An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

15S619–Farming and Natural Resources: Measures for Ecological Sustainability

Final Report

This project was funded under the Department of Agriculture, Food and the Marine Competitive Funding Programme.

SUMMARY

The primary objective of the FARM_ECOS project was to identify approaches to increase habitat quantity, enhance habitat quality and improve ecological connectivity, from farm to landscape scale. Key outcomes from include:

• Highlighting the importance of landscape-scale approaches in the design of agri-environment measures and schemes.

• Recognising that there are a variety of habitats on Irish farms, but some are valued more (by policy) than others. In the absence of policy-recognition, vital habitats (and ecosystem services that they deliver) are in danger of being lost to intensification or abandonment.

• Identifying a lack of focus on habitat quality in previous AES, which has contributed to the fact that there was no significant difference in the quality of habitats between farms that participated in AES and those that did not. The development of habitat quality indicators and scorecards as part of Farm_ECOS can contribute significantly to the design and implementation of future results-based approaches.

• Recognising that one-size does not fit all: Different habitats host different species, thus there is a need for a heterogeneity between habits, but also heterogeneity within habitats. Universal management prescriptions for a farmland linear habitat (such as a hedgerow) may not benefit all taxa equally.

• Modelling and mapping delivery of ecosystem services at a landscape scale and identifying habitats that act as hotspots for delivery of ecosystem services. The study also concluded that habitats with higher scores of habitat quality showed a positive relationship with carbon storage and pollinator abundance, but had lower values of income from food and fibre production.

A key impact of this project was the design and evaluation of indicators and rapid assessment tools to assess habitat quality. The lessons learned from these approaches have helped, and will continue to help inform the design of future agri-environment measures and schemes.

KEYWORDS

Habitat quality; Ecosystem Services; results-based

ACRONYM

FARM-ECOS

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Section 1 - Research Approach & Results

Start Date

01 June 2017

End Date

31 December 2021

Research Programme

Research Stimulus Fund

TRL Scale

TRL 5: Technology validated in relevant environment

NRPE Priority area

Sustainable Food Production and Processing

Total DAFM Award

€890,846.90

Total Project Expenditure

€770,680.56

Rationale for undertaking the Research

The widespread decline in global biodiversity, including farmland biodiversity, represents a major global conservation challenge. Approximately 50% of all European plant and animal species are dependent on agricultural practices. Changes in farming practices (e.g. intensification, specialisation, abandonment) can lead to a decrease in the quantity and quality of farmland habitats and a reduction in associated ecosystem services (including: provisioning services (e.g. production of food and fibre); regulatory services (e.g. water quality, biodiversity, agricultural pest control), cultural services (e.g. recreation, aesthetic) and supporting services (e.g. nutrient cycling), Emerging research and policy agendas are now based on sustainable management of agricultural land and natural resources, to enhance provision of ecosystem services. Conservation of natural resources and ecosystems services are key environmental objectives of the European Union, with agronomic and ecological objectives now integrated into EU strategies and policies (EU Farm to Fork; EU Biodiversity Strategy for 2030). Agri-environment schemes (AES) are an important policy mechanism for the protection of natural resources and provision of ecosystem services. There are requirements for ongoing monitoring and evaluation of existing measures, there is a need to identify novel, cost-effective measures and approaches for inclusion in future agri-environment policy. A key blind-spot with many historic AES has been a lack of habitat quality objectives. This project aimed to identify novel, cost-effective measures and approaches to increase habitat quantity, enhance habitat quality and improve ecological connectivity, and support the provision of ecosystem services.

.**Methodology**

The project consisted of a large, multi-disciplinary team, incorporating five primary research institutes. Six Post-Doctoral Researchers and two PhD students were recruited over the course of the project. The project was divided into seven research work-packages and two demonstration and dissemination

work-packages. The study employed a variety of research methods, including literature review, engagement with stakeholders, laboratory work, field-work, GIS activity and a variety of statistical and modelling approaches.

• A number of literature reviews were completed, focusing on soil quality parameters, agri-environment measures for biodiversity, and the role of connectivity and landscape scale approaches in improving the effectiveness of agri-environment schemes and measures. Elements of the socio-economic work-package

was based on the analysis of data from a farmer questionnaires and through engagement with experts (agricultural economics, ecology, agri-environmental policy and agricultural extension).

• The majority of the field-work was undertaken in two case-study regions (Sligo and Wexford), with habitat mapping completed for both regions. Fifty-four farms were selected for study, incorporating a gradient of farming intensities and enterprises. Habitat sampling within these farms included gathering data on quantity, quality, connectivity. Novel “rapid assessment habitat scorecards” were developed (and refined in the field) and used to assess the quality of habitats in participating farms. Coupled with habitat data, additional information in relation to more specific ecological and environmental parameters were

collected on study farms, including data on: soil quality (soil sampling), invertebrates (malaise traps); pollinators (pan-traps); botanical data (quadrats); and wider ecosystem services (InVEST model).

• Significant GIS activity was undertaken, initially with regard to mapping habitats in case-study regions, but also when determining the role of habitat connectivity. GIS, coupled with modelling, was used when identifying hotspots for delivery of ecosystem services and analysing trade-offs in ecosystem services.

• Robust statistical methods were employed when analysing the integrated datasets.

Project Results

• The importance of landscape-scale approaches: Considering landscape-scale in the design and implementation of agri-environment measures and schemes is vital to the success of biodiversity conservation and delivery of ecosystem services. At the time of study, landscape targeted measures were not widely implemented in Irish agri-environment schemes. It is note-worthy that the latest Irish scheme, ACRES, has now included cooperation approaches in its design.
• Addressing Habitats Quality: Habitat quantity and quality did not significantly differ between farms participating in an agri-environment scheme and those not participating in a scheme. However, most Irish AES to-date have focused more on measures to retain habitat quantity, as opposed to measures that enhance habitat quality. FARM_ECOS developed indicators and scorecards to assess habitat quality. The latest AES in Ireland has now incorporated result-based approaches (incorporating rapid assessment scorecards designed by FARM_ECOS) in an effort to enhance habitat quality. FARM_ECOS has identified that more work is needed to address habitat quality in soils (e.g. soil health).
• Valuing habitats: There was no difference, across farm management intensities, in the proportion of farm area occupied by (eligible) landscape features highlighting the importance of habitat recognition (valuing) by policy. However, at the time of study, many farmland habitats (e.g. heath, peatland, ponds, scrub), were deemed ineligible under the Basic Payment Scheme despite these habitats being as ecologically important as those that were eligible. These ineligible habitats have largely disappeared from most intensive farms; have reduced on intermediate farms, and are at risk of reducing on extensive farms. It is note-worthy that the latest Irish CAP Strategic Plan has begun to recognise the value of a number of ineligible habitats.
• One-size does not fit all: Different species have different habitat requirements, thus there is a need to retain a heterogeneity between habitats: Hoverflies were positively associated with farms with large fields and drainage ditches; Bumble bees were positively associated with arable crop farms, with a large quantity of hedgerow present; Solitary bees were negatively associated with arable crop farms but positively associated with high floral species richness. However, there is also a need for heterogeneity within habitats, syphids for example have a preference for dense hedgerows, whilst sciomyzidae have a preference for open hedgerows.
• Ecosystem services, trade-offs and hotspots. FARM_ECOS explored the spatial supply of four ecosystem services in two study regions, and identified hotspots of ES supply and trade-offs amongst the selected ecosystem services. Results highlighted a positive correlation between habitat quality, carbon storage and pollinator supply. Results also showed that some trade-off between these regulating services and provisioning services (food and fibre production associated income). Habitats with higher scores of habitat quality showed (overall) lower values of income from food and fibre production, while having a positive relationship with carbon storage and pollinator abundance. The separate ES model maps presented in this study allow policy-makers to understand the spatial distribution and patterns of each ES supply, whilst the hotspot maps facilitate understanding of where the supply of several ES is higher.

Section 2 - Research Outputs

Summary of Project Findings

The project has engaged frequently with:

Policy-makers
• The study highlighted the importance of habitat recognition by policy, and in the absence of policy recognition, ineligible habitats (and the ecosystem services that they deliver) were in danger of being lost. This information was published in a scientific journal, presented to policy-makers, and included in a presentation to the Citizens' Assembly on Biodiversity loss. Revisions to policy have subsequently been made.
• Habitat quality indicators and scorecards were developed as part of FARM_ECOS; published in scientific literature; and presented to policy-makers at a dedicated workshop. The results have helped inform elements of the results-based approaches in the new ACRES scheme.

Research community
• The FARM_ECOS study developed modelling approaches (e.g. choice modelling approach, modelling delivery of ecosystem services etc.). These approaches can inform future research to apply this methodology integrated with GIS landscape databases.
• There are knowledge gaps in terms of habitat impacts, scale and temporal effects and a lack of appreciation for the nuance that exists in providing sufficient ecological resources for different groups of species (e.g. pollinators, biocontrol agents) in agricultural landscapes. This study adds to the research base in this area.
• The project has trained 2 PhD students and six post-doctoral researchers.

Industry
• The study provides information on the potential of Tetanocera elata as a biological control agent of pestiferous slugs. These findings have potential benefits from an agri-industry point of view, particularly in light of objectives to seek greater biocontrol approaches (i.e. as per EU Biodiversity Strategy objectives).
• The study demonstrated approaches to map the quantity and quality of habitats. This information can help inform the agri-food industry, who are placing increased emphasis on nature-friendly production practices. Sustainability accreditation is likely to include biodiversity in future benchmarking of environmental sustainability.

Summary of Staff Outputs

Research Output	Male	Female	Total Number
PhD student	1	1	2
Post Doctorates	3	3	6
Research Technicians/ Assistants	0	1	1

Summary of Academic Outputs

Research Output	Total Number	Details
PhD Theses	2	S Ruas (2021): Factors affecting biodiversity-based ecosystem services in agricultural landscapes. PhD Thesis GMIT K D'Ahmed (2021): Evaluating the ecosystem function of selected dipteran families and their role as indicators of farm habitat quality in Ireland. PhD Thesis NUIG
Publications in Peer Reviewed Scientific Journals	11	1. Cullen, P., Ryan, M., O'Donoghue, C., Hynes, S., Ó hUallacháin, D., Sheridan. H. 2020. Impact of farmer identity and attitudes on participation in agri-environment schemes. Land Use Policy. 95. https://doi.org/10.1016/j.landusepol.2020.104660 2. Cullen, P., Dupraz, P., Moran, J., Murphy, P., O'Flaherty, R., O'Donoghue, C., O'Shea, R., Ryan, M. 2018. Agri-environment scheme design: past lessons and future suggestions. Eurochoices. 17(3) 26-30. https://onlinelibrary.wiley.com/doi/epdf/10.1111/1746-692X.12187 3. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J., Hodge, S., White, B., Gormally, M., 2020. Linear habitats across a range of farming intensities contribute differently to dipteran abundance and diversity. Insect Conservation and Diversity 14, (3) 335-347. 4. D.Ahmed, K.S., Gormally, M., Williams, C., McDonnell, R., Bistline-East, A., Carnaghi, M., Ó hUallacháin, D., Stephens, C. (2019) Biological control of pestiferous slugs using Tetanocera elata (Fabricius) (Diptera: Sciomyzidae): Larval behavior and feeding on slugs exposed to Phasmarhabditis hermaphrodita (Schneider, 1859). Biological Control 135: 1-8 5. O'Donoghue, C., Hynes, S., Kilgarriff, P., Ryan, M., Tsakiridis, A. (2020). Assessing preferences for rural landscapes: An attribute based choice modelling approach. Bio-based and Applied Economics 9(2): 171-200. 6. Rotches-Ribalta, R., Ruas, S., D.Ahmed, K.S., Gormally, M., Ryan, M., Stout, J., White, B., Lee, A. Moran, J, and Ó hUallacháín, D. (2020). Assessment of semi-natural habitats and landscape features on Irish farmland – New insights to inform EU Common Agricultural Policy implementation. Ambio: Published online 7. Ruas, S., Kellly, R., Ahmed, K., Maher, S., O'Hora, E., Volpato, A., Ó hUallachain, D., Gormally, M.J., Stout, J.S., Moran, J. (2021) Does landscape structure affect the presence of woodland specialist pollinators in farmland? Implications for Agri-Environment Scheme design. Biology and Environment. Accepted 8. Ruas, S. Rotchés-Ribalta, R., Ó hUallacháin, D., D'Ahmed, K., Gormally, M., Stout, J., White, B., Moran, J. (2021) Selecting appropriate plant indicator species for Results-Based Agri-environment payments schemes. Ecological Indicators, 126 9. Ruas, S., Rotchés-Ribalta, R., Ó hUallacháin, D., Volpato, A., Gormally, M., White, B., Moran J. (2022) Assessing stone walls habitat quality – which factors effect bryophytes and macrolichens on farmland stone walls in Ireland? Ecological Indicators 10. Tsakiridis, A., O'Donoghue, C., Ryan, M., Cullen, P., Ó hUallachain, D., Sheridan, H., Stout, J. (2022) Examining the relationship between farmer participation in an agri-environment scheme and the quantity and quality of semi-natural habitats on farms. Ecosystem Services 11. Volpato, A., D.Ahmed, K.S., Williams, C.D., Day, M. F., O'Hanlon, A., Ruas, S., Rotches-Ribalta, R., Mulkeen, C., Ó hUallacháin, D. and Gormally, M.J. (2019) Using Malaise traps to assess aculeate Hymenoptera associated with farmland linear habitats across a range of farming intensities. Insect Conservation and Diversity, 13(3), 229-238.
Peer Reviewed Conference Papers	19	12. D.Ahmed, K.S., Stephens, C., Bistline-East, A., Williams, C.D., Mc Donnell, R.J., Carnaghi, M., Ó hUallachain, D., & Gormally, M.J. (2019). Controlling pest slugs without chemicals the story of the fly Tetanocera elata and the worm Phasmarhabditis hermaphrodita. BES Annual Meeting, Belfast, UK, December 2019. 13. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J. White, B., Gormally, M., 2020. Assessing biodiversity value of farm linear habitats across different levels of farming intensity in northwest of Ireland, Co. Sligo using Diptera as bioindicators. ICE2020, Helsinki, Finland, July 2020 (accepted). Note: the revised conference date is July 2022 due to Covid 19. 14. D.Ahmed, K.S., Stephen, C., Bistline-East, A., Williams, C.D., McDonnell, R.J., Carnaghi, M., Ó hUallachain, D., and Gormally, M.J. (2019) Laboratory investigations on the effects of prey type and availability on the larval stages of the slug killing fly, Tetanocera elata (Diptera: Sciomyzidae). 2nd Ecology and Evolution Conference, Galway, January, 2019. 15. Day, M. F., D.Ahmed, K.S., Volpato, A., O'Hanlon, A., Hughes, A., Ó hUallacháin, D, Gormally, M.J. 2019. Malaise trap by-catch: How can it contribute to our understanding of invertebrate diversity in farmed landscapes? BES Annual Meeting, Belfast, UK, December 2019 16. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J., Hodge, S., White, B., Gormally, M., 2020. Evaluating different linear farm habitats for selected dipteran families: Implications for diversity and associated ecosystem functions. IEA3, Dublin, Ireland, 7-8-Jan 2021. 17. D.Ahmed K.S., Volpato A., Mulkeen C., O'Hanlon A., Carey J., Williams, C., Ruas, S., Moran, J., Rotches-Ribaltes, R,, Ó hUallacháin, D., Stout, J., White, B., Lee, A., and Gormally, M. (2019) Assessing habitat quality of farm linear habitats across a range of farming intensities in north west of Ireland using novel bioindicators. Ryan Institute Research Day, Galway, May 2019 18. Lee, A., Gormally, M., Ó hUallacháin, D., and White, B. (2019) Investigating various soil parameters pertaining to soil health status in Irish soils and potential impacts on biodiversity. Challenges in analysis of complex natural mixtures: Faraday Discussion. Edinburgh, May 2019 19. Ó hUallacháin, D. (2022) Two bees or not two bees: agri-ecology policy and practice. National Biodiversity Conference. 20. Ó hUallacháin, D. (2022) Agri-ecology policy and practice. European Dairy Farmers Conference

		21. Ó hUallacháin, D. et al. (2018) Farmland biodiversity – the Irish context. Eurodairy –Farmland Biodiversity in the European context. Moorepark, December, 2018 22. Ó hUallacháín, D., Moran, J., Ruas, S., Gormally, M., Ahmed, K.S., Stout, J., Maher. S., Kelly, R., Lee, A., White, B., Rotches-Ribalta, R. (2019) Farming and Natural Resources: Measures for Ecological Sustainability. CIEEM, Apr 2020 23. Rotches Ribalta, R. & Ó hUallacháin, D. (2018) Agri-environment scheme design: the importance of landscape scale. EAAE seminar on sustainability in the Agri-Food sector. Galway, August 2018. 24. Rotches Ribalta, R., Ruas, S., Moran, J. & Ó hUallacháin, D. (2018) Farm and landscape scale approach to assess habitat quality and biodiversity conservation in Irish agricultural systems. SIBECOL. Barcelona, February 2019 25. Rotches-Ribalta, R., Ruas, S., Moran, J., Gormally, M., Ahmed, K.S., Stout, J., and Ó hUallacháín, D. (2019) An assessment of semi-natural habitats across a gradient of farming intensities. 2nd Ecology and Evolution Conference, Galway, January, 2019. 26. Rotches Ribalta, R., Ruas, S., Moran, J. & Ó hUallacháin, D. (2018) Farm and landscape scale approach to assess habitat quality and biodiversity conservation in Irish agricultural systems. Teagasc Johnstown Castle Seminar Series, Wexford, April 2019 27. Ruas, S., Rotches-Ribalta, R., Ó hUallacháín, D., D.Ahmed, K.S., Gormally, M., Ryan, M., Stout, J., White, B., Lee, A. and Moran, J. (2019) Assessing multiple ecosystem services in Irish farmland – scaling up payments for ecosystem services (PES). 2nd Ecology and Evolution Conference, Galway, January, 2019. 28. Tsakiridis, A., O'Donoghue, C., Ryan, M., Ó hUallacháín, D. (2021). Marginal abatement costs of farm-based biodiversity enhancement measures using a scorecard approach. Environ 2021: 31st Irish Environmental Researchers Colloquium, 16-18 June (virtual). 29. Tsakiridis, A., O'Donoghue, C., Ryan, M., Cullen, P., Ó hUallacháín, D., Sheridan, H. (2020). Examining the effects of farmers' participation in an agri-environment scheme on the quality and quantity of semi-natural habitats. Environ 2020: 30th Irish Environmental Researchers Colloquium, 20-22 October (virtual). 30. Volpato, A., D.Ahmed, K.S., Williams, C.D., Day, M. F., O'Hanlon, A., Ruas, S., Rotches-Ribalta, R., Mulkeen, C., Ó hUallacháin, D. and Gormally, M.J. (2019) Using Malaise traps to assess aculeate Hymenoptera associated with farmland linear habitats across a range of farming intensities. Insect Conservation and Diveristy, (Submitted). Ryan Institute Research Day, Galway, May 2019 31. White, B. et al (2019) Life on Land. DCU and the Sustainable Development Goals: Recognising and enhancing our research contribution, Workshop. Dublin City University, May, 2019
Other	1	Ruas, S. et al. (2021) Spatial distribution of ecosystem services in Irish landscapes. Research Report

Intellectual Property

This study is of relevance to a wide range of stakeholders including land-managers, research community and to policymakers. Intellectual Property dis not arise, as 'Open science' underpinned all FARM_ECOS activities. The project adopted a FAIR (Findable, Accessible, Interoperable and Re-usable) approach and focused on the open and transparent sharing and distribution of knowledge and material throughout the project. As demonstrated in this report, information from the study was disseminated widely through publishing of reports, presentations at conferences, publishing of popular articles, and publishing in international scientific journals. New data, new research approaches and new modelling approaches were all developed throughout the timeframe of the project and were included in dissemination activity.

Summary of other Project Outputs

N/A

Potential Impact related to Policy, Practice and Other Impacts

Impact	Details
Environmental Sustainability	• The importance of landscape-scale approaches: Considering landscape-scale in the design and implementation of agri environment measures and schemes is vital to the success of biodiversity conservation and delivery of ecosystem services. At the time of study, landscape targeted measures were not widely implemented in Irish agri-environment schemes. It is note-worthy that the latest Irish scheme, ACRES, has now included cooperation approaches in its design • Addressing Habitats Quality: Habitat quantity and quality did not significantly differ between farms participating in an agri-environment scheme and those not participating in a scheme. However, most Irish AES to-date have focused more on measures to retain habitat quantity, as opposed to measures enhance habitat quality. FARM_ECOS developed a variety of indicators and scorecards to assess habitat quality. The latest AES in Ireland has now incorporated result-based approaches (incorporating rapid assessment scorecards designed by FARM_ECOS) in an effort to enhance habitat quality. FARM_ECOS has identified that more work is needed to address habitat quality in soils (e.g. soil health). • Valuing habitats: There was no difference, across farm management intensities, in the proportion of farm area occupied by (eligible) landscape features; highlighting the importance of habitat recognition (valuing) by policy. However, at the time of study, many farmland habitats (e.g. heath, peatland, ponds, scrub), were deemed ineligible under the Basic Payment Scheme despite these habitats being as ecologically important as those that were eligible. These ineligible habitats have largely disappeared from most intensive farms; have reduced on intermediate farms, and are at risk of reducing on extensive farms. It is note-worthy that the latest Irish CAP Strategic Plan has begun to recognise the value of a number of ineligible habitats. • One-size does not fit all: Different species have different habitat requirements, and thus there is a need to retain a heterogeneity between habitats: Hoverflies were positively associated with farms with large fields and drainage ditches; Bumble bees were positively associated with arable crop farms, with a large quantity of hedgerow present; Solitary bees were negatively associated with arable crop farms but positively associated with high floral species richness. However, there is also a need for heterogeneity

	within habitats, syphids for example have a preference for dense hedgerows, whilst sciomyzidae have a preference for open hedgerows.
Industry	• The study provide information on the potential of Tetanocera elata as a biological control agent of pestiferous slugs. These findings have potential benefits from an agri-industry point of view, particularly in light of objectives to seek greater biocontrol approaches (i.e. as per EU Biodiversity Strategy objectives). • The study demonstrated approaches to map the quantity and quality of habitats. This information can help inform the agri-food industry, who are placing increased emphasis on nature-friendly production practices. Sustainability accreditation is likely to include biodiversity in future benchmarking of environmental sustainability.

Dissemination Activities

Activity	Details
Media Events	• Ó hUallacháin (2020), Raidio na Gaeltachta 06/2020 • Ó hUallacháin (2020), Raidio na Gaeltachta 07/2020 • Ó hUallacháin (2020) Tillage Edge Podcast 10/2020 • Ó hUallacháin (2021), Raidio na Gaeltachta 02/2021 • Ó hUallacháin (2021), Raidio na Gaeltachta 04/2021 • Ó hUallacháin (2021), Raidio na Gaeltachta 09/2021 • Ó hUallacháin, D. (2021) - Webinar Multi-actor collaboration for sustainable farming • Ó hUallacháin, D. (2021) Contribution to Shared island climate and biodiversity dialogue
Seminars at which results were presented	Moran, J. (2020) CUA research symposium 16th-17th January. Presentation title: Agro-ecology: research policy and practices supporting sustainable rural development in Ireland and beyond. • Moran, J. (2020) The role of farming for nature in sustainable land use/food systems. The Sustainability Lunch Time Series, GMIT 21/2//2020 • Moran, J. (2021). High Nature Value Farmland in Ireland: Marginal farming or central role in combating climate and biodiversity challenges? Teagasc Signpost Webinar Series-02/07/2021. Available online at https://www.youtube.com/watch?v=eAhwzOvZpBU • Ó hUallacháin (2020) Seminar to dairy advisors (09/2020) • Ó hUallacháin (2020) Seminar to Teagasc Signpost Series (09/2020) • Ó hUallacháin and Finn (2020) Seminar to Wexford Field Naturalist Club (11/2020) Presentations to third level institutes and agricultural colleges. - • Ó hUallacháin (2021) Presentation to students in WIT (02/2021) • Ó hUallacháin (2021) Presentation to students in UCC (03/2021) • Ó hUallacháin (2021) Presentation to students in UCD (03/2021) • Ó hUallacháin (2021) Presentation to students in DkIT (04/2021) • Ó hUallacháin (2021) Presentation to students in UCC (05/2021)
Workshops at which results were presented	Ó hUallacháin (2020) Grange Open Day (07/2020) • Ó hUallacháin (2021) Moorepark Open Day (09/2020) • Ó hUallacháin (2021) Presentation to advisors (LAWPRO, ASSAP) (11/2020) • Ó hUallacháin (2021) Farmer Discussion Group Presentation (11/2020)

Knowledge Transfer Activities

Identify knowledge outputs generated during this project.	• Knowledge on approaches to measure habitat quality for a variety of habitats. • Knowledge on the habitat requirements of indicator species and the implications for future agri-environment schemes. • Knowledge on selecting appropriate plant indicator species for Result-Based Agri-Environment Payments approaches. • Knowledge on the design and implementation of individual and integrated Rapid Assessment Scorecards for assessing habitat quality (for incorporation into future results-based approaches). • Knowledge on quantifying the value of ecosystem services associated with dominate agricultural habitats, through research, expert opinion and stakeholder engagement; including: o Identifying habitat requirements for specific pollinators o Knowledge on the biological control of pestiferous slugs o Multifunctional habitats: Assessment of potential to deliver ecosystem services, • Knowledge on the spatial distribution of ecosystem services in Irish landscapes. • Knowledge on the use of choice modelling approaches to assess societal preferences for landscapes. • Habitat maps at farm and landscape scale. • Knowledge on above and below ground sampling techniques.
Identify any knowledge transfer activities executed within the project.	• FARM_ECOS submission (2021): Farm_ECOS response to the DAFM Integrated Scorecard (REAPS). • FARM_ECOS submission (2021): Farm_ECOS response to the DAFM draft CAP Strategic Plans. • FARM_ECOS (2021): Eligible Habitats Eco-services Assessment. FARM_ECOS submission to DAFM. • Teagasc Submission (2021): Teagasc Comments and suggestions on Draft AECM measures and structures

	• Briefing note to DAFM (2021) Evaluation of the Quantity and Quality of EFAs (2019) • Briefing note to DAFM (2021) Impact of Cross Compliance on biodiversity (2019) • Moran, J. (2020) Irelands Payments by Results: how to incentivise and reward nature friendly farming. RSPB NI and Nature Friendly Farming Network Agriculture Policy Webinars 22nd July 2020. Available at https://www.ringofgullion.org/news/agriculture-policywebinars/ and https://www.youtube.com/watch?v=VgzkrOH-Svc • Moran, J. (2020) Ireland's Results Based Payment System: Focus on Results Indicators. Results Based Payments Network Seminar- Assessing Results-Based Indicators". 20th June 2020 Available at RBP network webinar "Assessing Results-based Indicators" -YouTube
List any impacts resulting from the knowledge transferred during the project.	• The importance of landscape-scale approaches: Considering landscape-scale in the design and implementation of agri-environment measures and schemes is vital to the success of biodiversity conservation and delivery of ecosystem services. It is note-worthy that the latest Irish scheme, ACRES, has now included cooperation approaches in its design. • Addressing Habitats Quality: FARM_ECOS developed a variety of indicators and scorecards to assess habitat quality. The project engaged with DAFM when designing and revising the REAPS project methodology. The project made submissions to DAFM in relation to scorecards and indicators. The latest AES in Ireland has now incorporated result-based approaches (incorporating rapid assessment scorecards designed by FARM_ECOS) in an effort to enhance habitat quality. • Valuing habitats: The project disseminated widely in relation to the importance of recognising a heterogeneity of habitats throughout the farming landscape. It is note-worthy that the latest Irish CAP Strategic Plan has begun to recognise the value of a number of ineligible habitats highlighted by FARM_ECOS. • Engagement: The project has engaged with other projects (e.g. HNVFarmFOrBio, SMARTER_BufferZ) and a number of EIPs (e.g. BRIDE, Caomhnú Árann). Knowledge generated from FARM_ECOS and these projects/EIPS have helped inform

Section 3 – Leveraging, Future Strategies & Reference

Leveraging Metrics

N/A

Future Strategies

Continue to dissemination material from FARM_ECOS to relevant stakeholders.

Policy:

Continue to engage with policy-makers to help inform the design of agri-environment measures and schemes.

There are opportunities to integrate some of the messages from FARM_ECOS into revisions of the CAP Strategic Plan, e.g. potential to focus on habitat quality approaches in Pillar 1 as well as in Pillar 2.

Industry:

Engage with industry, disseminate key messages from FARM_ECOS to the wider agri-food industry .. e.g. integrate messages on the value of habitat quantity and quality on Teagasc Signpost farms. Share messages from FARM_ECOS to new ACRES Co-operation projects

Research:

Continue to evaluate approaches to support biodiversity in agricultural landscapes through robust scientific approaches. Share messages from FARM_ECOS with EIPS, research projects and disseminate material to third level institutes.

Project Publications

Scientific manuscripts

1. Cullen, P., Ryan, M., O'Donoghue, C., Hynes, S., Ó hUallacháin, D., Sheridan. H. 2020. Impact of farmer identity and attitudes on participation in agri-environment schemes. Land Use Policy. 95. https://doi.org/10.1016/j.landusepol.2020.104660

2. Cullen, P., Dupraz, P., Moran, J., Murphy, P., O'Flaherty, R., O'Donoghue, C., O'Shea, R., Ryan, M. 2018. Agri-environment scheme design: past lessons and future suggestions. Eurochoices. 17(3) 26-30.https://onlinelibrary.wiley.com/doi/epdf/10.1111/1746-692X.12187

3. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J., Hodge, S., White, B., Gormally, M., 2020. Linear habitats across a range of farming intensities contribute differently to dipteran abundance and diversity. Insect Conservation and Diversity 14, (3) 335-347.

4. D.Ahmed, K.S., Gormally, M., Williams, C., McDonnell, R., Bistline-East, A., Carnaghi, M., Ó hUallacháin, D., Stephens, C. (2019) Biological control of pestiferous slugs using Tetanocera elata (Fabricius) (Diptera: Sciomyzidae): Larval behavior and feeding on slugs exposed to Phasmarhabditis hermaphrodita (Schneider, 1859). Biological Control 135: 1-8

5. O'Donoghue, C., Hynes, S., Kilgarriff, P., Ryan, M., Tsakiridis, A. (2020). Assessing preferences for rural landscapes: An attribute based choice modelling approach. Bio-based and Applied Economics 9(2):171-200.

6. Rotches-Ribalta, R., Ruas, S., D.Ahmed, K.S., Gormally, M., Ryan, M., Stout, J., White, B., Lee, A. Moran, J,and Ó hUallacháín, D. (2020). Assessment of semi-natural habitats and landscape features on Irish farmland – New insights to inform EU Common Agricultural Policy implementation. Ambio: Published online

7. Ruas, S., Kellly, R., Ahmed, K., Maher, S., O'Hora, E., Volpato, A., Ó hUallachain, D., Gormally, M.J., Stout, J.S., Moran, J. (2021) Does landscape structure affect the presence of woodland specialist pollinators in farmland? Implications for Agri-Environment Scheme design. Biology and Environment. Accepted

8. Ruas, S. Rotchés-Ribalta, R., Ó hUallacháin, D., D'Ahmed, K., Gormally, M., Stout, J., White, B., Moran, J. (2021) Selecting appropriate plant indicator species for Results-Based Agri-environment payments schemes. Ecological Indicators, 126

9. Ruas, S., Rotchés-Ribalta, R., Ó hUallacháin, D., Volpato, A., Gormally, M., White, B., Moran J. (2022) Assessing stone walls habitat quality – which factors effect bryophytes and macrolichens on farmland stone walls in Ireland? Ecological Indicators
10. Tsakiridis, A., O'Donoghue, C., Ryan, M., Cullen, P., Ó hUallachain, D., Sheridan, H., Stout, J. (2022) Examining the relationship between farmer participation in an agri-environment scheme and the quantity and quality of semi-natural habitats on farms. Ecosystem Services
11. Volpato, A., D.Ahmed, K.S., Williams, C.D., Day, M. F., O'Hanlon, A., Ruas, S., Rotches-Ribalta, R., Mulkeen, C., Ó hUallacháin, D. and Gormally, M.J. (2019) Using Malaise traps to assess aculeate Hymenoptera associated with farmland linear habitats across a range of farming intensities. Insect Conservation and Diversity, 13(3), 229-238.

Conference presentations

12. D.Ahmed, K.S., Stephens, C., Bistline-East, A., Williams, C.D., Mc Donnell, R.J., Carnaghi, M., Ó hUallachain, D., & Gormally, M.J. (2019). Controlling pest slugs without chemicals the story of the fly Tetanocera elata and the worm Phasmarhabditis hermaphrodita. BES Annual Meeting, Belfast, UK, December 2019.
13. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J. White, B., Gormally, M., 2020. Assessing biodiversity value of farm linear habitats across different levels of farming intensity in northwest of Ireland, Co. Sligo using Diptera as bioindicators. ICE2020, Helsinki, Finland, July 2020 (accepted). Note: the revised conference date is July 2022 due to Covid 19.
14. D.Ahmed, K.S., Stephen, C., Bistline-East, A., Williams, C.D., McDonnell, R.J., Carnaghi, M., Ó hUallachain, D., and Gormally, M.J. (2019) Laboratory investigations on the effects of prey type and availability on the larval stages of the slug killing fly, Tetanocera elata (Diptera: Sciomyzidae). 2nd Ecology and Evolution Conference, Galway, January, 2019.
15. Day, M. F., D.Ahmed, K.S., Volpato, A., O'Hanlon, A., Hughes, A., Ó hUallacháin, D, Gormally, M.J. 2019. Malaise trap by-catch: How can it contribute to our understanding of invertebrate diversity in farmed landscapes? BES Annual Meeting, Belfast, UK, December 2019
16. D.Ahmed, K.S., Volpato, A., Day, M.F., Mulkeen, C., O'Hanlon, A., Carey, J., Williams, C., Ruas, S., Moran, J., Rotchés-Ribalta, R., Ó hUallacháin, D., Stout, J., Hodge, S., White, B., Gormally, M., 2020. Evaluating different linear farm habitats for selected dipteran families: Implications for diversity and associated ecosystem functions. IEA3, Dublin, Ireland, 7-8-Jan 2021.
17. D.Ahmed K.S., Volpato A., Mulkeen C., O'Hanlon A., Carey J., Williams, C., Ruas, S., Moran, J., Rotches- Ribaltes, R,, Ó hUallacháin, D., Stout, J., White, B., Lee, A., and Gormally, M. (2019) Assessing habitat quality of farm linear habitats across a range of farming intensities in north west of Ireland using novel bioindicators. Ryan Institute Research Day, Galway, May 2019
18. Lee, A., Gormally, M., Ó hUallacháin, D., and White, B. (2019) Investigating various soil parameters pertaining to soil health status in Irish soils and potential impacts on biodiversity. Challenges in analysis of complex natural mixtures: Faraday Discussion. Edinburgh, May 2019
19. Ó hUallacháin, D. (2022) Two bees or not two bees: agri-ecology policy and practice. National Biodiversity Conference.
20. Ó hUallacháin, D. (2022) Agri-ecology policy and practice. European Dairy Farmers Conference
21. Ó hUallacháin, D. et al. (2018) Farmland biodiversity – the Irish context. Eurodairy –Farmland Biodiversity in the European context. Moorepark, December, 2018
22. Ó hUallacháín, D., Moran, J., Ruas, S., Gormally, M., Ahmed, K.S., Stout, J., Maher. S., Kelly, R., Lee, A., White, B., Rotches-Ribalta, R. (2019) Farming and Natural Resources: Measures for Ecological Sustainability. CIEEM, Apr 2020
23. Rotches Ribalta, R. & Ó hUallacháin, D. (2018) Agri-environment scheme design: the importance of landscape scale. EAAE seminar on sustainability in the Agri-Food sector. Galway, August 2018.
24. Rotches Ribalta, R., Ruas, S., Moran, J. & Ó hUallacháin, D. (2018) Farm and landscape scale approach to assess habitat quality and biodiversity conservation in Irish agricultural systems. SIBECOL. Barcelona, February 2019
25. Rotches-Ribalta, R., Ruas, S., Moran, J., Gormally, M., Ahmed, K.S., Stout, J., and Ó hUallacháín, D. (2019) An assessment of semi-natural habitats across a gradient of farming intensities. 2nd Ecology and Evolution Conference, Galway, January, 2019.
26. Rotches Ribalta, R., Ruas, S., Moran, J. & Ó hUallacháin, D. (2018) Farm and landscape scale approach to assess habitat quality and biodiversity conservation in Irish agricultural systems. Teagasc Johnstown Castle Seminar Series, Wexford, April 2019
27. Ruas, S., Rotches-Ribalta, R., Ó hUallacháín, D., D.Ahmed, K.S., Gormally, M., Ryan, M., Stout, J., White, B., Lee, A. and Moran, J. (2019) Assessing multiple ecosystem services in Irish farmland – scaling up payments for ecosystem services (PES). 2nd Ecology and Evolution Conference, Galway, January, 2019.
28. Tsakiridis, A., O'Donoghue, C., Ryan, M., Ó hUallacháín, D. (2021). Marginal abatement costs of farm-based biodiversity enhancement measures using a scorecard approach. Environ 2021: 31st Irish Environmental Researchers Colloquium, 16-18 June (virtual).
29. Tsakiridis, A., O'Donoghue, C., Ryan, M., Cullen, P., Ó hUallacháín, D., Sheridan, H. (2020). Examining the effects of farmers' participation in an agri-environment scheme on the quality and quantity of semi-natural habitats. Environ 2020: 30th Irish Environmental Researchers Colloquium, 20-22 October (virtual).
30. Volpato, A., D.Ahmed, K.S., Williams, C.D., Day, M. F., O'Hanlon, A., Ruas, S., Rotches-Ribalta, R., Mulkeen, C., Ó hUallacháin, D. and Gormally, M.J. (2019) Using Malaise traps to assess aculeate Hymenoptera associated with farmland linear habitats across a range of farming intensities. Insect Conservation and Diveristy, (Submitted). Ryan Institute Research Day, Galway, May 2019
31. White, B. et al (2019) Life on Land. DCU and the Sustainable Development Goals: Recognising and enhancing our research contribution, Workshop. Dublin City University, May, 2019

Ph.D. theses

32. S Ruas (2021): Factors affecting biodiversity-based ecosystem services in agricultural landscapes. PhD Thesis GMIT
33. K D'Ahmed (2021): Evaluating the ecosystem function of selected dipteran families and their role as indicators of farm habitat quality in Ireland. PhD Thesis NUIG

Scientific Report

34. Ruas, S. et al. (2021) Spatial distribution of ecosystem services in Irish landscapes. Research Report Additional dissemination

Presentations at research seminar series etc held within Teagasc, GMIT, NUIG, DCU, TCD -

35. Moran, J. (2020) CUA research symposium 16th-17th January. Presentation title: Agro-ecology: research policy and practices supporting sustainable rural development in Ireland and beyond.
36. Moran, J. (2020) The role of farming for nature in sustainable land use/food systems. The Sustainability Lunch Time Series, GMIT 21/2//2020

37. Moran, J. (2021). High Nature Value Farmland in Ireland: Marginal farming or central role in combating climate and biodiversity challenges? Teagasc Signpost Webinar Series-02/07/2021. Available online at https://www.youtube.com/watch?v=eAhwzOvZpBU
38. Ó hUallacháin (2020) Seminar to dairy advisors (09/2020)
39. Ó hUallacháin (2020) Seminar to Teagasc Signpost Series (09/2020)
40. Ó hUallacháin and Finn (2020) Seminar to Wexford Field Naturalist Club (11/2020)

Presentations to third level institutes and agricultural colleges. -
41. Ó hUallacháin (2021) Presentation to students in WIT (02/2021)
42. Ó hUallacháin (2021) Presentation to students in UCC (03/2021)
43. Ó hUallacháin (2021) Presentation to students in UCD (03/2021)
44. Ó hUallacháin (2021) Presentation to students in DkIT (04/2021)
45. Ó hUallacháin (2021) Presentation to students in UCC (05/2021)

Presentation of findings to the DAFM, NPWS and other stakeholders.
46. FARM_ECOS submission (2021): Farm_ECOS response to the DAFM Integrated Scorecard (REAPS).
47. FARM_ECOS submission (2021): Farm_ECOS response to the DAFM draft CAP Strategic Plans.
48. FARM_ECOS (2021): Eligible Habitats Eco-services Assessment. FARM_ECOS submission to DAFM.
49. Teagasc Submission (2021): Teagasc Comments and suggestions on Draft AECM measures and structures
50. Briefing note to DAFM (2021) Evaluation of the Quantity and Quality of EFAs (2019)
51. Briefing note to DAFM (2021) Impact of Cross Compliance on biodiversity (2019)
52. Moran, J. (2020) Irelands Payments by Results: how to incentivise and reward nature friendly farming. RSPB NI and Nature Friendly Farming Network Agriculture Policy Webinars 22nd July 2020. Available at https://www.ringofgullion.org/news/agriculture-policy-webinars/ and https://www.youtube.com /watch?v=VgzkrOH-Svc
53. Moran, J. (2020) Ireland's Results Based Payment System: Focus on Results Indicators. Results Based Payments Network Seminar-Assessing Results-Based Indicators". 20th June 2020 Available at RBP network webinar "Assessing Results-based Indicators" - YouTube

Presentations at relevant workshops, agricultural shows, open days and farm walks.
54. Ó hUallacháin (2020) Grange Open Day (07/2020)
55. Ó hUallacháin (2021) Moorepark Open Day (09/2020)
56. Ó hUallacháin (2021) Presentation to advisors (LAWPRO, ASSAP) (11/2020)
57. Ó hUallacháin (2021) Farmer Discussion Group Presentation (11/2020)

Media engagement
Radio Interviews and podcasts where outcomes from FARM_ECOS were relayed.
58. Ó hUallacháin (2020), Raidio na Gaeltachta 06/2020
59. Ó hUallacháin (2020), Raidio na Gaeltachta 07/2020
60. Ó hUallacháin (2020) Tillage Edge Podcast 10/2020
61. Ó hUallacháin (2021), Raidio na Gaeltachta 02/2021
62. Ó hUallacháin (2021), Raidio na Gaeltachta 04/2021
63. Ó hUallacháin (2021), Raidio na Gaeltachta 09/2021
64. Ó hUallacháin, D. (2021) - Webinar Multi-actor collaboration for sustainable farming
65. Ó hUallacháin, D. (2021) Contribution to Shared island climate and biodiversity dialogue