2014b). Bird mortality is particular high in Ireland, and there is a need for prescriptions for predator control during the summer to protect nests, and for habitat actions over the winter to give younger birds a better chance of survival. From a broader perspective, forestry and wind farms can also present challenges for the hen harrier (Bleasdale & O'Donoghue 2015). However, restrictions on these activities in hen harrier SPAs limit the scope of funding and income available to landowners. With this in mind a new measure for hen harrier is being developed under the Locally Led Agri-Environment Scheme component of the RDP 2014-2020.

NPWS is currently involved in a number of projects with potential implications for future agri-environment scheme design, in particular those which will focus on protected habitats and species.

[8] Barry O'Donoghue (NPWS), *pers comm*.
[9] Barry O'Donoghue (NPWS), *pers comm*

Habitat focussed work includes a project testing hay meadow cutting regimes in the Shannon Callows to promote species richness and reduce the spread of undesirable vegetation (Owens et al. 2015). Initial results suggest the most effective method is to strew green hay as well as cutting meadows twice in the same summer, though the additional strewing will add an additional €175 ha^{-1} cost so it may only be worthwhile in the most species poor areas of the Callows.

Other Annex I work driven by NPWS includes a project in County Kerry to investigate impacts on vegetation and macro-invertebrate composition of experimental cattle-grazing regimes with the aim of identifying an appropriate prescription to optimise both biodiversity and cattle productivity in these habitats (Kelly et al. 2015). Species focussed work includes a project to gain a better understanding of population dynamics, breeding locations, and pressures affecting the curlew with the aim of devising a more targeted conservation effort (O'Donoghue 2015). The spatial data collected as part of this project has already informed the targeting of the curlew measure within GLAS towards appropriate farmers.

7.4 Other Designated Species Research

Grey partridge is another bird where GLAS introduces a specific measure for the first time. The design of this scheme has been informed by the Irish Grey Partridge Conservation Project which represents over a decade of research in Boora, County Offaly by The Irish Grey Partridge Conservation Trust (IGCPT) (NPWS 2015b). Key components of the management regimes tested and developed include provision of habitat (nesting cover, insect rich foraging resource, and winter cover crops), as well as predator control (avoiding placing habitat near tree lines which harbour crows and magpies) (IGPCT 2016).

Suggested management regimes for twite have been developed by NPWS based on a review of previous evidence (McLoughlin 2011). This included a number of suggestions for management of nesting areas, conservation actions for foraging during the breeding season, and measures which could be put in place to provide winter foraging resources. The author stresses that a number of the suggestions had not at the time being subject to thorough monitoring to judge effectiveness, and that this needed to be addressed. There was particular need for work on breeding biology and winter ecology.

Bats have been targeted in Irish agri-environment schemes though explicit measures (bat boxes) and also through generic measures which can potentially provide foraging resources (field margins, hedgerows, riparian margins, and species-rich grasslands). However, there has not been any explicit study of the effectiveness of these measures on Irish bat populations. The evidence from Scottish agri-environment schemes suggests that these measures do not necessarily have a positive impact on bat activity and prey abundance, and that bats instead would benefit more from landscape-scale changes, in particular the provision of a better woodland resource (Fuentes-Montemayor et al. 2011).

The impact of field boundaries have also been investigated in the context of badger ecology in Ireland. An area near Dublin consisting mainly of pasture interspersed with arable tracts and very little woodland cover was studied over a 4 year period. The study found the majority of badger foraging activity occurred in close proximity to field boundaries (mainly hedgerows) and there was also a clear preference for sett location and latrines within hedgerows than elsewhere (O'Brien et al. 2015). The concentration around these features was attributed to the lack of woodland resource in the particular landscape investigated. Although badgers are not specifically targeted within any agri-environment scheme, given the relationship between the species and bovine tuberculosis, the findings are potentially of relevance to scheme design.

With agri-environment measures becoming increasingly targeted towards the needs of certain protected species and habitats, there is a growing body of research investigating the effects of these measures on wider biodiversity. With a limited history of these measures in the Irish agri-environment

context, there is no explicit evidence base to evaluate. However, research has taken place to evaluate broader effects of targeted management regimes in England (Countryside Stewardship Scheme and Higher Level Stewardship) for stone curlew and cirl bunting. The fallow plots within the tillage system designed for the stone curlew did lead to higher abundance and species richness of other birds, brown hares, vascular plants, butterflies and bumblebees in comparison to conventionally managed fields; however, the management regime had no impact on carabid beetles (MacDonald, Maniakowski, et al. 2012). The low-input arable and pasture systems designed for the cirl bunting by contrast had less wide ranging effects: only carabid beetles abundance and species richness responded to the arable treatment, whilst the low input pasture system only increased plant species richness and butterfly abundance (MacDonald, Cobbold, et al. 2012).

7.5 HNV farmland

A criticism raised of previous agri-environment measures was that they did not sufficiently address the need to identify and conserve high nature value (HNV) farmed environments. Indeed this is a stated priority of the RDP 2014-2020. Part of the challenge in achieving this is that there are no specified rules or quantified criteria at EU level for defining what constitutes HNV farmland, and Member States themselves are responsible for the interpretation and application of the concept (EFNCP 2016). Since 2013 the Ideal-HNV project has been running in Ireland to help address the challenge of identifying these areas. The objectives are to estimate national distribution, trial remote sensing methods to identify HNV areas at farm scale, develop tools to assist on-farm assessment, profile the socioeconomic characteristic of farming systems and identify threats to HNV farmland (Ideal-HNV 2013).

Work has been underway for the past two years to develop methodologies to characterise and identify HNV farmland. The Ideal-HNV team have investigated ways to characterise areas of potential HNV farmland at national scale, and have also explored approaches to categorising farms into different HNV types. At a national scale, characterisation has been developed using 5 indicators representing extent of semi-natural land cover class, stocking density, percentage hedgerow cover, length of river and stream, and soil diversity. Scores for each indicator could range from 0-1, and weights were assigned at 40%, 30%, 10%, 10%, and 10% respectively. Mapping involved digitising indicator information into a 2km^2 raster grid of the country, performing a normalisation and weighted sum approach to score each cell on a 0-5 scale where higher values indicate a greater probability of finding HNV farmland. The output map shows the highest scoring areas associated with upland and commonage areas towards the west and north of Ireland (Matin et al. 2015). This result is not surprising given the greater proportion of semi-natural land cover and lower stocking densities associated with these areas. Overall estimates of HNV farmland area for Ireland range from 1.15 to 1.25 million ha or 20-25% of the utilisable agricultural area (McGurn & Moran 2013).

However, this national scale map output does not actually distinguish between HNV farmland types. A more precise differentiation of Irish HNV farmland has been developed using key HNV variables (semi-natural land cover, stocking density and hedgerow cover) but augmented by field surveys of 102 sample farms to derive further variables including farm management, landscape, and biodiversity (Sullivan et al. 2015). Principal Component Analysis (PCA) was then used to identify clusters of similar farms from which a typology of 6 groups could be established. Four of these groups would definitely meet “whole” HNV farmland criteria, covering mainly commonage areas but also larger non-commonage upland farms in the Burren, Donegal, Connemara, Waterford and Wicklow. The two other groups would meet “partial” HNV farmland criteria, representing areas of high semi-natural habitat in otherwise more intensively farmed areas, or farms with lower semi-natural habitat in areas otherwise important for biodiversity such as the Shannon Callows. A similar approach has also been developed for use at a finer

scale to differentiate farms within a region according to their environmental setting. When applied to a sample of 58 farms in Sligo, Mayo and Leitrim, 4 groups were identified from the PCA which were differentiated based on extent of semi-natural habitat, stocking density, species richness, and linear-habitat coverage (Boyle, Gormally, et al. 2015). Both typologies are relevant in order to inform design of future Irish agri-environment measures, but could also be used to evaluate the effectiveness of the general biodiversity objectives and the impact of targeted actions within GLAS.

At farm-level, the Ideal-HNV project has also designed a method to assign a quantitative score to farms of a similar typology against a "nature value index". An example has been developed for pasture farms in the Atlantic region and produces a score on a 10 point scale based on proportion of improved grassland, stocking density, and linear habitat density (Boyle, Hayes, et al. 2015). The scoring approach may seem somewhat simplistic, but the correlations between index value and habitat diversity, plant species richness, and plant diversity (Shannon Diversity Index) actually measured on the sample farms were all strongly positive. As such, this could be used as an easily measurable, rapid indicator of current farm status and performance. The index would have obvious use in the selection and evaluation of farms participating in agri-environment schemes, but would also help individual farmers with their own land management planning and decision-making process.

7.6 Results-based schemes

The emergence of the ecosystem services concept has provided a broader framework against which result-based schemes can be formulated and evaluated. A call has therefore been made for such an approach to be incorporated within future agri-environment scheme design, though there are a number of issues that must be overcome: scientific uncertainty, timing of payments, increased risk to land managers, compliance with EU and WTO regulations, as well as getting schemes to operate effectively across landowner boundaries (Reed et al. 2014).

A blueprint for how to incorporate a results-based approach into future agri-environment scheme design has been produced, including potential costings (McGurn & Moran 2013). The proposal has drawn from the experience with the BFCP and has a two-tiered structure. Tier 1 would cover standard management options previously available in AEOS such as field boundaries, field margins, riparian margins, wild bird cover which go above and beyond Pillar I management requirements and would be applicable to all areas of the farm. It would be compensated in a comparable way to AEOS or REPS with fixed payments based on the prescription. Tier 2 would only apply to areas of Natura 2000 and HNV farmland, with different regimes being developed for heath/uplands, semi-natural pasture, and designated species. The payment to areas of Tier 2 would be results-based reflecting performance against an initial and final habitat assessment, using an easily understood 0-10 scoring scale.

Given the significant overlap between areas of commonage and Natura 2000 or HNV farmland, the authors also propose that commonage land be subject to an outcome based approach, but with a different procedural approach to reflect the collective ownership structure. This proposal is also backed by the findings of a series of case studies carried out to gather information on existing commonage framework plans, though the authors acknowledge that this is a longer term objective and not an immediate reality (Monaghan et al. 2014).

The RBAPS project co-funded by the EC and the Irish Government has recently begun to trial how a results-based scheme could work in two contrasting regions (The Shannon Callows SAC/SPA and

undesignated lowland areas of Country Leitrim)[10]. From a designated biodiversity perspective, there will be a clear interest in the work delivered in the Shannon Callows in particular for breeding waders. However, the Leitrim project will also target the Marsh fritillary butterfly which is protected under the Habitats Directive. Both projects will use a set of indicators representing habitat quality as the basis on which farmers are judged and remunerated. The indicators for the Shannon Callows will be based on vegetation structure, condition of chick rearing areas, and extent of predator habitat. The indicators for marsh fritillary in Leitrim will be based on availability of its food (Maher et al. 2015).

There is strong evidence that the general public are willing to pay for marginal improvements in water quality in Irish waters, in particular to achieve good levels of water clarity and smell (Doherty et al. 2014). However, developing a results-based scheme for water-quality is challenging due to the complexity of source apportionment, and the effect of external factors beyond the farmer's control such as weather patterns and invasive species.

Work is ongoing to try to overcome some of these issues. One study has used a GIS approach to optimise the potential spatial distribution of agri-environment measures to reduce phosphorus loading in the Lough Melvin catchment (Gonbour et al. 2015). The optimisation is done with a hydrological model and a Bayesian Belief Network that links the probable reductions in phosphorus in any given part of the catchment with the monetary value of the resultant improved water quality as derived from increased salmon numbers in the spawning grounds. Preliminary findings suggest that the same effectiveness in terms of salmon spawning can be achieved with a highly targeted approach where agri-environment measures are concentrated on certain critical source areas where results are more likely to be realised. Indeed many fields within the catchment that might qualify for a conventional non-targeted agri-environment scheme turn out to be hydrologically unconnected to the spawning grounds. As such it is suggesting that action-based payments for water quality might not be actually cost-effective solutions to address the problem, though of course this they may well be achieving other objectives such as non-aquatic ecology and GHG abatement. It is also not clear from the study report if the modelling takes into consideration storm events, which are known to be more closely linked with diffuse nutrient loading from agriculture (Thompson et al. 2012; Davis et al. 2015). Nevertheless, knowledge about the connectivity of critical source areas in Irish catchments is becoming clearer and can even now be applied at the sub-field scale to identify the optimum location for a given measure, raising the prospect of future interventions becoming increasingly precise and cost-effective (Thomas et al. 2015).

[10] The project is also being delivered in partnership with Gestión Ambiental de Navarra and includes in pilot in the Navarra region of Spain. See rbaps.eu for further details.

8 Implications of the Literature Assessed

8.1 Does the literature change or confirm previous understanding of Irish agri-environment schemes?

The overall perspective on presented in the REPS review and the mid-term evaluation was that the programme had been generally positive for water quality and GHG abatement, and had improved awareness of environmental issues within the farming community. The impact on biodiversity was more mixed: a considerable quantity of habitat was created but the quality of this had not yet reached a level where material increases in species richness were being observed. The REPS Review also highlighted a number of important gaps in the knowledge base on Irish agri-environment schemes. These include the lack of national level and long-term studies to evaluate the scheme's effectiveness, in particular for GHG emissions and water quality. The lack of counterfactuals and consistent methodologies had also made it hard to evaluate the true outcome of the scheme, especially for biodiversity. Furthermore, relatively little was known in 2010 about farmer motivations for entry or exit into schemes or individual measures.

The literature assessed in this review from life cycle assessment and field studies have shed more light on the likely GHG abatement potential of certain measures such as minimum tillage, cover crops, white clover, and hedgerow creation. These do support the view that REPS and AEOS would have had a positive effect on GHG abatement, but as they have not been assessed in a national context it is difficult to interpret how material this change would actually be.

Evidence from long term nutrient leaching studies on REPS that has subsequently been published also corroborates the position that the scheme was not just resulting in less nutrient input, but was also having a knock-on improvement on leaching. However, other work has also highlighted the complexity of translating on-farm measures into actual nutrient levels observed in water bodies. Extraneous factors such as invasive species and storm events need to be factored into scheme design and evaluation. REPS has also been criticised for not providing the most cost-effective or popular nutrient abatement options, and for providing adequate levels of support to farmers in their application, which may have hindered its effectiveness. It is also not clear to what extent improvements in water quality are attributable to REPS explicitly, as opposed to mandatory actions required by farmers under the Nitrates Directive.

There has been little in the way of new research to add to the understanding of REPS or AEOS effect on designated biodiversity, except possibly in terms of the lower stocking density helping less damaged peatlands. Research efforts have instead concentrated on developing new and more targeted "bottom-up" schemes to address this issue. There was already strong evidence that the one of these schemes (the Burren) was having a positive effect on the habitat quality, and this has been further confirmed by the last five years of the project reports. Information is also available about the outcomes of certain aspects of the FPS, in particular the corncrake and chough measures, with generally positive results. Evidence has also been presented to suggest effectiveness of past grey partridge and twite conservation work, though there would still appear to some gaps in the knowledge base. There is limited knowledge available on the environmental effectiveness of farm measures related to the KerryLIFE and DuhallowLIFE schemes. However, as both schemes have ecological objectives that are directly linked to water quality, it may be some time before there is data to inform effectiveness, especially as the KerryLIFE project is still in progress.

The picture is still the same with wider indicators of biodiversity. Recent work generally corroborates the previous view that REPS measures delivered a considerable quantity of habitat or feature, but that they would have benefitted from more attention to delivering a higher quality, which would have been

able to influence key indicators such as species richness. A similar conclusion can also be extended to the hedgerow measures under REPS, whose effectiveness has now been investigated. However, improving measure design is only part of the challenge: an important new finding is that there was that the optional biodiversity undertaking measures farmers actually took up were not the most optimal ones for the habitat type.

Despite this, there is now evidence to suggest that REPS measures may have at least been effective at changing the trajectory of functional biodiversity metrics such as invertebrate abundance and species richness. Recent work has also demonstrated that certain treatments (e.g. Species Rich Grassland for Natura) are more effective than others (e.g. Species Rich Grassland and Traditional Hay Meadow) at creating areas of semi-natural grassland at field scale. Similar observations have been made regarding different approaches to create and manage field margins: rotovation and reseeding are important factors, but once established, the management also needs to consider the typology of the field margin itself and additional actions may be required where biodiversity is of lower initial quality. It is also now known that different treatments (e.g. management of riparian margins) and farm contexts (intensive dairy vs. extensive pasture) can lead to different results for the same overall measure, in some cases favouring wider biodiversity and in others individual species.

The previous reviews suggest a positive perception for REPS effect on other environmental factors such as landscape or archaeology. However, this topic does not appear to have been studied in the intervening years. Subsequent studies attempting to assess multiple environmental objectives also appear to be lacking, though the RDP 2014-2020 itself has been subject to an SEA process.

There has been fresh work on socioeconomic factors driving scheme adoption including major econometric studies of NFS data on REPS through all four iterations. This allows a fresh understanding as to why certain farm types chose to participate, how the pricing of measures affected uptake, and what external factors also came into play. The work indicates why intensive dairy farms participated more at certain points and what motivations were driving this such as the limits on derogation farmers, the relatively low premiums offered, and changes in external risks to their business. It also informs that poor uptake of certain measures such as riparian margins was related to inadequate compensation. Other work with the NFS dataset also suggests that it was not optimal in terms of its value for money distribution and that many of the farmers who participated could have done so at a lower cost. There do not appear to be any studies of attitudinal typology of REPS or AEOS explicitly, though work on adoption of similar measures in different schemes in Ireland and Wales does shed light on what underlying motivations drive participation in voluntary measures.

More is now known about the socioeconomic effects of the Burren, FPS, and the NAP. Studies of those who participated in the Burren and FPS schemes suggest a strong 'buy-in' from participants into these programmes, and there is evidence that the BFCP in particular offers good value for money albeit at a localised scale. The ACP research has also revealed more about the attitudinal typology of Irish farmers in relation to adopting nutrient management actions, and has also indicated why certain measures in AEOS, such as riparian margins may have had poor uptake.

8.2 Does the literature address issues raised in the previous review and evaluation?

8.2.1 Scale and methodology

The previous work on REPS was criticised for not employing a sufficiently adequate spatial scale to establish what the effects of the scheme or its constituent measures were at the national level. In addition, because baseline information was not always available prior to scheme implementation, many

studies lacked an adequate temporal dimension to understand the before and after effect. Furthermore the biodiversity literature was too divergent in terms of methodology for the reviewers to be able to form a consistent impression.

The spatial scale aspect has not changed materially in the intervening years. With the exception of the socioeconomic studies that consider a national dataset (NFS) the majority of new papers are focussed on assessing the effectiveness of a particular measure or facet within a particular catchment or in a small sample of farms. The temporal scale has improved with some nutrient leaching and socioeconomic studies considering considerable timeframe of data going back to the initial scheme, and is thus able to provide a better clarification of REPS effectiveness. However, interpreting some of the more recent work on REPS biodiversity effects has suffered from a lack of pre-scheme data against which to derive a baseline comparison.

Attempts to construct a consistent approach to evaluating metrics for agri-environment evaluation were beginning with the development of the AFI. This project showed promise but funding was discontinued before it was possible to apply it on a national basis. However, other frameworks to evaluate biodiversity effects of schemes have or are been developed in other contexts such as the BFCP, RBAPS and the Ideal-HNV.

8.2.2 Farmer behaviour and scheme exit

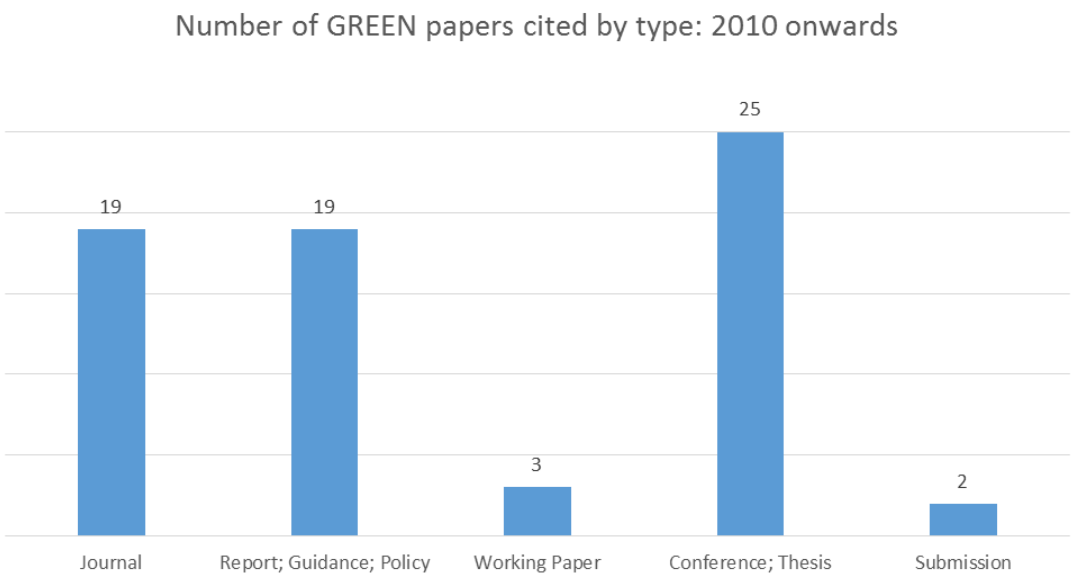
At the time of the previous review a major concern was whether the conditions of re-entry to a new scheme with limited budget and restrictive participation would successfully target the farms offering the greatest environmental benefit, and what might happen to the environmental quality of land which exits the scheme and does not continue.

This question was specifically composed with AEOS in mind, however no studies of REPS exit and AEOS participation could be identified on which to form this judgement, so answers can only be inferred from other findings. It is difficult to infer anything from the GHG and biodiversity research in this regard. However, in terms of nutrient management, the result observed in Italy (that Nitrates Directive measures were having more effect than agri-environment schemes) is interesting and may suggest that scheme exit would be less damaging, though this study should be replicated in Ireland explicitly before any conclusion can be drawn. The socioeconomic papers identified also reveal something about the link between farm typology, farmer motivations and agri-environment scheme participation. The principal inference would be that without any particular additional financial incentive, more intensive dairy farms would be less likely to participate in future schemes, and as such the environmental quality achieved would fall back to conditions set out under the GAP regulations and Pillar I cross-compliance.

8.2.3 Publication type

Much of the research that was identified by Finn & Ó hUallacháin had not been published in peer-reviewed journals, and this was raised as a concern. Subsequent to this, a number of the papers they cited in their have now passed through this process. There are 68 GREEN papers referred to in this paper, representing work directly addressing Irish agri-environment scheme published since 2010. The count of papers of each type of literature is presented in the chart below. The 19 peer-reviewed articles represent a lower proportion (27%) than that identified in the REPS Review (45%), and there is considerably more reference now to preliminary results presented in conferences or theses (37% vs 5%) as opposed to published reports (27% vs 49%). This may be reflective of the decline in Irish government

expenditure on research and development which dropped from 33.7% of all sources in 2008 to 27.3% in 2013 (EC 2015).



8.3 What are implications for GLAS evaluation?

A key point made by Finn and Ó hUallacháin was the need for a national scale, longitudinal evaluation of future schemes, which would consider in particular counterfactual scenarios against which an objective assessment could be made. This is echoed in the *ex ante* report on the RDP 2014-2020 which recommended the development of a plan to evaluate the agri-environment components specifically, in particular to monitor the link between uptake of GLAS measures and the likelihood of these activities supporting Ireland's compliance with EU biodiversity and water quality legislation (Fitzpatrick Associates 2014).

This review has further highlighted the importance of these points. Very few of the studies evaluated provide results at national scale and over a sufficient timescale. However, a number of studies do provide explicit information about the effectiveness of certain measures in an Irish context which can help calibrate models used to assess GHG abatement and nutrient management factors. Climate change adaptation is a cross-cutting objective of the RDP, but this facet of Irish agri-environment schemes does not appear to have been previously studied, and may require consideration in the evaluation framework. The socioeconomic studies considered will provide useful information about farm structural and attitudinal typology that will inform the analysis of the GLAS and broader NFS datasets, as well as the development and targeting of questionnaires to elicit relevant information.

Some of the ongoing research programmes will have implications for the upcoming GLAS evaluation. The COSAINT project, for example, will provide explicit environmental and socioeconomic information that will be of material value when considering the cattle-exclusion measure. There is a need to develop appropriate indicators to judge the effectiveness of GLAS measures at achieving their desired results. The previous work on the AFI can provide insight as to how to do this, as will current efforts to develop ecological indicators to assess results-based schemes such as the RBAPS project, Burren Life, and AranLIFE. Similarly, indicators for HNV farmland could also be of material use.

The GLAS evaluation will take on board these points and will seek to establish baseline information (pre-scheme) and a counterfactual scenario (non-uptake) so that any changes in the monitored variables can be more clearly attributed to the scheme itself. Sampling will also cover a sufficient geography to be able to scale the results to national scale.

Another point apparent in the review is the success of the Burren and NPWS schemes in terms of achieving both desirable biodiversity and socioeconomic outcomes. There would be merit in ensuring the metrics being used to evaluate GLAS are designed to be comparable with the metrics used to evaluate locally-led schemes within the RDP as well as the extant FPS contracts.

8.4 What are implications for future agri-environment scheme design?

The failure to adequately address water-related problems has been a European Court of Auditors (ECA) criticism of some Member State RDPs, though Ireland's was not investigated explicitly in this regard (ECA 2014). However, the ECA does recommend that all RDPs put increased emphasis on water issues in their content and better align them with RBMPs, as well as making more appropriate and sound financial use of funds earmarked to address water quality. Although conceived in the context of mandatory rather than voluntary actions, the ACP is helping provide a better understanding water management in the Irish agri-environment which will help inform the development of agri-environment measures. The studies mentioned on pathways and critical source areas which can better inform the spatial targeting of voluntary measures. Work on the nutrient and sediment attenuation capacity of specific features such as riparian buffers, field margins, drainage ditches, and hedgerows can also help improve their design and maintenance. The COSAINT project will also inform the future development and targeting of measures to improve water quality.

The Appropriate Assessment of the RDP 2014-2020 recognised the overall potential of GLAS to conserve and enhance biodiversity, in particular wild bird cover measures (Blackthorn Ecology 2014) . However, the report raised concerns about the potential impacts (pre-mitigation) of the GLAS scheme on Natura 2000 sites where management prescriptions may result in overgrazing (salt-marshes and associated birds) or undergrazing (grassland, heath, turloughs) inappropriate to the required regime. Another possible problem could be the inflexibility of the scheme prescriptions to respond to changing environmental background conditions, such as weather patterns. The report also stressed that some of the GLAS management options could be unsuitable for species requiring very specific habitat requirements such as breeding waders. Concerns were raised about the potential for maintenance of extensive agriculture from GLAS to conflict with afforestation targets that could benefit some habitats. Similar points were also raised regarding the potential for GLAS to offer a competing and non-complementary funding scheme to locally-led schemes.

This assessment took place in 2014 whilst the actual prescribed measures were being developed, and indeed the proposed mitigation to avoid inappropriate targeting was expected to occur through a process of consultation with key stakeholders as the measures were developed (Bleasdale & O'Donoghue 2015). In addition, the proposed monitoring regime is expected to identify any issues and remedy before significant impacts result. Given the relatively short history of research into these measures, the outcomes of this monitoring will therefore be of great importance.

Other ongoing research programmes will be of important value in informing future scheme design, in particular the RBAPS project which seek to develop outcome oriented measures that are more likely to deliver biodiversity benefits, and the Ideal-HNV projects which can better help with spatial targeting. There has also been a limited use to date of ecosystem services frameworks to develop agri-environmental policy. Future schemes could therefore be informed by current work on functional land management which seeks to identify how farmland can be managed to meet the multiple objectives of food production, carbon sequestration, water purification, nutrient cycling and habitat provision (Schulte et al. 2014; O'Sullivan et al. 2015).

The major synthesis of EU entry-level schemes (Keenleyside et al. 2011) has some particular recommendations for scheme design, many of which have already been taken on board in the formulation of the RDP 2014-2020. Payments structures should be used to incentivise the most environmentally beneficial options, and try to include transaction costs within their structure. Farmer engagement is also an essential feature, by involving them in scheme design and also ensuring all farmers receive appropriate training and feedback on implementation. They also recommend that novel measures are tested at a small scale first to improve efficiency and iron out problems before being introduced to a wider audience. Another important improvement would be to ensure internal review processes for schemes happen within the first 2 years of implementation to ensure corrections can be made early enough to have an effect.

The other socioeconomic studies can provide guidance for future scheme design by revealing more about Irish farmers' underlying attitudes and responses to the incentives offered. The participation model work in particular concluded that the fixed payment per hectare approach of REPS was not a true reflection of most participants' opportunity costs, and that an auction-based approach to allocating contracts could deliver better value-for-money for the government. Irish agri-environment scheme designers could learn from work already carried out on auction approaches in the English context.

9 Conclusions

This study has investigated the post-2010 literature on REPS and AEOS to establish if there has been any change to the conclusions of the previous REPS Review and Mid-Term RDP Evaluation. It has also sought to assess to what extent the issues raised in these reviews had been addressed. The implications of the literature for the evaluation of GLAS itself and the design of future agri-environment schemes in Ireland have also been assessed. The study has also considered research carried out on the BFCP, other LIFE projects, and the FPS that have been or could be incorporated into the design of measures included in the RDP 2014-2020. Relevant work from the ACP and from agri-environment measure studies outside Ireland has also been considered.

Relatively little is known about AEOS explicitly, probably as it was relatively small and short-lived. REPS has been more extensively evaluated with evidence suggesting a positive impact on water quality and GHG abatement, as well as improved awareness of environmental issues within the farming community. Knowledge of climate adaptation effects of REPS and AEOS is lacking. New information is available about the GHG abatement of certain measures and the long term impact of nutrient management prescriptions in REPS, but is not sufficient to establish a national perspective on either. The evidence for a positive effect of REPS on biodiversity is less strong, though it may have still played an important role. REPS measures were successful at generating a large quantity of features such as field margin and hedgerow, or getting large areas of habitat under management, but would have benefitted from more focus on the quality of what was created and managed, as well as more appropriate selection of biodiversity options by farmers. As such, REPS appears to improve functional indicators of biodiversity, such as invertebrate and below-ground species richness rather than higher level ones like vegetation species richness or bird abundance. Participation in REPS was mainly attractive to lower income, extensive farmers; but for a brief time (REPS4) it was able to attract the more intensive dairy farms. However, the rates proposed for GLAS are unlikely to draw much interest from this sector. Like other horizontal schemes around the EU, there would be scope to improve cost-effectiveness.

The approach taken in the Burren and the FPS to deal with the unique issues of SAC and SPA management has been more extensively studied, and has generally led to positive outcomes for these features. There appears to be value in providing farmers with difficult management challenges a vision for the desired result and allowing them flexibility in how they approach their task. The applicability of this method to wider biodiversity still needs to be established, but initiatives such as the other LIFE projects and RBAPS could certainly help inform future agri-environment scheme design. The approach applied in the Burren has also been shown to be cost effective, though this has only been evaluated at a local scale. Adapting a results-driven approach to water quality will be more challenging as more factors are outside the farmer's direct control. However, the knowledge from the ACP research, COSAINT and other projects will help devise more precise and cost-effective measures.

This literature review has also highlighted important points for the overall GLAS evaluation, in particular the need for a national scale long-term evaluation using a consistent methodology. It will be important to verify that any changes detected can be attributed to GLAS as opposed to mandatory requirements or previous schemes. Data collection pre-scheme or at inception is important, as is the regular collection of data at sufficient intervals. The relative success of the Burren and FPS measures could also provide benchmarks against which to judge the environmental and socioeconomic performance of GLAS. Finally, the evaluation methodology should take into consideration the work on monitoring frameworks in the Ideal-HNV, RBAPS, and ACP projects.

10 List of Abbreviations and Acronyms

ACP	Agricultural Catchments Programme
AEOS	Agri-Environment Options Scheme
AFI	Agri-environment Footprint Index
BFCP	Burren Farming for Conservation Programme
BLP	Burren Life Programme
CAP	Common Agricultural Policy
CMEF	Common Monitoring and Evaluation Framework
DAFM	Department of Agriculture Food and the Marine
DAHG	Department of Arts, Heritage, and the Gaeltacht
ECA	European Court of Auditors
ECJ	European Court of Justice
ELS	Entry Level Stewardship
EPA	Environmental Protection Agency
FPM	Freshwater Pearl Mussel
FPS	Farm Plan Scheme
FP6	Research and Innovation 6th Framework Programme
GAP	Good Agricultural Practice
GLAS	Green Low-carbon Agri-environment Scheme
GHG	Greenhouse Gas
GVA	Gross Value Add
HNV	High Nature Value
ICMSA	Irish Creamery Milk Supplier Association
IFA	Irish Farmers' Association
IGCPT	The Irish Grey Partridge Conservation Trust
IPCC	Intergovernmental Panel on Climate Change
ITAES	Integrated Tools to design and implement Agro Environmental Schemes
LCA	Life Cycle Analysis
LINNET	Land Invested in Nature, Natural Eco Tillage
MACC	Marginal Abatement Cost Curve
NAP	Nitrates Action Programme
NFS	National Farm Survey
NHA	Natural Heritage Area
NPWS	National Parks and Wildlife Service
PCA	Principal Component Analysis
RBAPS	Results-Based Agri-Environment Payment Scheme
RBMP	River Basin Management Plan
RDP	Rural Development Programme
REPS	Rural Environment Protection Scheme
REA	Rapid Evidence Assessment
RoI	Republic of Ireland
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
WFD	Water Framework Directive
UAA	Utilised Agricultural Area

11 References

ADAS, 2011. *Faecal Indicator Organism Losses from Farming Systems and nitrogen source apportionment. Final Report to Defra: WQ0111*, London. Available at: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14423.

ADAS, UEA & FERA, 2015. *Scoping the strengths and weaknesses of different auction and PES mechanisms for Countryside Stewardship. Report to DEFRA Project LM0105*, London.

An Taisce, 2014. *Reponse to Consultation on the Draft Rural Development Programme for 2014-2020*,

Anderson, A. et al., 2013. The influence of conservation field margins in intensively managed grazing land on communities of five arthropod trophic groups. *Insect Conservation and Diversity*, 6(3), pp.201–211.

AranLIFE, 2015. AranLIFE - Newsletter Spring 2015. , (1), p.5. Available at: http://www.aranlife.ie/#!reports-and-publications/cfvg.

Austin, Z. et al., 2015. Integrating quantitative and qualitative data in assessing the cost-effectiveness of biodiversity conservation programmes. *Biodiversity and Conservation*, 24(6), pp.1359–1375. Available at: http://link.springer.com/10.1007/s10531-015-0861-4.

Baily, a. et al., 2011. Spatial and temporal variations in groundwater nitrate at an intensive dairy farm in South-East Ireland: Insights from stable isotope data. *Agriculture, Ecosystems and Environment*, 144(1), pp.308–318. Available at: http://dx.doi.org/10.1016/j.agee.2011.09.007.

Batáry, P. et al., 2015. The role of agri-environment schemes in conservation and environmental management. *Conservation Biology*, 29(4), pp.1006–1016. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25997591.

Birdwatch Ireland, 2016. The Shannon Callows Breeding Wader Project. Available at: http://www.birdwatchireland.ie/OurWork/ResearchSurveys/BreedingwadersShannonCallows/tabid/257/Default.aspx [Accessed January 12, 2016].

Black, K. et al., 2014. *Carbon Sequestration by Hedgerows in the Irish Landscape. Climate Change Research Programme (CCRP) 2007-2013 Report Series No . 32*.

Blackthorn Ecology, 2014. *RDP 2014-2020 Draft Appropriate Assessment Report*.

Bleasdale, A. & O'Donoghue, B., 2015. NPWS perspectives on Locally-led Agri- environment Schemes. Available at: https://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/locallyledschemes/AndyBleasdalepres16oct15221015.pdf. [Accessed January 5, 2016].

Bleasdale, A. & O'Donoghue, B., 2015. The role of DAHG in the identification and targeting of biodiversity priorities in the Green Low-carbon Agri-environment Scheme (GLAS). In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 14–15.

BLP, 2015. *The Burren Life Programme 2015 Summary Report*.

Boyle, P., Hayes, M., et al., 2015. Development of a nature value index for pastoral farmland—A rapid farm-level assessment. *Ecological Indicators*, 56, pp.31–40. Available at: http://www.sciencedirect.com/science/article/pii/S1470160X15001351 [Accessed April 13, 2015].

Boyle, P., Gormally, M., et al., 2015. Typology of a High Nature Value farmland region in an Atlantic pastoral area. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision.*

Teagasc Biodiversity Conference. Wexford: Teagasc, pp. 38–39.

Browne, A. et al., 2015. Investigating the composition and management of calcareous grassland of the Aran Islands. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 24–25.

Buckley, C., Howley, P. & Jordan, P., 2015. A study of nutrient management best practice adoption by farmers. In *Agri-Environment Conference*. Tullamore: Teagasc, p. 3.

Buckley, C., Hynes, S. & Mechan, S., 2012. Supply of an ecosystem service-Farmers' willingness to adopt riparian buffer zones in agricultural catchments. *Environmental Science and Policy*, 24, pp.101–109. Available at: http://dx.doi.org/10.1016/j.envsci.2012.07.022.

Campbell, D. et al., 2006. *Quantifying the landscape benefits arising from the Rural Environment Protection Scheme: results from a public survey.*

Carlin, C. et al., 2010. *Experts ' assessments of biodiversity options and supplementary measures in REPS 4*, Available at: http://www.nuigalway.ie/applied_ecology_unit/documents/expertgroup_report.pdf.

Casey, J.W. & Holden, N.M., 2006. Greenhouse gas emissions from convent ional, agr ienvironmental scheme, and organic Irish suckler-beef units. *Journal of Environmental Quality*, 35, pp.231–9.

Casey, J.W. & Holden, N.M., 2005. The relationship between greenhouse gas emissions and the intensity of milk production in Ireland. *Journal of Environmental Quality*, 34, pp.429–36.

Clarke, J.D., 1998. *A study on the uptake of the Rural Environmental Protection Scheme in Co. Louth in the first four years of the operation of the scheme*.

Collins, A.L. et al., 2010. A preliminary investigation of the efficacy of riparian fencing schemes for reducing contributions from eroding channel banks to the siltation of salmonid spawning gravels across the south west UK. *Journal of Environmental Management*, 91(6), pp.1341–1349.

Connolly, L. et al., 2009. *National Farm Survey 2009*.

Copland, A., 2015. Farmland Birds in GLAS. In *Agri-Environment Conference*. Teagasc. Available at: http://www.teagasc.ie/publications/2015/3751/index.asp.

Copland, A.S. & O'Halloran, J., 2010. Agri-environment impacts and opportunities for summer bird communities on lowland Irish farmland. , 100, pp.77–88. Available at: https://www.researchgate.net/publication/272137719_Agri-environment_impacts_and_opportunities_for_summer_bird_communities_on_lowland_Irish_farmland.

Curtin, J. & Whelan, J., 1998. *A study of farms participating in the REPS Scheme in Country Roscommon and benefits to the rural environment of this scheme in its present form. In Protecting Ireland's national heritage*.

DAF, 1999. *Evaluation of the Rural Environment Protection Scheme*.

DAFM, 2015. *FoodWise 2025: A 10 year vision for the Irish agri-food industry*.

DAFM, 2014. *Ireland - Rural Development Programme 2014-2020*, Dublin.

DAHG, 2015. *Judgment of the Court of Justice of the European Union in Case C 418 / 04 Commission v Ireland " The Birds Case " A Programme of measures by Ireland to ensure full compliance with the Judgment of the Court of Justice of the European Union Update – July 20*.

Davis, S. et al., 2015. The impact of hydrochemical disturbance on stream ecology. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 82–83.

DEHLG, 2010. *National Parks and Wildlife Service Farm Plan Scheme. Terms and Conditions*.

DEHLG & EHS, 2005. *All Ireland Species Action Plans: Corncrake (Crex crex)*.

van Dijk, W.F.A. et al., 2013. Temporal effects of agri-environment schemes on ditch bank plant species. *Basic and Applied Ecology*, 14(4), pp.289–297. Available at: http://www.sciencedirect.com/science/article/pii/S1439179113000510 [Accessed October 30, 2015].

Doherty, E. et al., 2014. Valuing ecosystem services across water bodies: Results from a discrete choice experiment. *Ecosystem Services*, 7, pp.89–97. Available at: http://dx.doi.org/10.1016/j.ecoser.2013.09.003.

Donnellan, T., Hanrahan, K. & Breen, J.P., 2014. Development and Application of Economic and Environmental Models of Greenhouse Gas Emissions from Agriculture: Some Difficult Choices for Policy Makers. In C. Zopoundis et al., eds. *Agricultural Cooperative Management and Policy*. Switzerland: Springer International Publishing, pp. 243–263.

Doody, D.G. et al., 2012. Approaches to the implementation of the Water Framework Directive: targeting mitigation measures at critical source areas of diffuse phosphorus in Irish catchments. *Journal of environmental management*, 93(1), pp.225–34. Available at: http://www.sciencedirect.com/science/article/pii/S0301479711003318 [Accessed October 15, 2015].

Doody, D.G. et al., 2009. Stakeholder participation in the development of agri-environmental measures. *Tearmann: Irish Journal of Agri-Environmental Research*, 7, pp.229–40.

Drennan, M.J. & McGee, M., 2009. Performance of spring-calving beef suckler cows and their progeny on four contrasting grassland management systems. *Livestock Science*, 117(2–3), pp.238–248. Available at: http://www.sciencedirect.com/science/article/pii/S1871141307005732.

Duignan, L. et al., 2015. The forage quality of semi-natural calcareous grasslands of the Aran Islands. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 85–87.

Dunford, B., 2015. Starting from scratch - the story of one Locally-Led Scheme. In D. O hUallachain & J. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 20–21.

EC, 2014. Gross Nutrient Balance (kg Nitrogen per hectare of UAA). *Eurostat*. Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do [Accessed March 15, 2016].

EC, 2015. R&D Expenditure. *Eurostat*. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure [Accessed February 1, 2016].

ECA, 2013. *Can the Commission and Member States show that the EU budget allocation to Rural Development Policy is well spent?*, Luxembourg. Available at: http://eca.europa.eu.

ECA, 2014. *Integration of EU water policy objectives with the CAP: a partial success*.

ECJ, 2007. *Commission of the European Communities v Ireland*.

EFNCP, 2016. Identification of HNV Farming. Available at: http://www.efncp.org/what-we-do/high-nature-value-farming/identifying-high-nature-value-farming/ [Accessed January 13, 2016].

Emerson, H.J. & Gillmor, D.A., 1999. The Rural Environment Protection Scheme of the Republic of Ireland. *Land Use Policy*, 16(4), pp.235–245. Available at: http://www.sciencedirect.com/science/article/pii/S0264837799000186 [Accessed October 15, 2015].

EPA, 2016. *Greenhouse Gas Emission Projections to 2020 – An update*.

EPA, 2015a. Ireland's Nitrates Action Programme. Available at: http://www.environ.ie/en/Environment/Water/WaterQuality/NitratesDirective/#Ireland's Nitrates

Action Programme [Accessed January 8, 2016].

EPA, 2015b. *Ireland's Provisional Greenhouse Gas Emission In 2014*.

EPA, 2015c. *Water Quality in Ireland 2010 - 2012*.

Evans, D.J., Gibson, C.E. & Rossell, R.S., 2006. Sediment loads and sources in heavily modified Irish catchments: A move towards informed management strategies. *Geomorphology*, 79(1-2), pp.93–113.

Facey, S.L. et al., 2014. Moth communities and agri-environment schemes: Examining the effects of hedgerow cutting regime on diversity, abundance, and parasitism. *Insect Conservation and Diversity*, 7(6), pp.543–552. Available at: http://doi.wiley.com/10.1111/icad.12077.

Feehan, J., Gillmor, D.A. & Culleton, N., 2005. Effects of an agri-environment scheme on farmland biodiversity in Ireland. *Agriculture, Ecosystems & Environment*, 107(2-3), pp.275–286. Available at: http://www.sciencedirect.com/science/article/pii/S0167880904003287 [Accessed October 15, 2015].

Fenton, O. et al., 2009. Variations in travel time for N loading to groundwaters in four case studies in Ireland : Implications for policy makers and regulators. *Tearmann: Irish journal of agri-environmental research*, 7, pp.129–142.

Finn, J.A. et al., 2007. *Estimating the environmental performance of agri-environmental schemes via use of expert consultations. ITAES WP5 Final Report*, Available at: https://w3.rennes.inra.fr/internet/ITAES/website/Publicdeliverables.html.

Finn, J.A. et al., 2010. *Methodology for environmental assessment of agri-environment schemes : the Agri Environmental Footprint Index END OF PROJECT REPORT RMIS 5730*.

Finn, J.A., 2010. *Monitoring the environmental impacts of the Rural Environmental Protection Scheme : a scoping study RMIS 5757*.

Finn, J.A. & Ó hUallacháin, D., 2012. a Review of Evidence on the Environmental Impact of Ireland ' S Rural Environment Protection Scheme (Reps). *Biology and Environment: Proceedings of the Royal Irish Academy*, 112(B), pp.1–24.

Firbank, L. et al., 2013. Delivering multiple ecosystem services from Enclosed Farmland in the UK. *Agriculture, Ecosystems and Environment*, 166, pp.65–75. Available at: http://linkinghub.elsevier.com/retrieve/pii/S016788091100394X.

Fitzpatrick Associates, 2014. *Ex Ante Evaluation of the Rural Development Programme 2014-2020. Report to Department of Agriculture , Food and the Marine*.

Fraser, R., 2009. Land heterogeneity, agricultural income forgone and environmental benefit: An assessment of incentive compatibility problems in environmental stewardship schemes. *Journal of Agricultural Economics*, 60(1), pp.190–201.

Fritch, R.A. et al., 2011. Methods of enhancing botanical diversity within field margins of intensively managed grassland: a 7-year field experiment. *Journal of Applied Ecology*, 48(3), pp.551–560. Available at: http://doi.wiley.com/10.1111/j.1365-2664.2010.01951.x.

Fuentes-Montemayor, E., Goulson, D. & Park, K.J., 2011. Pipistrelle bats and their prey do not benefit from four widely applied agri-environment management prescriptions. *Biological Conservation*, 144(9), pp.2233–2246. Available at: http://www.sciencedirect.com/science/article/pii/S0006320711002254 [Accessed November 2, 2015].

Gabbett, M. & Finn, J.., 2005. *The farmland wildlife survey*.

Gibbons, J.M. et al., 2014. Sustainable nutrient management at field, farm and regional level: Soil testing, nutrient budgets and the trade-off between lime application and greenhouse gas

emissions. *Agriculture, Ecosystems & Environment*, 188, pp.48–56. Available at: http://www.sciencedirect.com/science/article/pii/S0167880914000966 [Accessed July 30, 2015].

Gonbour, M. et al., 2015. Targeting agri-environment scheme payments for terrestrial ecosystem services to conserve freshwater aquatic ecology. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 84–85.

Greene, S., McElarney, Y.R. & Taylor, D., 2014. Water quality effects following establishment of the invasive Dreissena polymorpha (Pallas) in a shallow eutrophic lake: implications for pollution mitigation measures. *Hydrobiologia*, 743(1), pp.237–253. Available at: http://link.springer.com/10.1007/s10750-014-2041-z.

Hof, A.R. & Bright, P.W., 2010. The impact of grassy field margins on macro-invertebrate abundance in adjacent arable fields. *Agriculture, Ecosystems & Environment*, 139(1-2), pp.280–283. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167880910002173.

Horrocks, C.A. et al., 2014. Does extensification lead to enhanced provision of ecosystems services from soils in UK agriculture? *Land Use Policy*, 38, pp.123–128. Available at: http://www.sciencedirect.com/science/article/pii/S0264837713002184 [Accessed September 27, 2015].

Huebsch, M. et al., 2013. Impact of agronomic practices of an intensive dairy farm on nitrogen concentrations in a karst aquifer in Ireland. *Agriculture, Ecosystems & Environment*, 179, pp.187–199. Available at: http://www.sciencedirect.com/science/article/pii/S0167880913002818 [Accessed October 30, 2015].

Humphreys, J., 2012. *Quantification of the potential of white clover to lower GHG emissions from Irish grassland-based dairy production. Technology Update Project No 5783*,

Hynes, S. et al., 2008. The impact of REPS participation on farm chemical input usage and the production of negative externalities. *Tearmann: Irish Journal of Agri-Environmental Research*, 6, pp.15–28.

Hynes, S. & Hanley, N., 2009. The “Crex crex” lament: Estimating landowners willingness to pay for corncrake conservation on Irish farmland. *Biological Conservation*, 142(1), pp.180–188. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0006320708003947.

Hynes, S. & Murphy, E., 2002. *An analysis of the Rural Environmental Protection Scheme*.

ICSA, 2013. *ICSA Submission on the Rural Development Programme 2014-2020*.

Ideal-HNV, 2013. Mapping High Nature Value farmland in Ireland. Available at: https://idealhnv.wordpress.com/2013/09/09/ideal-hnv-identifying-the-distribution-and-extent-of-agricultural-land-of-high-nature-value/ [Accessed January 13, 2016].

IFA, 2014. *Response by the Irish Farmers Association to CAP Rural Development Consultation Paper 2014-2020*.

Igoe, F. et al., 2015. Farmers are stakeholders too! A bottom up approach to Catchment Management in a predominantly agricultural catchment in Duhallow, North Cork. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 26–27.

IGPCT, 2016. Grey Partridge - Habitat Management. Available at: http://www.greypartridge.ie/?page_id=76 [Accessed January 10, 2016].

Indecon, 2010. *Mid-Term Evaluation of the Rural Development Programme Ireland*.

Ingram, J. et al., 2013. Incorporating agri-environment schemes into farm development pathways: A temporal analysis of farmer motivations. *Land Use Policy*, 31, pp.267–279. Available at: http://www.sciencedirect.com/science/article/pii/S0264837712001317.

IRD Duhallow Ltd, 2011. IRD Duhallow LIFE Project. Available at:

http://www.duhallowlife.com/content/reports [Accessed January 18, 2016].

Jordan, P. et al., 2012. The seasonality of phosphorus transfers from land to water: implications for trophic impacts and policy evaluation. *The Science of the total environment*, 434, pp.101–9. Available at: http://www.sciencedirect.com/science/article/pii/S0048969712002537 [Accessed October 21, 2015].

Keenleyside, C. et al., 2011. *Delivering environmental benefits through entry level agri-environment schemes in the EU. Report Prepared for DG Environment, Project ENV.B.1/ETU/2010/0035*, Available at: http://www.ieep.org.uk/assets/896/IEEP_Entry-level_AE.pdf.

Kelley, H., Rensburg, T.M. van & Yadav, L., 2013. A micro-simulation evaluation of the effectiveness of an Irish grass roots agri-environmental scheme. *Land Use Policy*, 31, pp.182–195. Available at: http://www.sciencedirect.com/science/article/pii/S0264837712001226 [Accessed October 15, 2015].

Kelly, K., Higgins, T. & Twamley Stein, G., 2015. Conservation grazing with native cattle in south-west Ireland. In *Uplands Workshop 2015: Research for a Sustainable Future*. Dublin: Trinity Centre for Biodiversity Research, p. 22. Available at: http://www.irishuplandsforum.org/documentbank/uploads/2015 Uplands Research Workshop %E2%80%93 Proceedings.pdf.

Kleijn, D. & Sutherland, W.J., 2003. How Effective Are European Agri-Environment Schemes in Conserving and Promoting Biodiversity? *Journal of Applied Ecology*, 40(6), pp.947–969. Available at: http://www.jstor.org/stable/3506035.

Kuosmanen, N., 2014. Estimating stocks and flows of nitrogen: Application of dynamic nutrient balance to European agriculture. *Ecological Economics*, 108, pp.68–78. Available at: http://www.sciencedirect.com/science/article/pii/S0921800914003188 [Accessed October 30, 2015].

Lanigan, G., 2012. *Assessing the greenhouse gas budget of tillage mitigation options for arable systems. Technology Update*, Available at: http://www.teagasc.ie/publications/.

Lastra-Bravo, X.B. et al., 2015. What drives farmers' participation in EU agri-environmental schemes?: Results from a qualitative meta-analysis. *Environmental Science & Policy*, 54, pp.1–9. Available at: http://www.sciencedirect.com/science/article/pii/S1462901115300058 [Accessed June 29, 2015].

Leip, A. et al., 2010. *Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS)–final report*, Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Evaluation+of+the+livestock+sector+'+s+contribution+to+the+EU+greenhouse+gas+emissions+(+GGELS+)+-+Final+report+-#0.

Li, D., Lanigan, G. & Humphreys, J., 2011. Measured and Simulated Nitrous Oxide Emissions from Ryegrass- and Ryegrass/White Clover-Based Grasslands in a Moist Temperate Climate. *PLoS ONE*, 6(10), p.e26176. Available at: http://dx.plos.org/10.1371/journal.pone.0026176.

Louwagie, G. et al., 2012. Development of indicators for assessment of the environmental impact of livestock farming in Ireland using the Agri-environmental Footprint Index. *Ecological Indicators*, 18, pp.149–162. Available at: http://www.sciencedirect.com/science/article/pii/S1470160X11003682 [Accessed August 18, 2015].

MacDonald, M.A., Cobbold, G., et al., 2012. Effects of agri-environment management for cirl buntings on other biodiversity. *Biodiversity and Conservation*, 21(6), pp.1477–1492.

MacDonald, M.A., Maniakowski, M., et al., 2012. Effects of agri-environment management for stone curlews on other biodiversity. *Biological Conservation*, 148(1), pp.134–145. Available at: http://www.sciencedirect.com/science/article/pii/S0006320712000535 [Accessed October 8, 2015].

Maher, C. et al., 2015. Developing Result Based Agri-Environmental Payment Schemes for the conservation of species and habitats in Ireland and Spaid. In D. Ó hUallacháin & J. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 28–29.

Marconi, V., Raggi, M. & Viaggi, D., 2015. Assessing the impact of RDP agri-environment measures on the use of nitrogen-based mineral fertilizers through spatial econometrics: The case study of Emilia-Romagna (Italy). *Ecological Indicators*, 59, pp.27–40. Available at: http://www.sciencedirect.com/science/article/pii/S1470160X15001260 [Accessed November 2, 2015].

Matin, S. et al., 2015. Characterisng indicator based HNV farmland distribution in Ireland - a GIS approach. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 32–33.

Mauchline, A.L. et al., 2012. Environmental evaluation of agri-environment schemes using participatory approaches: Experiences of testing the Agri-Environmental Footprint Index. *Land Use Policy*, 29(2), pp.317–328. Available at: http://www.sciencedirect.com/science/article/pii/S0264837711000706 [Accessed October 30, 2015].

McEvoy, O., 1999. *Impact of REPS—analysis from the National Farm Survey*.

McGurn, P. & Moran, J., 2013. *A National , Outcome-based Agri- environment Programme Under Ireland ' s Rural Development Programme 2014-2020.*

McLoughlin, D., 2011. Management prescriptions for twite in Ireland. *Irish Wildlife Manuals*, 52, p.80.

McMahon, B.J., Sheridan, H., et al., 2013. Regional and farm system drivers of avian biodiversity within agriculture ecosystems. In *Aspects of Applied Biology (vol. 121) : Rethinking Agricultural Systems in the UK*. Oxford: Association of Applied Biologists. Available at: http://hdl.handle.net/10197/5246.

McMahon, B.J., Carnus, T. & Whelan, J., 2013. A comparison of winter bird communities in agricultural grassland and cereal habitats in Ireland: implications for Common Agricultural Policy reform. *Bird Study*, 60(2), pp.1–9. Available at: http://dx.doi.org/10.1080/00063657.2012.758227.

Metz, B. et al., 2007. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

Mihailescu, E. et al., 2014. Phosphorus balance and use efficiency on 21 intensive grass-based dairy farms in the South of Ireland. *The Journal of Agricultural Science*, 153(03), pp.520–537. Available at: http://www.journals.cambridge.org/abstract_S0021859614000641.

Miler, J., Coughlin, D. & Kirk, S., 2013. *Guidance Document for the production of Quick Scoping Reviews and Rapid Evidence Assessments (version Beta 8.0).*

Monaghan, F. et al., 2014. *Commonage Case Studies 2014 Informing the development of commonage management plans under Ireland's RDP 2014-2020*

Moran, J. et al., 2008. Past and present land management of 12 turloughs in the west of Ireland Past and present land management of 12 turloughs in the west of Ireland. *Tearmann: Irish Journal of Agri-Environmental Research*, 6, pp.83–102.

Murphy, G., Hynes, S., et al., 2014. An investigation into the type of farmer who chose to participate in Rural Environment Protection Scheme (REPS) and the role of institutional change in influencing scheme effectiveness. *Land Use Policy*, 39, pp.199–210. Available at: http://www.sciencedirect.com/science/article/pii/S0264837714000350 [Accessed September 4, 2015].

Murphy, G. et al., 2011. Assessing the compatibility of farmland biodiversity and habitats to the specifications of agri-environmental schemes using a multinomial logit approach. *Ecological Economics*, 71, pp.111–121. Available at:

http://www.sciencedirect.com/science/article/pii/S0921800911003430 [Accessed October 15, 2015].

Murphy, G., Donoghue, C.O., et al., 2014. Modelling the Participation Decision in Agri-Environmental Schemes. *Agri-Food and Rural Innovations for Healthier Societies*, p.19. Available at: http://ageconsearch.umn.edu/bitstream/183069/2/O%26%2339Donoghue-Modelling_the_participation_decision_in_agri-environmental_schemes-473_a.pdf.

Murphy, P. et al., 2015. *Interim report on greenhouse gas emissions from Irish agriculture : Teagasc submission made in response to the discussion document on the potential for Agriculture and Forestry sector* .,

Murphy, P., 2015. NMP-online - An integrated tool for adaptive nutrient management planning Summary. In *Agri-Environment Conference*. Tullamore: Teagasc, pp. 19–21.

NPWS, 2015a. *A Framework for Corncrake Conservation to 2022*,

NPWS, 2014a. *CORNCRAKE FARM PLAN SCHEME (CFPS) Terms & Conditions (2014)*, Available at: http://www.npws.ie/farmers-and-landowners/schemes/npws-farm-plan-scheme/npws-farm-plan-methods.

NPWS, 2015b. Grey Partridge Project. Available at: http://www.npws.ie/research-projects/animal-species/grey-partridge-project [Accessed January 10, 2016].

NPWS, 2014b. *Hen Harriers and the Farmed Landscape*.

NPWS, 2015c. KerryLIFE Project. Available at: http://www.npws.ie/research-projects/kerrylife [Accessed January 18, 2016].

NPWS, 2012. *National Summary for Article 12*.

NPWS, 2013. *The Status of EU Protected Habitats and Species in Ireland. Overview Volume 1*.

Ó hUallacháin, D. et al., 2015. Evaluation of agri-environment measures for the conservation of grassland on Irish farmland. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 54–55.

Ó hUallacháin, D. & Madden, D., 2011. Riparian vegetated margins and small mammal communities: Implications for agri-environment schemes. *Irish Journal of Agri-Environmental Research*, 8, pp.15–24. Available at: http://hdl.handle.net/11019/218.

O'Brien, J., Elliott, S. & Hayden, T.J., 2015. Use of hedgerows as a key element of badger (Meles meles) behaviour in Ireland. *Mammalian Biology - Zeitschrift für Säugetierkunde*. Available at: http://www.sciencedirect.com/science/article/pii/S1616504715001020 [Accessed October 30, 2015].

O'Callaghan, P. et al., 2015. COSAINT - Cattle Exclusion from Watercourses: Environmental and socioeconomic implications. In D. Ó hUallacháin & J. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 72–73.

O'Donoghue, B., 2015. *Agri-Ecology Research*.

O'Donoghue, B. et al., 2015. Agri-environment measures for Chough. In D. Ó hUallacháin & J. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 48–49.

O'Donoghue, B., 2011. Duhallow Hen Harriers Circus cyaneus – from stronghold to just holding on. *Irish Birds*, 9, pp.349–356.

O'Donoghue, B. & Bleasdale, A., 2015. Corncrake Conservation. In D. Ó hUallacháin & J. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 92–93.

O'Donoghue, B., O'Donoghue, T.A. & King, F., 2011. Opinion Article: the Hen Harrier in Ireland: Conservation Issues for the 21St Century. *Biology & Environment: Proceedings of the Royal Irish Academy*, 111(2), pp.1–11. Available at: http://www.jstor.org/stable/23033868.

O'Dwyer, B. et al., 2013. A palaeolimnological investigation into nutrient impact and recovery in an agricultural catchment. *Journal of environmental management*, 124, pp.147–55. Available at: http://www.sciencedirect.com/science/article/pii/S0301479713000765 [Accessed October 30, 2015].

O'Neill, K.A. et al., 2015. Sustainable land use management for the conservation of the Freshwater Pearl Mussel. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 76–77.

O'Rourke, E., Kramm, N. & Chisholm, N., 2012. The influence of farming styles on the management of the Iveragh uplands, southwest Ireland. *Land Use Policy*, 29(4), pp.805–816. Available at: http://www.sciencedirect.com/science/article/pii/S0264837711001542 [Accessed October 15, 2015].

O'Shea, R. et al., 2015. Greenhouse gas (GHG) Mitigation and Technology Adoption Theory: Extended Grazing as a Case Study Robert O'Shea. In *89th Annual Conference of the Agricultural Economics Society*. Warwick, pp. 1–16. Available at: http://ageconsearch.umn.edu/bitstream/204293/2/Robert_O'Shea_OShea Discussion Paper Session 2.pdf.

O'Sullivan, L. et al., 2015. Functional Land Management for managing soil functions: A case-study of the trade-off between primary productivity and carbon storage in response to the intervention of drainage systems in Ireland. *Land Use Policy*, 47, pp.42–54. Available at: http://www.sciencedirect.com/science/article/pii/S0264837715000800 [Accessed April 13, 2015].

OECD, 2009. *Environmental Performance Review of Ireland*.

Owens, J. et al., 2015. Restoring species richness to hay meadows on the River Shannon Callows. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 64–65.

Parr, S. et al., 2009. Vegetation analysis of upland Burren grasslands of conservation interest. *BIOLOGY AND ENVIRONMENT: PROCEEDINGS OF THE ROYAL IRISH ACADEMY*, 109B(1), pp.11–33. Available at: http://www.jstor.org/stable/20694870.

Phelan, P. et al., 2015. The KerryLIFE Project Area. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 22–23.

Philip Farrelly & Co Ltd, 2015a. *Food Wise 2025: Appropriate Assessment - Final Natura Impact Statement*.

Philip Farrelly & Co Ltd, 2015b. *Food Wise 2025: Strategic Environmental Assessment - Final Report*.

Posthumus, H. et al., 2008. Agricultural land use and flood risk management: Engaging with stakeholders in North Yorkshire. *Agricultural Water Management*, 95(7), pp.787–798.

Posthumus, H. & Morris, J., 2010. Implications of CAP reform for land management and runoff control in England and Wales. *Land Use Policy*, 27(1), pp.42–50.

Purvis, G., Anderson, A., et al., 2009. *AG-BIOTA – Monitoring, Functional Significance and Management for the Maintenance and Economic Utilisation of Biodiversity in the Intensively Farmed Landscape*, Wexford. Available at: http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=108.

Purvis, G., Louwagie, G., et al., 2009. Conceptual development of a harmonised method for tracking change and evaluating policy in the agri-environment: The Agri-environmental Footprint Index. *Environmental Science and Policy*, 12, pp.321–337.

Reed, M.S. et al., 2014. Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services*, 9, pp.44–53. Available at: http://dx.doi.org/10.1016/j.ecoser.2014.06.008.

Reinhard, S. & Linderhof, V., 2015. Convergence of EU nitrogen surplus, the RDP indicator of water quality. *Ecological Indicators*, 59, pp.19–26. Available at: http://www.sciencedirect.com/science/article/pii/S1470160X14005962 [Accessed October 30, 2015].

Renou-Wilson, F. et al., 2011. *BOGLAND: Sustainable Management of Peatlands in Ireland. STRIVE Report prepared for the EPA by University College Dublin*, Wexford. Available at: http://erc.epa.ie/safer/reports.

Van Rensburg, T.M., Murphy, E. & Rocks, P., 2009. Commonage land and farmer uptake of the rural environment protection scheme in Ireland. *Land Use Policy*, 26(2), pp.345–355. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0264837708000598.

Richards, K.G. et al., 2015. Effect of an agri-environmental measure on nitrate leaching from a beef farming system in Ireland. *Agriculture, Ecosystems & Environment*, 202, pp.17–24. Available at: http://www.sciencedirect.com/science/article/pii/S0167880914005647 [Accessed October 15, 2015].

Roarty, S. & Schmidt, O., 2013. Permanent and new arable field margins support large earthworm communities but do not increase in-field populations. *Agriculture, Ecosystems & Environment*, 170, pp.45–55. Available at: http://www.sciencedirect.com/science/article/pii/S0167880913000637 [Accessed October 15, 2015].

Schlaich, A.E. et al., 2015. Testing a novel agri-environment scheme based on the ecology of the target species, Montagu's harrier Circus pygargus. *Ibis*, 157(4), pp.713–721. Available at: http://onlinelibrary.wiley.com/doi/10.1111/ibi.12299/abstract.

Schulte, R. et al., 2012. *A Marginal Abatement Cost Curve for Irish Agriculture*.

Schulte, R.P. et al., 2009. Lough Melvin: Developing cost-effective measures to prevent phosphorus enrichment of a unique aquatic habitat. *Tearmann: Irish Journal of Agri-Environmental Research*, 7, pp.211–228. Available at: http://t-stor.teagasc.ie/handle/11019/206.

Schulte, R.P.O. et al., 2014. Functional land management: A framework for managing soil-based ecosystem services for the sustainable intensification of agriculture. *Environmental Science & Policy*, 38, pp.45–58. Available at: http://www.sciencedirect.com/science/article/pii/S1462901113002104 [Accessed October 2, 2015].

Sheridan, H. et al., 2011. Pastoral farmland habitat diversity in south-east Ireland. *Agriculture, Ecosystems & Environment*, 144(1), pp.130–135. Available at: http://www.sciencedirect.com/science/article/pii/S0167880911002507 [Accessed October 15, 2015].

Sheridan, H. et al., 2008. Plant and invertebrate diversity in grassland field margins. *Agriculture, Ecosystems and Environment*, 123, pp.225–232.

Sheridan, H., Finn, J.A. & O'Donovan, G., 2009. Botanical Rejuvenation of Field Margins and Benefits for Invertebrate Fauna on a Drystock Farm in County Longford. *Biology & Environment: Proceedings of the Royal Irish Academy*, 109(2), pp.95–106. Available at: http://www.jstor.org/stable/20694881.

Shore, M. et al., 2015. An agricultural drainage channel classification system for phosphorus management. *Agriculture, Ecosystems & Environment*, 199, pp.207–215. Available at: http://www.sciencedirect.com/science/article/pii/S016788091400440X [Accessed October 30, 2015].

Shortle, G., 2014. Policy Challenges for Improving Water Quality. In *National Agri-Enivornment Conference*. Carlow: Teagasc, p. 7.

Smart, J. et al., 2013. Managing uplands for biodiversity: Do agri-environment schemes deliver benefits for breeding lapwing Vanellus vanellus? *Journal of Applied Ecology*, 50(3), pp.794–804.

Smith, R.S. et al., 2008. Long-term change in vegetation and soil microbial communities during the phased restoration of traditional meadow grassland. *Journal of Applied Ecology*, 45(2), pp.670–679.

SNH, 2003. *The Orkney Hen Harrier Scheme*.

Spratt, S.E., 2012. *An ecological study of grassland field margins in Northern Ireland*. University of Ulster. Available at: http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.587492.

Sullivan, C. et al., 2015. The types of High Nature Value (HNV) farmland in Ireland. In D. Ó hUallacháin & J. A. Finn, eds. *Farmland Conservation with 2020 Vision. Teagasc Biodiversity Conference*. Wexford: Teagasc, pp. 34–36.

Sullivan, C.A. et al., 2013. FIELD BOUNDARY HABITATS AND THEIR CONTRIBUTION TO THE AREA OF SEMINATURAL HABITATS ON LOWLAND FARMS IN EAST GALWAY, WESTERN IRELAND. *BIOLOGY AND ENVIRONMENT: PROCEEDINGS OF THE ROYAL IRISH ACADEMY*, 113B(2), pp.1–13.

Sullivan, C.A. et al., 2011. Modelling semi-natural habitat area on lowland farms in western Ireland. *Biological Conservation*, 144, pp.1089–99. Available at: https://www.researchgate.net/publication/223065191_Modelling_semi-natural_habitat_area_on_lowland_farms_in_western_Ireland.

Sullivan, E., 2006. *The archaeology of REPS— seeing is believing. In New Challenges*,

Teagasc, 2013. *Agricultural Catchments Programme: Phase 1 Report*, Wexford. Available at: http://www.teagasc.ie/agcatchments/.

Thomas, I. et al., 2015. Identifying the “at risk” areas for nutrient losses on Irish Farms. In *Agri-Environment Conference*. Tullamore: Teagasc, pp. 10–11.

Thompson, J.J.D. et al., 2012. Dynamics of critical source areas: does connectivity explain chemistry? *The Science of the total environment*, 435-436, pp.499–508. Available at: http://www.sciencedirect.com/science/article/pii/S0048969712009370 [Accessed November 3, 2015].

Visser, M. et al., 2007. The Irish agri-environment: How turlough users and non-users view converging EU agendas of Natura 2000 and CAP. *Land Use Policy*, 24(2), pp.362–373. Available at: http://www.sciencedirect.com/science/article/pii/S0264837706000226 [Accessed October 15, 2015].

Vollenweider, X., Di Falco, S. & O’Donoghue, C., 2011. *Risk preferences and voluntary agri-environmental schemes : does risk aversion explain the uptake of the Rural Environment Protection Scheme ?*, London. Available at: http://eprints.lse.ac.uk/37585/.

Wall, D. et al., 2011. Using the nutrient transfer continuum concept to evaluate the European Union Nitrates Directive National Action Programme. *Environmental Science & Policy*, 14(6), pp.664–674. Available at: http://www.sciencedirect.com/science/article/pii/S1462901111000694 [Accessed October 30, 2015].

Walsh, K., 2009. *A Survey of the needs of Burren Farm Families Commissioned by Burrenbeo Trust Limited in association with the Burren Irish Farmers Association Supported by The Heritage Council by*, Bunboyne. Available at: http://www.heritagecouncil.ie/landscape/publications/?L=zxlvjyvzdybqv.

Whelan, J. & Fry, J., 2010. *The Irish Rural Environment Protection Scheme and the lack of Strategic*

Environmental Assessment, Available at: http://t-stor.teagasc.ie/handle/11019/700.

Whelan, J., Fry, J. & Green, S., 2010. *Consideration of landscape in the framework documentation during the evolution of the Rural Environment Protection Scheme (REPS) in the Republic of Ireland*, Available at: www.tnet.teagasc.ie/rerc/.

Wilkinson, M.E., Quinn, P.F. & Welton, P., 2010. Runoff management during the September 2008 floods in the Belford catchment, Northumberland. *Journal of Flood Risk Management*, 3(4), pp.285–295.

Yan, M.-J., Humphreys, J. & Holden, N.M., 2013. Life cycle assessment of milk production from commercial dairy farms: The influence of management tactics. *Journal of Dairy Science*, 96(7), pp.4112–4124.

Zimmermann, A. & Britz, W., 2016. European farms' participation in agri-environmental measures. *Land Use Policy*, 50, pp.214–228. Available at: http://www.sciencedirect.com/science/article/pii/S0264837715002902 [Accessed October 30, 2015].