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Scoping study: data collection requirements to inform strategies for sustainable agriculture at farm-level

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Executive summary

The aim of this small-scale study is to conduct a short literature review and a preliminary scoping exercise to identify data collection requirements to inform strategies for sustainable practices at farm level. The review and scoping exercise, focused on social science data, identifies data available in relation to farmers' implementation of sustainable practices at farm-level; deficits and gaps in the data currently available; and approaches to collect more comprehensive data. Data currently collected in relation to the extent of implementation of core practices at farm level are identified, specifically practices operationalising the Marginal Abatement Cost Curve (MACC)[1]. These existing data rely primarily on national inventory accounting data and Teagasc's National Farm Survey. Data in relation to factors determining implementation of practices at farm-level are not routinely collected in Ireland, however. Multiple social science studies published in the literature have undertaken data collection in relation to the implementation of sustainable practices, providing insights for the future development of more comprehensive and impactful instruments for routine data collection in Ireland. These studies include surveys identifying behavioural and attitudinal factors influencing implementation of sustainable practices at farm-level; studies identifying and monitoring indicators of farm-level and system-level resilience; and qualitative research on how and why implementation occurs at farm level considering contextual influences (such as the effectiveness of policy and extension interventions). However, most of the data generated by such publicly funded large and small-scale ad-hoc studies are not available in the form of Open Data in accordance with Findable, Accessible, Interoperable- or Reusable (FAIR) principles. Much is potentially to be gained from consolidating a national open dataset of social scientific data concerning the implementation of sustainable practices at farm level.

It is clear from this review and scoping exercise that diverse social science data is required to gain a comprehensive understanding of farm-level implementation factors necessary to inform effective policy and extension design. Both 'bottom up' and 'top down' policy and extension approaches to support farmers to implement sustainable practices are profiled in this review, and these require different data collection approaches. Mixed quantitative and qualitative data collection approaches are needed to capture the diversity of features, processes and associated success/fail factors of how policy and extension approaches operate on the ground. Multi-disciplinary social science knowledge is urgently needed to provide an evidence base to guide the effectiveness of rapidly diversifying sustainability programmes and projects. A social science data platform in relation to behavioural factors at farm-level - with diverse data from sociology, economics, anthropology, geographic and spatial sciences - stands to enhance other platforms such as the upcoming Sustainability Digital Platform. A main recommendation of this small-scale report is the establishment of such a social science data platform to provide policy-makers with an evidence-based decision-support tool in relation to achieving national impact in the promotion of sustainable practices at farm level.

[1] 'A marginal abatement cost curve – or MACC – is simple to understand when you break it down. In this context, 'abatement' means 'reducing'. A MACC presents the costs or savings expected from different opportunities, alongside the potential volume of emissions that could be reduced if implemented' www.climateworkscentre.org

Introduction

The aim of this small-scale study is to conduct a **short literature review** and a **preliminary scoping exercise** to identify data collection requirements to inform strategies supporting sustainable practices at farm level[2]. A diversity of sustainable practices at farm-level that are operationalised in the Irish are profiled in **Annex 1**.

National policy in Ireland recognises the importance of sustainable agriculture practices at farm level and the significant role they play in strengthening resilience towards climate change. Specifically, the Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan (2020) commits to take action (no. 11) to,

- 'Support the sector and foster sustainable growth, development, innovation and adaptation including through LIFE, Horizon Europe, the European Maritime and Fisheries Fund and Common Agriculture Policy (CAP) funding' (p. 27).
- 'Seek to adapt on-farm practices to enhance sustainable agriculture production', is an identified step to deliver this action with DAFM and Teagasc as lead authority and stakeholders (p. 75).

In Ireland, farmers are encouraged and supported through various channels (policy, agricultural extension and market signals) to make transitions towards implementing sustainable agriculture practices. This small-scale study undertakes a short review of current evidence regarding the extent to which farmers are implementing sustainable agriculture practices. The study will identify opportunities (key thematic areas for investigation; and indicators/metrics) for future qualitative research and quantitative surveys, which are supportive of informing strategies to enhance implementation of sustainable agriculture practices at farm level.

This small-scale study will undertake a short literature review and scoping study of:

- The **various channels** (programmes/measures/ground-up initiatives etc.) in Ireland through which farmers are encouraged and supported to make the transition to employing sustainable agriculture practices.
- The **sustainable agriculture practices** supported by the various channels.
- **Existing quantitative evidence** (in Ireland) regarding the extent of farmers' uptake of the identified sustainable agriculture practices; and **potential future survey approaches** to collecting other forms of quantitative evidence (relating to farmers' uptake of sustainable agriculture practices, the impacts of these practices, and also farm-level resilience).
- **Existing qualitative evidence** (in Ireland and internationally) regarding the influence of farmers' knowledge and behaviours etc. where uptake of sustainable agriculture practices is concerned; and **gaps & opportunities** for further qualitative studies.

[2] Sustainable farming 'is farming that meets the needs of existing and future generations, while also ensuring profitability, environmental health and social and economic equity. It favours techniques that emulate nature– to preserve soil fertility, prevent water pollution and protect biodiversity. It is also a way to support the achievement of global objectives, like the Sustainable Development Goals and Zero Hunger' https://www.unep.org/news-and-stories/story/beginners-guide-sustainable-farming.

- The profile of **extension/engagement/incentivising approaches** used within the various channels to mobilise and support farmers; and evidence (from Ireland and internationally) regarding the effectiveness of these approaches where farmer uptake/engagement is concerned.

Where available, activity data from sources such as the Central Statistics Office (CSO) and the Department of Agriculture, Food and the Marine (DAFM) are used in the estimation of national inventories for greenhouse gases (GHG) and ammonia. However, these data sources are at the aggregate level and are unable to capture specific farm management practices that can affect emissions; and shape farm-level resilience. Hence, other sources are required. In these instances, instruments such as the Teagasc National Farm Survey (NFS) can provide valuable nationally representative farm-level activity data to provide more insight[3]. It is necessary to identify additional opportunities to expand the **national quantitative dataset** in relation to the extent of farmers' use and uptake of sustainable agriculture practices on Irish farms, complementing research on the environmental impacts of these practices.

Furthermore, for agri-food systems to achieve enhanced **resilience** (i.e. absorptive, adaptive and transformative capacities) in responding to threats and shocks such as those caused by climate change, Ireland's Agri-Food Strategy 2030 identifies the need for a **systems-based** perspective. A systems-based perspective seeks to understand the social, economic and environmental dimensions of sustainability; and how associated variables inter-relate within an agri-food system to generate conditions for sustainability across a sub/system. It is necessary in the Irish context to identify a suite of indicators to understand existing and evolving conditions of system-level resilience, particularly indicators expressed at farm-level. These indicators are suitable for quantitative assessment, although the systems-oriented variables impacting resilience may also be identified and assessed qualitatively (using systems mapping).

The Agricultural Knowledge and Innovation System (AKIS) concept is particularly relevant for understanding **channels of influence** where farm-level activity is concerned, as it focuses on the roles, influences and impacts of different actors/institutions/policies operating together as a sub-/system (Knierim, 2015; Europa, 2021). Both quantitative and qualitative approaches are used to investigate challenges of influence through AKISs. Social Network Analysis (SNA) is an approach used quantitatively or qualitatively to understand and graphically construct AKISs, by identifying actors/institutions involved in a network; their inter-relations; and their relative degrees of connectedness and prominence in a network. Some limited SNA has been undertaken in the Irish context (Harrahill et al., 2023). While SNA studies are limited, there have been several **qualitative studies** of how (diverse) farmers may be engaged and supported (though policy programmes and extension across the AKIS) to farm more sustainably (Shortall, 2022); and of farm-level values and behaviours that determine implementation of sustainable agriculture practices (Farstad et al., 2022). There have also been studies of farmers as innovators of sustainable agriculture practices; and of how farmers (through policy and extension) may be facilitated to become innovators (O'Flynn, 2017). It is necessary to synthesise this evidence and to identify gaps. Key areas of application for existing

[3] The Teagasc National Farm Survey is conducted as part of the EU Farm Accountancy Data Network (FADN) and is representative by farm size and system based on the Irish census of agriculture conducted by the Central Statistics Office. Further information can be found at: https://www.teagasc.ie/rural-economy/rural-economy/national-farm-survey/

qualitative social science evidence across the AKIS must be identified, so that positive impacts of existing policies and programmes are increased and widened.

In this context, we incorporate a focus on the potential of **mixed (quantitative & qualitative) data & insights** that are necessary to provide an evidence-base to enhance strategy where implementation of sustainable agriculture practices at farm level is concerned. In this short-term study we propose to examine current state-of-the-art where data and evidence are concerned; and to identify gaps and opportunities in providing a comprehensive evidence-base to inform future strategies – policy and extension - to improve farm-level sustainability in the context of climate change.

1. Policy and extension strategies

Agriculture is the largest contributor to Irish greenhouse gas emissions by sector, with 37.5% of the national emissions total in 2020 (EPA, 2022). The Climate Action and Low Carbon Development (Amendment) Act 2021 (Government of Ireland, 2021b) sets out an ambition for a climate neutral economy by 2050 for the state. The Act commits Ireland to a legally-binding reduction in emissions of 51% by 2030 (compared to 2018 levels). The agricultural sector was assigned a sectoral target of reducing absolute emissions by 10% for the first budgeting period (2021-2025) and a total reduction of 25% for the second budgeting period (2025-2030). The consequence of this budget is that the agricultural sector must reduce emissions from a 21.56 MtCO2e (2018 base) to 17.25 MtCO2e yr-1 by 2030.

A range of policy and extension strategies – most of which are associated with EU level policies - have the shared objective of meeting these targets and of supporting transitions to more sustainable practices at farm-level. Key EU policies seek to transform the sustainability performance of agriculture. The European Green Deal strives for Europe to be the first climate-neural continent and the CAP is a significant instrument in that context. Policy strategies in Ireland such as AgClimatise detail specific sub-targets in making progress towards climate neutrality. Several Common Agriculture Policy (CAP) measures and schemes changed with the adoption of Ireland's CAP Strategic Plan, which came into effect on 1st January 2023. Overarchingly, and at the international level, policy strategies that seek to impact positively on climate change targets must be cognisant of the United Nations Intergovernmental Panel on Climate Change (IPCC) reporting framework.

It is important to note that some of the CAP measures and schemes promote specific, pre-defined sustainable agriculture practices at farm level for national implementation. Others take area-based approaches to promote sustainable agriculture practice according to regional specificities (e.g. Burren LIFE). Others promote ground-up initiatives to identify new or adapted sustainable agriculture practices. The range of practices, profiled in **Annex 1**, are primarily promoted and supported by the following schemes and measures:

- Agri-Environment CAP Schemes are comprised of the Agri-Climate Rural Environment Scheme (ACRES) and the Organic Farming Scheme.
    - ACRES, a successor to the Green Low Carbon Agri-environment Scheme (GLAS), is accessible to all farmers. A general approach to the scheme offers a range of (pre-defined) actions for implementation at farm-level and is available to all farms. A 'co-operation' approach, with customised plans for particular conditions, is available to farms in defined high priority areas[4].
    - The Organic Farming Scheme involves sustainable agriculture practices that fulfil particular actions/criteria.

Some of the CAP Direct Payment measures (Pillar 1) now incorporate enhanced sustainability criteria.

- The Basic Income Support for Sustainability (BISS) is a new income support payment where entitlement to receipt of support under which is now conditional on enhanced environmental performance (eco-conditionality).

[4] https://www.gov.ie/en/service/f5a48-agri-climate-rural-environment-scheme-acres/

- The eco-scheme is a new voluntary annual agri-environmental scheme for all farmers, aimed at maximising farmers' participation in achieving climate and environmental improvements across all farmed lands. The list of eight agricultural practices proposed for the Eco-Scheme include: Space for Nature, extensive livestock production, limiting chemical nitrogen input, planting of native trees/hedgerows, use of GPS-controlled spreader and/or sprayer, soil sampling & appropriate liming, enhanced crop diversification, and sowing a multi species sward. A farmer must select at least two agricultural practices to receive the Eco-Scheme payment

- The Complementary Redistributive Income Support for Sustainability (CRISS) is designed to redistribute CAP funds from larger farms to medium/smaller sized farms and is mandatory within the EU Regulation governing the CAP Strategic Plan. However, this payment is subject to meeting certain sustainability and good agricultural practice criteria.

Some of the schemes/measures within Ireland's CAP Strategic Plan commenced in 2022, while the majority commence in 2023[5]. These schemes involve meeting/achieving fixed indicators/measures on farms.

Furthermore, as highlighted in Ireland's Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan (2020), instruments of various EU programmes support sustainable agriculture production at farm level. Sustainable growth, development, innovation and adaptation (towards more sustainable agriculture practices are supported by:

- The EU LIFE programme funds large and small companies, local government and other public authorities, NGOs, Higher Education Institutions and community groups to implement projects. While the themes of projects are pre-defined by the LIFE programme (nature and biodiversity, circular economy and quality of life, climate change mitigation and adaptation, and clean energy transition); there is **flexibility for groups to design their own projects** under these themes in a **'bottom up'** way. Therefore, sustainable farm practices supported by LIFE are not pre-prescribed but are decided by implementing groups. LIFE projects are typically large, with each project funded at between €1 and €5 million; and have durations of three to five years[6].
- EIP-AGRI Operational Groups (OGs) are 'intended to bring together multiple actors such as farmers, researchers, advisers, businesses, environmental groups, consumer interest groups or other NGOs to advance innovation in the agricultural and forestry sectors'[7]. OGs are formed and design & implement projects in a **'bottom up'** way. Therefore, sustainable farm practices incorporated by OGs are decided by groups themselves.
- Horizon Europe (and its predecessor Horizon 2020) incorporates the 'Multi-Actor Approach', which places farmers and other actors influencing practices at farm-level as central partners in innovation processes[8]. Sustainability is a cross-cutting objective of Horizon Europe. Widened implementation of existing sustainable practices at farm level; and the innovation, new design, testing and implementation of practices at farm-level are core expected

[5] https://www.gov.ie/en/publication/114fb-new-cap-schemes-for-farmers/#cap-schemes-opening-dates
[6] gov.ie - LIFE Programme.
[7] Operational Groups | EIP-AGRI.
[8] Horizon 2020 multi-actor projects

outcomes of the programme. Many of these practices are developed in a **'bottom up'** way, while other, **more established practices** are sought to be replicated and expanded by the programme.

While much of the portfolio of Ireland's extension programmes is designed to deliver EU and national policy objectives, there are examples of independent initiatives that aim to support sustainable practices at farm level.

- The primary example is Teagasc's Signpost Farm Programme, which involves a wide variety of partners[9]. The Signpost Farm Programme is the leading extension programme provided by Teagasc as Ireland's agriculture and food development authority, and the programme complements other programmes, particularly the Agricultural Sustainability Support and Advisory Programme (ASSAP) and other (mainly CAP) schemes supported by Teagasc.
- The programme is targeted at all Irish farmers and aims to enrol 10,000 farms annually in meeting a target of 50,000 farmers by 2030. The programme's extension activities are centred around a current number of 120 demonstration farmers, peer-to-peer learning events for farmers, and **customised plans formulated for each participating farm** to increase its overall sustainability. There are currently twelve actions[10], informed by measures of the Marginal Abatement Cost Curve (MACC), around which plans for each participating farm are centred. The MACC is currently under revision, and the Signpost Programme is attentive to these revisions as well as to Teagasc's and other sources of evolving research, much of which will be consolidated through a National Centre for Agri-food Climate Research and Innovation[11]. The specific measures promoted by the programme with reference to the Intergovernmental Panel on Climate Change (IPCC) reporting framework are described in **Annex 2.**

In addition to extension/advisory programmes themselves, there are specific extension/advisory tools that are used to support sustainable practices at farm-level, and which generate data in relation to sustainability at farm level. The Sustainability Digital Platform[12] is a data collection and analysis tool to allow farmers to calculate emissions and carbon balances on their farms, with results forming the basis for the development of their tailored plans for participating in the Signpost Farm Programme. Longer established tools such as the Carbon Navigator[13] also collect data at farm-level for potentially informing sustainability strategies (as well as its accreditation) at farm-level.

Furthermore, there is a range of programmes led by industry, which promote specific sustainable agriculture practices. For example, the Glanbia/Tírlán and Baileys/Sustainable Farming Academy supports Glanbia/ Tírlán Ireland suppliers' on-farm sustainability journey through education. The Tirlán Sustainability Action Payment involves a programme designed to assist dairy suppliers in reducing their carbon footprint by implementing measures to enhance water quality and biodiversity

[9] https://www.teagasc.ie/environment/climate-change--air-quality/signpost-programme/
[10] Where are you on the 12 Steps to reduce Gaseous Emissions on YOUR FARM?
[11] Virtual National Centre for Agri-food Climate Research and Innovation - Teagasc
[12] Teagasc Climate Action Strategy - Sustainability Digital Platform
[13] https://www.teagasc.ie/media/website/about/our-organisation/Instruction-Carbon-Navigator-V2.pdf

and improve air quality and soil health in line with Glanbia Ireland's sustainability strategy, *Living Proof*. The measures are closely aligned with the climate action measures identified in Teagasc's emissions reduction Marginal Abatement Cost Curve (MACC) report. Kerry Group's *Evolve* dairy sustainability programme supports the accelerated adoption of science-based sustainable action and best practices, underpinned by Bord Bia's Origin Green and Teagasc's Marginal Abatement Cost Curve (MACC) report.

Annex 1 presents a table, which profiles pre-defined sustainable agriculture practices (column H) promoted and supported by a range of policies and extension initiatives.

2. Data collection requirements to inform strategies supporting sustainable practices at farm-level

It is crucial for Ireland to have up-to-date data in relation to the extent to which sustainable agriculture practices are being implemented at farm-level, and the factors influencing their implementation. Such data are crucial for understanding how farms, as part of the overall agriculture sector, are meeting and are likely to meet targets where sustainability, biodiversity and climate are concerned. Understanding strengths and weaknesses in the implementation of specific farm practices, at national and regional levels, within particular farm systems, in various population cohorts etc. provide important insights for the targeting of initiatives to maximise opportunities and address threats to meeting national targets.

Quantitative studies, often conducted through analysis of secondary data (e.g. analysis of existing data generated by surveys instruments) or collection of primary data (through bespoke survey instruments) are ordinarily employed to evaluate current practices or to assess attitudinal/behavioural factors in relation to those practices using pre-determined indicators. In this context, quantitative approaches can, through the evaluation of current practices, generate data in relation to the characteristics of population cohorts who implement current practices; and, through the assessment of attitudinal/ behavioural factors, can identify influences of factors on the implementation of practices. The results of such quantitative studies can inform policy and associated public policy interventions by guiding the targeting of certain cohorts and practices used by cohorts with respect to particular changes/innovations required for greater sustainability at farm-level. Similarly, the results are of potential value of industry actors, to guide the design of market-based interventions.

However, there are limitations to quantitative approaches. These limitations are oriented to how quantitative studies may inform policy to change/innovate conditions/practices at farm-level. For instance, a quantitative study may find that farmers in particular regions, or with certain levels of educational attainment, or with particular demographic characteristics, are more likely to implement particular sustainable practices at farm level than others. While it is useful for policy-makers to be aware of these factors for the purpose of understanding the nature of particular challenges (and prospects of meeting these challenges), findings of such quantitative studies may not be sufficient to inform the strategising of interventions to address the challenges: put simply, geographical location, age & gender characteristics, and diverse, influential experiences across life-courses are not changeable/easily changed.

It is also important to note that quantitative studies, although valuable because they provide statistically representative data, 'can only produce results for the questions that are asked', (Akram-Lodhi and Komba, 2018, p. 12). An implication is that if a wider variety of factors are implicated than those for which data are collected, understandings will be limited (and misunderstandings will be causes) in relation to the nature of the problems and opportunities in improving implementation of sustainable agriculture practices at farm level.

Qualitative research is designed to work within contextual scenarios, to identify the nature of context-specific challenges, processes and dynamics in the pursuit of sustainability (and other) goals. Unlike quantitative research, where data are generated in response to fixed questions designed by researchers, data generated in qualitative research are in-depth and multifactorial, to the extent that

data in relation to all factors relevant to a research question are collected. Put simply, while quantitative research prioritises analytical breadth and statistical representativeness, qualitative research prioritises analytical depth and theoretical representativeness (Flyvjberg, 2006). Mixed methodological approaches, combining quantitative and qualitative approaches is recommended where possible, allowing for testing and triangulation of research findings and more comprehensive datasets for informing policy and extension. Examples of such mixed methodological approaches are empirical studies of social networks and agri-food system resilience, which, as outlined below, involve combinations of qualitative, participatory, and quantitative approaches.

The sections below outline state of the art & gaps and opportunities where data in relation to the implementation of sustainable farm practices are concerned, taking in turn:

- 2.1 Quantitative survey data in relation to the *extent of implementation* of sustainable agriculture practices;
- 2.2 Quantitative survey data in relation to *behavioural/attitudinal factors* influencing implementation;
- 2.3 Assessment of farm-level and system-*level resilience*
- 2.4 Qualitative and participatory approaches to understanding *why and how sustainability practices and their promotion (through policy & extension) are effective.*

A comprehensive literature review of all studies related to the topic of sustainable agriculture practices in Ireland and internationally is beyond the scope of this short review. Instead, our task is to identify existing data collection mechanisms, and gaps and opportunities. While some key Irish and international studies are identified and referenced in that context, recent and comprehensive reviews of the literature with regard to the implementation of sustainable farm practices are available from Brown et al. (2021), Coyne et al. (2021 – specifically Table 1), and Baaken (2022).

2.1 Quantitative/survey data in relation to the extent of implementation of sustainable agriculture practices at farm-level: state of the art and gaps & opportunities

Where emissions are concerned, it is crucial that changes to farm practice are captured so that implications for emissions can be counted and credited in the IPCC national inventories framework (Duffy et al., 2022). It is also important from a policy perspective to know what sustainable practices are being implemented at farm level and which farmer cohorts are/not adopting practices.

Some of the required activity data can be captured with aggregate-level data. For example, the transition to the use of protected urea chemical fertiliser can be tracked from fertiliser sales data as tracked by the DAFM. However, for other measures (e.g., quantity of slurry spread by low emissions slurry spreading equipment) there are no such aggregate-level data sources. Hence, for such measures policymakers have relied on instruments such as the Teagasc National Farm Survey (NFS) to track practices at farm-level, which can then be aggregated up to the farming population based on the representativeness of the sample. The NFS has also been used to generate sustainability metrics (economic, environmental and social) across a range of farm system types to better understand temporal trends in these metrics (Buckley et al., 2022).

As detailed in **Annex 2**, farm practices to reduce farm level GHG emissions fall under 3 main categories i) Efficiency Measures ii) Measures that drive absolute emissions reduction and iii) Measures that

address emissions and sequestration of GHG associated with land use and land use change and forestry. Below is a list of measures of the MACC (Lanigan et al., 2018, Lanigan et al., 2023) promoted by Teagasc and other AKIS agencies to reduce GHG emissions.

For each measure, it is specified:

- How the implementation of a farm practice-based mitigation measure could lead to a reduction in national GHG emissions
- Whether data are available in relation to the measure from a national inventory accounting perspective
- The main gaps/unknowns/issues/questions around implementation of the measure.

Measure: Selecting for dairy / beef animals that can are genetically more efficient at producing product (milk/meat) while minimizing enteric methane based emissions
Effect of measure on GHG emissions: generation of the same quantity of product with reduced emissions per unit product (or an increased level of output with static emissions) due to improved genetics.
Data from national inventory: a system for accounting for the absolute emissions reduction associated with alterations in genetic improvement would be required.
Gaps/unknowns/issues/questions pertaining to data collection using survey instruments: An ongoing measurement campaign to track this efficiency gain Getting the population of farmers to engage with a breeding programme Potential for rebound effect (stable or increase in animal numbers due to higher productivity)

Measure: Use of sexed semen (Artificial Insemination)

Effect of measure on GHG emissions: reduction in pure male dairy calves that would otherwise occur. Thereby increasing the proportion of beef arising from the dairy herd and potentially leading to a reduction in the suckler cow population.

Data from national inventory: Emissions reductions could will be realised on foot of a potential reduction in suckler cow based animal numbers. Data are currently available on use of semen from Animal Breeding companies.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

Willingness of a certain cohort of farmers to transition from stock bull to AI in the first instance.

Willingness of farmers to transition from conventional Artificial Insemination (AI) to sexed semen – issues around cost and conception rates.

Willingness of suckler cow based cattle farmers to transition from this system of production to a system based on output from the dairy herd.

Measure: Improved Animal Health

Effect of measure on GHG emissions: GHG emissions reduction would arise due to less animals being required to meet a given level of production (less replacements are required) and animals will have lower emissions per head as their maintenance energy requirement is reduced when health status is good.

Data from national inventory: less animals required to generate a given less of volume of output (milk / meat) than in a counterfactual scenario.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

Animal health covers a myriad of potential diseases so identifying the numerous factors that can affect good/poor health status is challenging. Data on this issue is difficult to collect at farm scale and would put a large data burden on farmers.

Potential for rebound effect - What impact will this have on the overall bovine and ovine national population (stable or increase in animal numbers due to higher productivity).

Measure: Reduced age at slaughter
Effect of measure on GHG emissions: getting animals to slaughter weight earlier, less time on farm generating emissions.
Data from national inventory: less animals required to generate a given less of output (meat) than in a counterfactual scenario. Data sources such as the AIMS data can be used to track this measure.
Gaps/unknowns/issues/questions pertaining to data collection using survey instruments: Feeding regimes may change to get animals to slaughter quicker, this could potentially have an adverse effect on emissions. Management factors that influence early age (0-18 months) daily live-weight gain across the farming population. Potential for rebound effect (emissions do not decline as a farmer may keep more animals as a reaction to getting them to slaughter earlier).

Measure: slurry acidification during housing period
Effect of measure on GHG emissions: addition of a compound such as alum, ferric chloride or polyaluminium chloride to slurry during storage has been shown to reduce ammonia emissions on land spreading and reduce methane and ammonia during slurry storage phases.
Data from national inventory: although this is a mature technology in places like Denmark, none of the required infrastructure currently exists in Ireland. No way to track the use of these compounds at farm or national level. This is something that could potentially be tracked through the Teagasc National Farm Survey and/or through national sales data.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

At between €170 to €212 per tonne CO2e abated, acidification is a relatively costly measure.

There is no policy instrument that currently promotes this practice and therefore awareness of the practice among farmers and other AKIS actors is a likely issue. Slurries that are acidified would not be suitable for anaerobic digestion.

If this practice were to become established at farm level, then it could potentially be tracked through the Teagasc National Farm Survey and/or through national sales data.

Measure: Use of protected urea fertilisers

Effect of measure on GHG emissions: straight Urea fertiliser treated with either NBPT or NPPT (becomes protected urea) has been demonstrated to reduce both ammonia and N_2O loss. Ammonia was reduced by 80% relative to straight untreated urea, with an N_2O EF of 0.4%, which is far lower than that of CAN. Protected urea has greater nitrogen use efficiency compared to straight urea; hence, the substitution will facilitate a reduction in chemical N application rates

Data from national inventory: this measure is straightforward to account for in the national inventories as national fertiliser sales data (type and quantity) is used for emission modelling from of chemical fertiliser application on farms.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

The main uptake barrier to uptake for of protected urea has been availability. To date, availability has been limited. Supply chain actors have been reluctant to embrace protected urea compared to more traditional fertiliser products.

Previously, concern has been expressed about potential residues from protected urea but this has been disproven by research.

While sales data at national level can elucidate on aggregate-level use, an instrument like the Teagasc National Farm Survey could be used to explore the profile of farmers who are transitioning towards this fertiliser.

Measure: Low emissions slurry spreading equipment

Effect of measure on GHG emissions: low emission slurry spreading substantially reduces ammonia emissions, which in turn, has two impacts on N_2O emissions. Firstly, the nitrogen fertiliser replacement value of slurry is increased, reducing the need for chemical fertiliser. Second, the reduction in ammonia results in a reduction in wet and dry deposition of N, which reduces indirect N_2O emissions.

Data from National inventory: reductions in GHG emissions associated with the use of LESS (trailing hose or trailing shoe) manifest in the inventories via a) reductions in mineral fertiliser sales and b) a reduction in atmospheric deposition of N resulting from ammonia emissions. Activity data around the use of LESS at farm level are generated by the Teagasc National Farm Survey. This measure is also underpinned by regulation implementing the Nitrates Directive, which in Ireland mandate its use farmers operating under a Nitrates Derogation.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

The TAMS capital grant scheme has proved highly successful in incentivising farmers to purchase this machinery. However, there is currently a 10-12 month waiting list for units to be delivered to farmers, a bottleneck that is likely to continue.

Non-derogation farmers who own a splash plate tanker have invested in this technology and may be reluctant/unable to modify this to spread by LESS or may be unwilling to bear the cost of employing a contractor (with LESS equipment) to spread their slurry. This may be especially the case for farmers in low-income categories.

Measure: Optimising Soil pH – Liming

Effect of measure on GHG emissions: In the year of application liming directly release CO2 thereby increasing emissions. However, through liming the achieving the optimum soil pH can be achieved, this will optimise grass / crop growth and can reduce requirement for chemical fertiliser.

Data from national inventory: reduced chemical N applications at farm level would lead to a reduction in fertiliser-based GHG emissions. The quantity of lime applied nationally can be tracked from sales data.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

At a farm scale the NFS can be used to track lime use but additional data / link to crop requirement based on a soil test needs to be undertaken.

A soil sample has to be taken periodically for every 3 hectares of land targeted at a cost of €25 per sample (plus costs associated with the time to take sample in the field) to be tested in the laboratory.

Soil test results are complicated and need interpretation and appropriate advice needs to be given to farmers on foot of a soil test result

Measure: Introduction of clover into grass swards

Effect of measure on GHG emissions: N_2O emissions arising from the use of chemical N fertilisers can be reduced by substitution of biologically fixed nitrogen. Biological nitrogen fixation occurs when N fixing crops (legumes e.g. clover) form symbiotic relationships with bacteria (Rhizobia) in the soil. This allows the transformation of atmospheric N_2 to N compounds and this can displace N provided by chemical fertilisers

Data from national inventory: substituting chemical N fertiliser sources would be reflected in the national inventories through reduced sales of chemical fertilisers nationally, and, potentially, national seed sales.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

The implementation of this measure is difficult to track, as the level of clover at field scale can be very variable. The Teagasc National Farm Survey could potentially try to track the implementation of this measure at farm scale. There may be a role for remote sensing technology, which can distinguish swards with clover from those without clover.

At farm-level, several management factors are likely to influence successful implementation. In order to establish clover in the sward, soil pH and soil P/K levels need to be correct. The establishment and ongoing maintenance of clover requires a high level of sward management compared to traditional rye-grass with chemical nitrogen systems. There is a significant cost to establishing a grass clover sward in terms of capital and labour. Cattle can sometimes suffer from bloat from eating grass clover swards.

Measure: Reduced Crude protein in Animal Diets

Effect of measure on GHG emissions: On average the crude protein in animal diets (concentrate feeds) may be excessive. Reducing crude protein (CP) content to an optimum level can reduce both organic nitrogen excreted by an animal as well and the proportion of N in urine and lead to a reduction in ammonia and N_2O emissions.

Data from national inventory: this measure will appear in the inventory as a reduction in N excretion and will impact on the full nitrogen cycle cascade, resulting in lower direct N_2O emissions from manure management and manure land-spreading. In addition, reductions in indirect N_2O associated with a) ammonia from housing, storage and spreading of liquid and solid manures and b) N leaching upon slurry/FYM spreading will occur. Aggregate level data can be secured from the animal feed industry around average crude protein in different diets.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

When/where specific concentrates are fed (e.g. indoors / at grazing) is a data gap.

Measure: Feed additives

Effect of measure on GHG emissions: feed additives such as 3-Nitrooxypropanol, (3NOP) reduce methane production in the rumen. Some studies based on indoor feeding regimes have shown a reduction of up to 30% reduction in enteric methane production by livestock.

Data from national inventory: If proven, this measure could provide a reduction in the enteric fermentation methane emission factor for the various livestock categories. However, the activity data to justify this would need to be generated both at national level (sales of a given product) and at farm level (e.g. via the Teagasc National Farm Survey). The farm level data will be important in associating/allocating use of feed additives to different bovine and ovine production systems.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

A cost-effectiveness assessment of these feed additives needs to be undertaken across different farm system types. If a feed additive is certified for use, its use and the costs of such products at farm level could be measured through the Teagasc National Farm Survey.

Many feed additives are more suited to a system of production where animals are housed full-time and are fed under a controlled diet. The additives are less suited to a grazing regime and may require a different delivery method (e.g. slow release bolus). More research is required to determine efficacy in a grazing based system.

Research is required to ensure there are no harmful residues associated with any feed additives where final products are concerned.

Measure: Afforestation

Effect of measure on GHG emissions: Forest and harvested wood product (HWP) sinks have made a significant contribution to offsetting emissions from Ireland's LULUCF sector in the past. However, the forest contribution has been declining in recent years due to a reduction in the level of afforestation, an increase in the level of harvest from the private sector, a decline in growth rates associated with age class legacy shifts and continued emissions from forestry on organic soils.

Data from the national inventory: Carbon sequestration from forestry is established from area under forestry, species and age of plantation.

Gaps/unknowns/issues with regard to data collection through survey instruments*:*

For non-economic reasons farmers have historically been very slow to change land use to forestry and away from more traditional farming enterprises.

Measure: Hedgerows

Effect of measure on GHG emissions: Hedgerows can sequester carbon in above ground or below ground biomass and in soil organic carbon pools. Management has a large impact on the ability of hedgerows' sequestration capacity, with above ground biomass sequestration in highly managed hedgerows severely curtailed.

Data from the national inventory: using aerial photography, the carbon sequestered in hedgerows can be estimated. A national high-resolution Lidar study would be beneficial in this area to better estimate biomass in hedgerows.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

Over the last decade, there has been a gradual decline in hedgerows in order to maximise the agricultural area. Incentivises to encourage new planting but also encourage improved management from a climate change perspective, are required.

Research on using different, faster growing species within the hedge mix is also required.

Measure: Re-wetting of Organic Soils

Effect of measure on GHG emissions: A significant part of what are classified as organic soils in Ireland are drained for agricultural production. By their very nature these soils emit significant quantities of CO_2e. While regulation now pertains to any drainage works exceeding 15 hectares, this was not historically the case. The majority of agricultural drainage works have been carried out prior to 1990. It is therefore assumed that most farmland on poorly draining carbon rich soils has been artificially drained at some stage in the past. Rewetting these soils could lock in carbon that would otherwise be emitted under the counterfactual of continued agricultural production.

Data from national inventory: The incorporation of soil organic carbon sequestration will require the development of a Tier 2 Land management factor in order for additional sequestration to be included in national inventories.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

The management of these organic soils is a significant data gap currently.

There is also a significant level of uncertainty about the state of these organic soils currently. While they may have been drained in the past a lack of drainage maintenance may mean that over time, soils have reverted back towards their original undrained state. The state and level of agricultural activities in these organic soils is unknown. There may be a role for remote sensing technology here in identifying land that has been drained but where those drains do not appear to be functioning.

Cost of rewetting and compensation for loss of current and future income is an issue.

Farmers' willingness to engage with this measure is an issue, as re-wetting represents a significant change of land use and may have knock-on effects for neighbouring farms depending on the local biophysical environment. This type of measure may require collective agreement for a group of farmers in a contiguous spatial area.

Measure: Cover crops

Effect of measure on GHG emissions: The principal loss pathway for carbon within a tillage system is the extended fallow period, during which time there is no uptake of CO_2 through photosynthesis. Cover crops are traditionally used to reduce leached N emissions to groundwater during the fallow period.

Data from national inventory: The incorporation of soil organic carbon sequestration will require the development of a Tier 2 Land management factor in order for additional sequestration to be included in national inventories.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

Little is known about this activity currently. Satellite imagery could potentially be used to track this activity as well as an instrument like the Teagasc National Farm Survey.

Research questions need to explore cost as a barrier to implementation along with a large degree of uncertainty as to the amount of N saved by this measure.

Tracking the area under cover crops can be problematic as can be the time when crops were sown, which can have a significant effect on the efficacy of the measure.

Measure: straw incorporation

Effect of measure on GHG emissions: Straw incorporation increases soil carbon, as organic matter is directly incorporated back into the soil. For every 4 tonnes of straw incorporated over 15-20 years, a 7-17% increase in soil carbon organic can be observed.

Data from the national inventory: The inclusion of straw incorporation in the national inventory will require the development of a Tier 2 Land management factor in order for additional sequestration to be included in national inventories.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

Little is known about this practice currently.

Cost is likely the main barrier to uptake along with a large degree of uncertainty as to the amount of nitrogen saved by this measure

Tracking the quantity of straw incorporated maybe problematic.

Measure: Bio methane / biogas
Effect of measure on GHG emissions: Anaerobic digestion of biomass produced from Irish grassland (i.e. grass fed-biomass) would produce biogas (55% methane) that could be used directly for heat and electricity generation. Alternatively, the biogas could be upgraded to the same standard as natural gas (bio-methane – 97% methane), injected into the natural gas grid and subsequently used for a range of commercial purposes
Data from national inventory: This measure can be incorporated into national inventories as the fossil fuel displacement with bio-methane or renewably-sourced heat and power all have constant fixed emission factors.
Gaps/unknowns/issues/questions pertaining to data collection using survey instruments: Research questions relating to barriers in relation to cost; specifically in relation to investment in regarding infrastructure and cultivation of grass. Furthermore, whether farmers are willing to substitute away from the current grass production model (rye grass and chemical Nitrogen model) to grow grass for use in an anaerobic digester (grass has to be grown with zero chemical N requires exploration and is the subject of ongoing research in Teagasc supported by the SEAI. Another consideration is that this activity is credited to the energy sector and not to agriculture or LULUCF.

Measure: Forestry thinnings
Effect of measure on GHG emissions: Forestry thinnings and waste residue can be utilised in heat production or in combined heat and power (CHP) systems.
Data from national inventory: Emission factors are already in the inventory. Activity data required would be sales of firewood and/or firelogs.

Gaps/unknowns/issues/questions pertaining to data collection using survey instruments:

The main barrier is likely to be forest management as delays in clear felling or thinning would impact supply. Afforestation rate will not impact this measure over the period to 2030 although ongoing supply would be impacted in the absence of increased afforestation rates.

Another consideration is that this activity is credited to the energy sector and not to agriculture or LULUCF.

Measure: Renewable energy on farms
Effect of measure on GHG emissions: Generation of renewable energy on farms (solar, micro-wind) for use on-farm as well as surplus sale to the national grid.
Data from national inventory: Displacement of fossil fuel based energy use on-farm as well as in the national grid. This is tracked under the IPCC energy category.
Gaps/unknowns/issues/questions pertaining to data collection using survey instruments: Data are also collected on this through the Bord Bia Sustainability assessment. The Teagasc National Farm Survey will be developed to capture more data in this area. Other considerations are that this activity is credited to the energy sector and not to agriculture. The mechanism to sell excess energy back to grid is not well established. Capital cost for low-income farmers could be an issue.

Overall, while aggregate level activity data are available for national inventory accounting purposes in many of areas, in relation to implementation of sustainable practices at farm-level, there are multiple gaps in relation to implementation of sustainable practices at farm-level. Monitoring the implementation of measures using survey instruments could be useful. While this is so, implementation considerations and caveats exist in relation to assessing many of the measures using survey instruments, which are highlighted above.

It should furthermore be noted that the above review focused on current state of the art data, mainly in relation to mitigation practices related to agriculture and disseminated through Teagasc channels. It will be imperative that farmers implement practices that support building adaptative capacity and resilience towards the negative impacts of climate change. Identifying co-benefits of current practices in supporting farm level resilience and that support building adaptative capacity need to be considered now and into the future when developing farm level practices. It should also be noted that the practices reviewed in this report could be synergistic of indeed antagonistic for other environmental dimension such as water quality or biodiversity. Teagasc through its research programme is endeavouring to explore these relationships.

2.2 Quantitative data regarding behavioural and attitudinal factors influencing implementation of sustainable practices at farm-level: state of the art, gaps & opportunities

Farmers' practices in the context of climate change can be broadly categorised into practices concerning adaptation and those related to mitigation. Adaptation refers to practices to mitigate the impacts of climate change; for example, farmers adopting new varieties of crops that are more resilient to severe weather events or to sustained shifts in rainfall or temperature. Adaptation is defined by the IPCC as changes in practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change (IPCC, 2001). Mitigation, conversely, relates to practices that directly reduce farmers' climatic impact; an example of such would be the adoption of low emissions slurry spreading. Mitigation is defined as an intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001). Generally, farmers need to be aware, at least tacitly, of climate change and of agricultural sources of greenhouse gas emissions to be strongly motivated to enact mitigation measures (Arbuckle *et* al. 2013). Therefore, survey instruments capturing adaptation and mitigation are very different. Adaptation data are typically gathered by accessing perceived risks and vulnerabilities whereas mitigation is obtained from assessments of knowledge and awareness of consequential impacts of behaviour.

In developed countries, farmers typically favour adopting adaptation measures rather than undertaking practices to reduce greenhouse gas emissions in response to climate change (Mellett et al., (2019). Irish farmers are no different; similar findings were evident in a study by Tzemi and Breen (2018). Furthermore, while it is likely that farmers' awareness of climate related issues has changed over the past two to three years, the most recently published studies indicate that Irish farmers are generally unaware of the impact of their activities on climate change nor of the potential consequences of climate change to their farming operation (Tzemi and Breen, 2018; Mellett et al., 2019;). It is therefore imperative that a greater understanding of the behavioural factors that influence Irish farmers is attained through robust research.

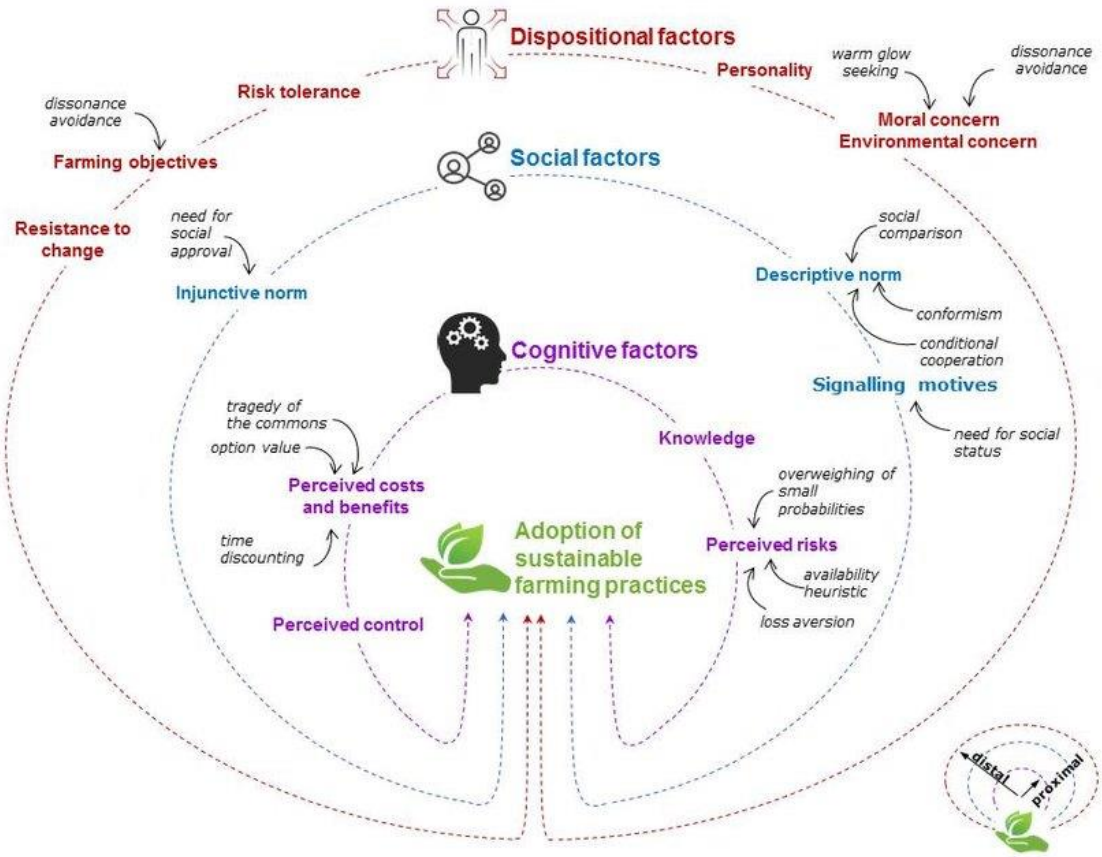

Figure 1 A schematic representation of an integrated framework of behavioural factors affecting farmers' adoption of environmentally sustainable practices.

Source: Dessart et al., 2019.

Behavioural factors influencing farmers' decisions to adopt mitigation or adaptation measures related to climate change have been assessed through a large body of literature internationally. Where factors for investigating such behaviour are concerned, in a relatively recent review Dessart *et al.* (2019) identify three types of behavioural categories that affect decision-making regarding sustainable farming practices based on their 'distance' from the decision-making in question: cognitive, social, and dispositional factor categories (Fig. 1). Within each of these three categories lies numerous behavioural factors that have been found to influence sustainable farming practices. Cognitive factors refer to perceived control, perceived costs and benefits, knowledge, and perceived risks[14]. Cognitive factors are consequently decision-specific and vary case by case. Dispositional factors such as farmer personality have general effects and relate to multiple behaviours. Dispositional factors include

[14] Perceived control: Perceptions that one possess the relevant skills and sufficient time to undertake an action. Perceived costs and benefits: Economic costs and benefits of a behaviour. Knowledge: Farmers need to be aware that such practices exist. Perceived risks: A sustainable practice may be riskier than a conventional one.

resistance to change, farming objectives, risk tolerance, personality, and environmental concern[15]. Social factors encompass injunctive norms, descriptive norms, and signalling motives[16].

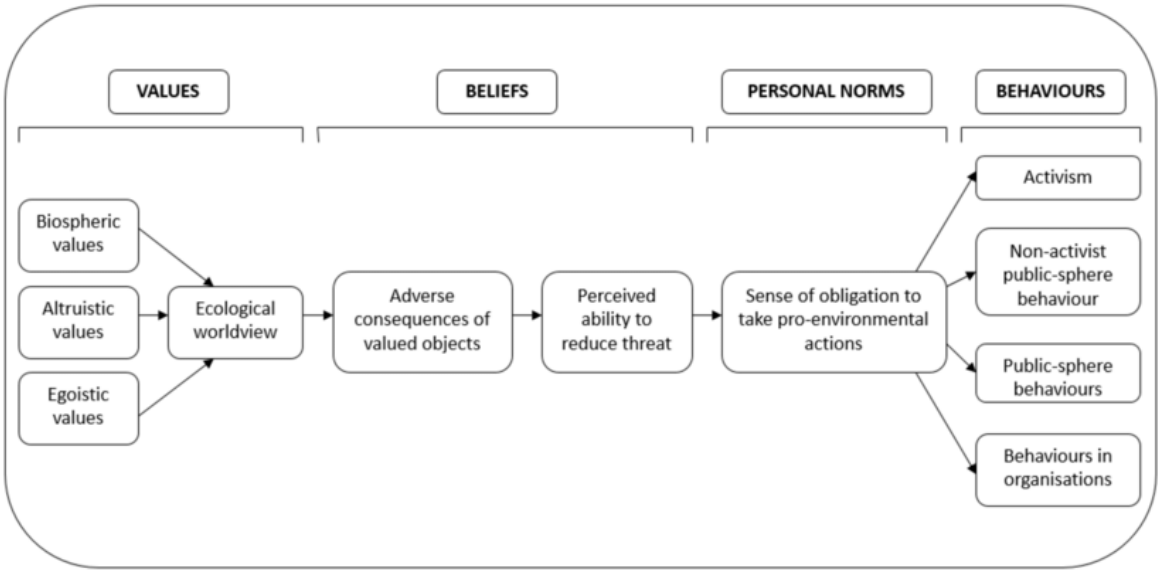

Figure 2: A schematic representation of the Value Belief Norm (VBN) theory of environmentalism (Stern et al. 1999)

Two of the most popular theoretical frameworks to investigate behavioural factors in an environmental context are the Value-Belief-Norm (VBN) theory (Fig. 2) and the Theory of Planned Behaviour (TPB) (Fig. 3). These theories can quantify the causal relationships between behavioural factors that mediate behavioural change. They are especially useful when trying to determine what behavioural factors are significant with respect to the investigated behaviour. Theories also provide a more condensed provision of factors that influence behaviour but their suitability to access behavioural change depends on the overall research objective. The VBN theory introduces two important concepts, values and the New Environmental Paradigm (NEP) (ecological worldview). Altogether, the VBN theory posits that values (e.g. biospheric, altruistic, egoistic), beliefs (e.g. ecological worldview, awareness of consequence, ascription of responsibility) and pro-environmental norms all impact behaviour (Stern *et al*., 1999) (Fig. 2)[17]. The VBN is often appropriate to use when

[15] Resistance to change: If farmers lack openness to new experiences, it may lead them to be particularly reluctant to change. Farming objectives: The goals that farmers pursue through their activity/Risk tolerance: How tolerant is a farmer to increased risk. Personality: Differences in patterns of thinking, feeling and behaving. Environmental concern: A farmer's conscience, ethical principles and concern for the environment

[16] Injunctive norms: Farmers may be influenced by what they think others expect from them. Descriptive norms: Norms that concern what other farmers do. Signalling motives: Farmers who engage in a particular behaviour because they seek higher status.

[17] Altruistic values: Concern for others and other species. Biospheric values: Concern for the biosphere, environment and ecosystem. Egoistic values: Self-serving concerns. The NEP: A concept that represents environmental concerns toward human - nature relationships. Adverse consequences: Consciousness of adverse environmental consequences. Ascription of responsibility: Sense of responsibility to minimise environmental impact. Personal norms: Moral obligation for pro-environmental behaviour.

trying to influence 'low cost' pro-environmental behaviours and 'good intentions' (e.g. willingness to change, willingness to sacrifice, joining environmental organisations) (Lindenberg and Steg, 2007). Conversely, the TPB posits that individuals make decisions to engage in a specific behaviour based on their attitudes, subjective norms (if others approve), perceived behavioural control (their capacity to enact) and intention (Ajzen, 1991) (Fig. 3). TPB assumes that people make planned, rational decisions, generally directed by self-interest (in terms of hassle, or social approval). Its constructs are particularly relevant in certain contexts when explaining behaviours involving relatively 'high-cost' (in terms of cost, effort, convenience, time) (Lindenberg and Steg, 2007). Zhang *et al*. (2020) found that TPB is more successful at predicting self-interest-oriented farming behaviours that primarily benefit the farmer; such as climate change adaptation. VBN on the other hand performed better when explaining altruistic (unselfish) behaviours like mitigation behaviours. Both theories predominately gather data for analysis through the use of Likert type quantitative questionnaires (see **Annex 3** for sample questionnaires). Structural Equation Modelling (SEM) or multiple linear regressions are options for statistical analysis to assess causal relationships between factors for both theories. Researchers need to apply a careful approach in framing questions and in developing appropriate sampling strategies and analysis guidelines when designing and administering surveys (e.g. Francis *et al*., 2004). Behavioural theories are often modified and additional elements are added to increase their explanatory power in a specific research context.

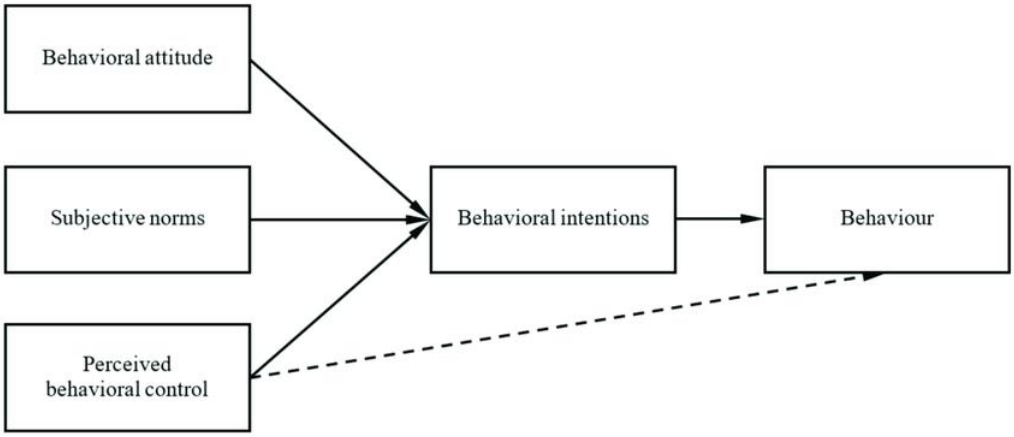

Figure 3: Schematic representation of the Theory of Planned Behaviour (Ajzen, 1991)

Rather than concentrate on a specific behaviour, many studies instead explicitly focus on deciphering the heterogeneities that exist amongst the farming population with respect to broader climate change perceptions. This type of segmentation is generally data-driven (e.g. cluster analysis of survey respondents) and not guided by an overarching theory; it is especially useful for increasing understanding of different audiences and their characteristics (see **Annex 3** for sample questionnaire). The approach divides the target population into homogeneous, mutually exclusive subgroups, which may facilitate effective communication when targeting these subgroups to promote pro-sustainability behaviours (Hine *et a*l., 2014). Statistical analyses for segmentation often involve Principal Component Analysis (PCA) to reduce the dimensionality of the dataset so that it is suitable for the cluster analysis that follows. For instance, using this approach Hyland *et al*. (2016) in a study of Welsh farmers found four distinct typologies that they termed; 'The Productivist', 'The Countryside Steward', 'The Environmentalist' and 'The Dejected'. The Productivist and The Countryside Steward sub-groups portrayed low levels of awareness of climate change, but differed in their motivation to adopt pro-

environmental behaviours. Conversely, both The Environmentalist and The Dejected typologies scored higher in their awareness of the issue. In addition, 'The Dejected' had a high sense of perceived risk. The inherent differences between sub-groups can be used as communication framing points to increase engagement with climate change and adoption of associated mitigation or adaptation practices**.** Please refer to **Annex 3** for a sample questionnaire for segmenting farmers based on their climate change perceptions.

In contrast to other sectors (such as education or health), there has been little research undertaken in relation to the effectiveness of nudge interventions in influencing behavioural change with regard to environmental actions in agriculture. Kuhfuss et al. (2016) and Howley and Ocean (2021) have demonstrated that social norms can be an important factor in changing farmers' stated intentions in this regard. Similarly, they outline that providing farmers with an opportunity to demonstrate their green credentials could nudge other farmers towards conservation initiatives. The research also suggests that policy modifications could also be used to nudge farmers into green behaviours. A small number of field experiments have also examined the effect of nudge interventions on farmers' behaviour. Chabé-Ferret et al. (2019) found that social norm comparison nudges were not effective in reducing water consumption overall, but did present some evidence to suggest that they could be effective when focused on farmers who used irrigation most. By statistically analysing administrative data Lunn et al. (2020) established that age and farm size have significant effects on Irish farmer's likelihood to adhere to nitrate regulations but stress that noncompliance is ultimately caused by famer behaviour and decision making.

In an Irish context the study of famer behaviour relating explicitly to climate change has been quite sparse. Studies by Tzemi and Breen (2018) and Mellett et al. (2019) assess Irish farmers' attitudes towards climate change but do not rely on the theoretical frameworks outlined nor do they use segmentation. There is consequently a considerable opportunity to further understand farmer behaviour in Ireland by implementing established behavioural approaches. There is some potential to explore the possibility of utilising such approaches through the Teagasc National Farm Survey. A clear advantage of utilising the NFS is the ability to collect data pertaining to actual farmer behaviour in subsequent years.

2.3 Assessment of resilience at farm-level and system-level: state of the art and gaps & opportunities

The ability of farm systems to cope with challenges such as climate change can be conceptualised as resilience (Meuwissen et al., 2019). Bene et al. (2016) describe resilience as being reflective of three capacities: *absorptive* (ability to persist), *adaptive* (ability to adjust) and *transformative* (ability to transform). An understanding of resilience at farm-level can provide insights to how farmers react in the face of uncertainty and vulnerability, through a frame that is based on their optimism vis-à-vis possibilities for adaptation and transformation (Darnhofer 2014). The CAP (2023-27) underlines the importance of improving farm-level resilience (European Commission, 2020a) and the concept of resilience is increasingly of interest to policy makers (Buitenhuis et al., 2020; Slijper et al., 2022).

The existing resilience literature identifies a suite of farm-level indicators which could be used to understand existing and evolving conditions of system-level resilience in Ireland. Two types of resilience assessments are dominant within the literature: (i) perceived-resilience assessments (e.g. Marshall and Marshall, 2007; Spiegel et al., 2021) and (ii) resilience assessments based on pre-defined

indicators (e.g. Cabell and Oelofse, 2012; Slijper et al., 2022). The potential of these approaches in assisting the development of suitable metrics in an Irish context is considered with reference to a number of recent examples.

Spiegel et al. (2021) investigate how a cohort of European farmers perceive the robustness, adaptability, and transformability of their farms[18]. The work builds on the approach of Marshall et al. (2007, 2009) who suggested four components of resilience relating to farmers' perceptions and adaptability, namely: (i) perception of risk; (ii) ability to plan, learn, and reorganise; (iii) perception of ability to cope with change; and (iv) level of interest in adapting to change. A latent variable model (as in Hickendorff et al., 2018) is used to classify the farm dataset into groups based on particular characteristics (relating for example to the farmer or farm household), which allows for the exploration of differences in reported resilience across farms.

The perceived resilience assessment framework is suitable for use in an Irish context through the Teagasc National Farm Survey (NFS), particularly given the latter's broad range of ancillary data (e.g., financial, technical and demographic) and the scope for comparison across farm systems and regions[19]. The approach is currently being piloted through a special survey of small farms conducted through the NFS on 2022 farm data, which should be available in Q4 2023.

Using data from the Farm Accountancy Data Network (FADN),[20] Slijper et al. (2022) quantify farm resilience along the dimensions of robustness, adaptation and transformation, and identify influential farm and farmer characteristics using data for a number of European countries. As the Teagasc NFS is part of the FADN, the feasibility of modifying this approach in an Irish context can be further explored.

The use of an existing database such as the FADN, in designing an indicator framework, allows for a dynamic component investigating changes over time. This compares to the more static approach outlined above in relation to the design of perceived resilience assessments, undertaken at a particular point in time. While this is so, in pursuing an assessment based on pre-defined indicators, FADN data may not currently contain adequate data (across all Member States) to provide particular insight on specific farm circumstances, particularly in relation to sustainability performance, the uptake of sustainable practices and the impact of same. In selecting indicators, Slijper et al. (2022) suggest that robust metrics relate to year-on-year changes to, for example, average profitability or crop diversity (most metrics have an economic focus). Adaptation capacity measures include changes to (some) direct costs and annual work units. And finally, transformation can be considered through investigation of data on farm diversification and other economically gainful activity. To assist in ease of interpretation, Slijper et al. (2022) aggregate individual resilience capacity indicators into composite

[18] These are defined as follows: Robustness - the capacity of a farm to withstand stresses and (un)anticipated shocks. Adaptability - the capacity to change the composition of inputs, production, marketing and risk management in response to shocks without changing the structures, feedback mechanisms or identity of a farm. Transformability - the capacity to significantly change the internal structure and feedback mechanisms of a farm in response to either severe shocks or enduring stresses that make business as usual impossible or undesirable.

[19] The Teagasc National Farm Survey operates as part of the EU Farm Accountancy Data Network (FADN) and fulfils Ireland's statutory obligation to provide farm level financial and production data to the European Commission. Data are collected annually from approximately 900 farms, with each farm assigned a weighting factor from the CSO Census of Agriculture to ensure results are representative of the national farm population. Further information available at: https://www.teagasc.ie/rural-economy/rural-economy/national-farm-survey/

[20] https://agriculture.ec.europa.eu/data-and-analysis/farm-structures-and-economics/fadn_en

indicators across robustness, adaptation and transformation. The analysis found that the results were heterogeneous across regions and farm types. Furthermore, the direction of effects often differed between resilience capacities, implying that there were trade-offs between robustness, adaptation and transformation. This underlines the importance of exploring the issue in a holistic way.

The assessment of pre-defined indicators approach could be modified and employed through the NFS to allow for a comparison across farms where selected sustainable practices are being utilised and where they are not, in order to evaluate their role in building resilience. Furthermore, in the event of data on the uptake of such practices being available across other FADN countries, therein lies the potential to undertake a cross-country comparison. This may be particularly feasible in time, as a result of the FADN transitioning to the FSDN (Farm Sustainability Data Network) as proposed in the Farm to Fork strategy.[21]

A scoping study could be undertaken through the Teagasc NFS to explore the feasibility and suitability of both perceived-resilience assessments and those undertaken using pre-defined indicators in an evaluation of farm-level resilience and the impact of sustainable practices on farm-level resilience. Sample questions for such purposes are presented in **Annex 4.**

Furthermore, it is possible to assess resilience of agriculture at the level of the agri-food system. Authors such as Bizikova et al. (2017) attempt to gain an empirical picture of economic, social and environmental elements of the system. Indicators are identified to describe trends within a system, describing what makes the 'whole complex system resilient, what elements in the system need to be strengthened, and what elements of the system might undermine resilience' (Bizikova et al., 2017, 2). Collaborative research involved a qualitative multi-actor effort to brainstorm and define agri-food system components, and identify a comprehensive range of indicators for resilience in relation to those components (Figure 4). In the Irish context, some corresponding data to conduct such an analysis are prospectively available from the NFS/FADN:

- Yearly agricultural output compared with long-term average;
- Mix of crop type (perennial versus annual);
- Proportion of farmland under conservation/no-till/ rotational grazing;
- Livestock density;
- Portion of farms with off-farm income;
- Level of debt per farm type;
- Relative shares of small/ medium/large farms.

[21]https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12951-Conversion-to-a-Farm-Sustainability-Data-Network-FSDN-_en

Climate change	
What specific climate change features undermine resilience?	Changes in growing season; late spring frost; extreme heat; heat and wet spell duration; drought frequency and severity; deficit and excess water
Population	
What are population characteristics that can undermine resilience?	Agricultural producers as proportion of total rural population; rural inhabitants as proportion of total regional population; age of farmers; share of rural population more vulnerable to climate change due to age, poverty and location limiting access to basic services
Farmers and farmland production	
What farm practices can be a source of resilience?	Yearly agricultural output compared with long-term average; mix of crop type (perennial versus annual); proportion of farmland under conservation/no-till/ rotational grazing; livestock density; portion of farm infrastructure in flood-plains; portion of land with tile drainage; portion of barns with air-conditioning; manure management strategies
Market, Economy	
What are the characteristics of the farms with impacts on resilience?	Portion of farms with off-farm income; small and medium farms with insurance coverage; level of debt per farm type; GDP in rural areas; relative shares of small/ medium/large farms
Rural infrastructure	
What is the condition of the infrastructure to support resilience?	Portion of population with small/private drinking systems; frequency of drinking water shortages or contamination; road density in the flood plain; age and condition of the infrastructure; access/density of health emergency systems
Natural environment	
What are the critical features of the environment that can support resilience?	Species range shifts (e.g., hantavirus, invasive); erosion risk; watershed buffer zone; undisturbed buffer zone, rate of reforestation and deforestation; rural land management and species biodiversity

Figure 4: Overview of suite of resilience indicators within six themes (Bizikova et al, 2017)

However, it is likely that not all of the data necessary (pertaining to a full range of indicators) are currently available to conduct a comprehensive assessment of systems-level resilience in Ireland. While this is so, it is possible to undertake the (qualitative, multi-actor) phase where elements, variables and interconnections within the system are mapped and planned. Such maps (e.g. Figure 5) can be used as a diagnostic, planning and scenario-building tool where agri-food resilience is concerned. Such a qualitative, multi-actor mapping exercise was the focus of a large participatory workshop involving over 80 policy-makers and decision-makers at Ireland's agri-food system event in June 2022. Systems maps, identifying variables and pathways of cause and effect, were produced by participants in relation to key sustainability challenges facing Ireland's agri-food system (DAFM/Teagasc, forthcoming 2023). Social science knowledge is highly applicable in putting into practice the challenges of implementing a systems-based approach to sustainability (Macken-Walsh et al., 2022), providing frameworks for involving diverse actors within a system to identify and monitor appropriate indicators for system-level resilience. Similarly, Social Network Analysis (SNA) is an approach to create graphical representations of systems of actors. SNA is particularly useful for mapping AKISs and for understanding knowledge flows and relationships of collaboration and power within AKISs.

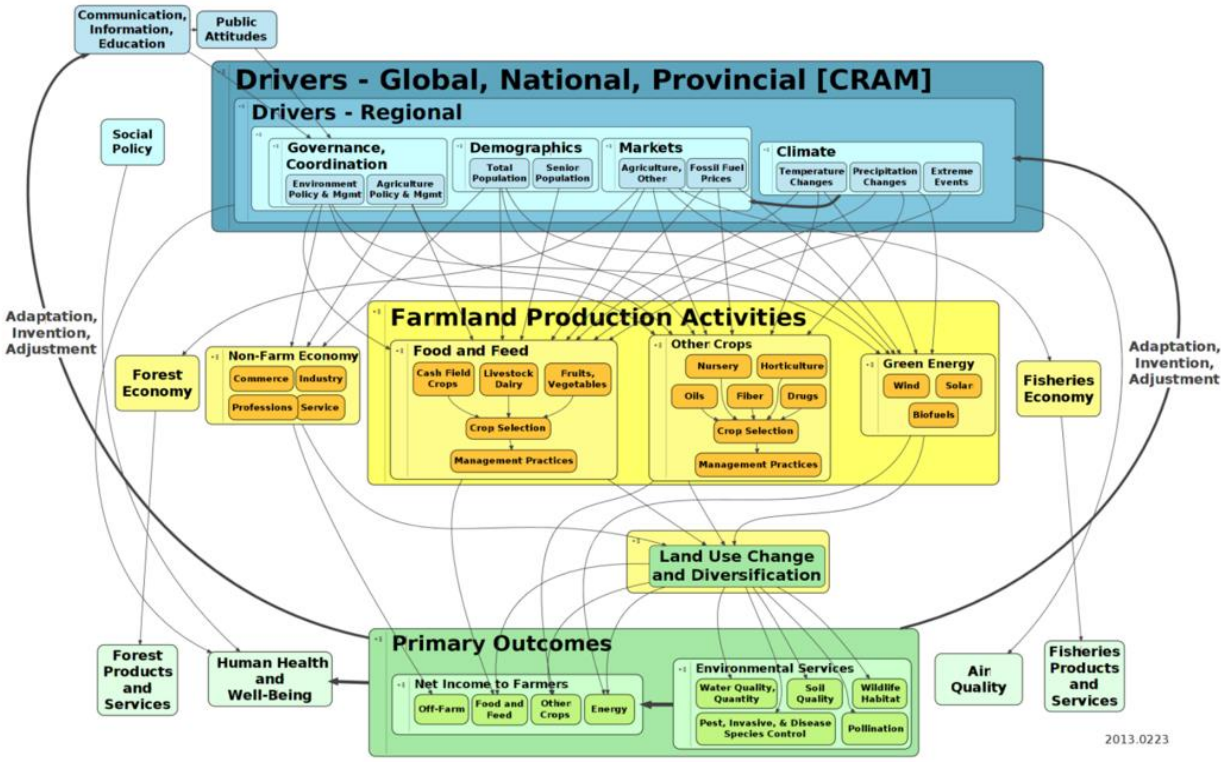

Figure 5: Drivers and pathways of resilience within a system (Bizikova et al., 2017)

2.4 Qualitative data on sustainable agriculture practices at farm-level: state of the art and gaps & opportunities

The collection of qualitative data in Ireland in relation to farmers' implementation of sustainability is typically ad-hoc, occurring in the context of relatively small scale projects such as short-term projects and PhD theses. There is no instrument in Ireland currently that routinely collects qualitative data in relation to farm-level activity[22]. By comparison to data collected routinely by annual survey instruments, there is a paucity of qualitative studies of farmers' implementation of sustainable agriculture practices at farm-level, and therefore few qualitative data exist in relation to the practices profiled in **Annex 1**. Thus, instead of identifying specific gaps, priority areas where qualitative research could impactfully inform policy and extension design are identified.

In summary, 'qualitative methods are used to explore and obtain depth of understanding as to the reasons for success or failure to implement evidence-based practice or to identify strategies for facilitating implementation while quantitative methods are used to test and confirm hypotheses based on an existing conceptual model and obtain breadth of understanding of predictors of successful implementation' (Palinkas et al., 2015, p.533). While qualitative research approaches, for instance narrative interviews and case-studies, are actor/context specific, insights can nonetheless be theoretically generalisable to other actors/context. For example, a qualitative study of a particular

[22] While this is so, Teagasc has initiated through the Irish Qualitative Data Archive (IQDA) at Maynooth University the archiving of qualitative data at the Digital Repository of Ireland https://dri.ie/dri-blog-two-new-collections-irish-agriculture. An initial collection of data has been deposited, which provides an example for the further depositing of qualitative data.

cohort of farmers and the value systems that shape their experiences of a particular scheme or initiative generates findings that can be interpreted by skilled qualitative researchers to identify learnings for cases elsewhere, taking into account differences between cases and adjusting insights from findings as necessary (Flyvbjerg, 2006).

Specific but generalisable principles arising from qualitative observations are summarised by Vanclay (2004), providing guidance in relation to how policy and extension initiatives can be made more effective to have greater influence on practices at farm-level. From qualitative studies that have been conducted in Ireland, lessons emerge in relation to how programmes promoting implementation of sustainable practices at farm-level may become more effective. These lessons are largely consistent with the main principles underpinning findings of similar qualitative studies internationally. A qualitative approach reveals that, overarchingly, factors influencing farmers' implementation of practices relate to cultural (pride oriented), social (relationships and community) and economic (financial) values held by farmers (Macken-Walsh at al., 2012). How these values manifest in relation to why a farmer does/not implement a particular sustainable practice at farm level varies according to circumstances, conditions and contexts. Ultimately, most qualitative evidence points to the need to engage with farmers comprehensively in relation to their cultural, social and economic values, acknowledging that 'farming is a socio-cultural process, not just a technical or income-generating activity' (Vanclay, 2004; Cook et al., 2021).

A study of factors influencing farmers' engagement in agri-environmental schemes for instance found that while economic gains from participation motivated farmers to become involved, they highly valued social, peer-to-peer aspects of participation (Lastro-Brava et al., 2015). The importance of social and human dimensions emerges repeatedly from qualitative studies of the factors influencing implementation of sustainability practices at farm level (Nettle et al., 2022). A recent qualitative study undertook qualitative interviews with Irish dairy farmers to understand norms that promote certain behaviours among Irish dairy farmers where grassland management is concerned. It provides evidence to inform how these norms may be changed by pointing to the need for policy, industry and extension services to construct an altered narrative that re-shapes 'good farmer' norms to support more sustainable farm practices (Shortall, 2022).

The challenge of understanding and making targeted interventions to alter farmers' values and norms in relation to particular practices, disrupting 'esteemed' practices and roles where necessary and generating esteem around sustainable practices, has been emphasised in the sociological literature for some time (Burton et al., 2008). Another frequently observed point is that policy and extension approaches to improving sustainability practices on farms should avoid a dependence on simply farmers passively 'reacting to schemes', and instead farmers should be supported to proactively and reflexively rethink their farming practices (Wilson and Hart, 2001). Participatory approaches, where farmers are actively engaged in processes of knowledge exchange and co-design with scientists, advisors and other relevant actors, are identified as highly effective in achieving optimal sustainability practices at farm level. Such participatory approaches can be combined with more 'top down' programmes. While the conclusions of qualitative studies in relation to how farmers may be supported to implement sustainable practices at farm-level point to the importance of participatory, multi-actor collaborative and empowering learning approaches that operate at the levels of the social and cultural as well as the economic, many of the programmes specified in **Annex 1** maintain a predominantly top-down approach.

Relatively recent innovation initiatives – such as EIP-AGRI Operational Groups - follow a bottom up 'farmer-led' approach to identifying and implementing sustainability practices at farm level. There is an urgent need for new qualitative research to understand and identify lessons the dynamics and factors that shape success within these bottom-up initiatives so that they can be replicated, particularly as these initiatives proliferate and are mainstreamed as a dominant delivery vehicle for the CAP and other policies (McCarthy et al., 2021). Aligned with some of the earliest and most successful programmes to support sustainability practices at farm level, such as the Burren LIFE programme, there is a need for current and forthcoming bottom up initiatives to apply learnings from past experiences (Cullen et al., 2018; Nietzschmann and Sattler, 2020).

There is a need to encourage the blending of traditional top down approaches with more experimental bottom up approaches to maximise impacts at farm level. Consistent with the findings that more collaborative small-group based and one-to-one learning approaches are more effective, they deliver more impact when combined with other extension approaches (Nettle et al., 2022).

Annex 5 overviews the types of qualitative data collection approaches that could be employed to undertake research on a purposively selected collection of case-studies to achieve theoretical generalisability (Flyvbjerg, 2006).

Building on the table of programmes and practices presented in **Annex 1**, a comprehensive profiling of these programmes and practices is needed for a purposive sampling approach[23] in identifying a number of case-studies that offer the greatest opportunity for data collection and data use. A collection of case-studies chosen purposively will have considered characteristics relating to programmes/initiatives that promote particular practices, the different geographical regions in which they operate, the type of actors or multi-actor partnerships that implement them, the different extension approaches used, and the policy/costing model used to fund them. The collection of case-studies should include all features of programmes, practices, contexts, participants etc. that offer insights to a comprehensive range of research issues where farmers' implementation of sustainable agriculture practices is concerned. It is strongly recommended that a multi-actor, transdisciplinary approach to be taken for the comprehensive profiling of programmes/initiatives & practices to inform the purposive sampling approach, so that the richest cases are chosen for policy-makers, extensionists, conservationists, sociologists, economists etc. – i.e. all the relevant end-users of the data.

Qualitative approaches, such as narrative interviewing (Wengraf, 2001), focus groups and ethnographic techniques (involving field observation of e.g. farmers implementing practices) combine to generate evidence and insights that have wide-reaching relevance where multi-actor, approaches are concerned but also where top-down extension and policy implementation approaches are concerned. Qualitative approaches serve to verify actual occurrences and practices on farms rather than relying on actors' reporting of occurrence and practices. In-depth and observational qualitative approaches are preferred over techniques such as semi-structured interviewing in the case of identifying opportunities to expand the national dataset on sustainability practices at farm level,

[23] 'Purposeful sampling is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest' (Palinkas et al., 2015).

because the latter overlap with survey and remote sensing approaches already reviewed in the previous sections of this short review, particularly those assessing behavioural/attitudinal factors

The strategic approach of in-depth qualitative approaches, and the purchase of these approaches analytically for informing more effective policy and extension implementation, is further augmented when they are utilised as a formative evaluation tool. Informed by sociological theories of power, social networks, as well as diversity and gender, qualitative evaluation and impact assessment tools can be implemented in a time efficient manner to gain evidence in relation to the operation of programmes/initiatives and how they may be improved. A user-friendly handbook of evaluation and impact assessment tools was produced in the context of sustainability-oriented multi-actor innovation projects (Macken-Walsh, 2021). The tools, informed by social science knowledge, are suitable for use by practitioners involved in extension & policy implementation in collaboration with researchers and some were used recently for evaluating farmers' learning and empowerment in the context of the Comeragh Upland Communities EIP-AGRI Operational Group (Foley and Carton, 2022).

3. Conclusions and Recommendations

It is clear from the short review presented in this report that a variety of quantitative and qualitative data are collected either routinely or ad hoc; and that there are gaps in these data. However, in order to fully exploit existing data and prioritise how these data may be enhanced to inform policy and extension, a major challenge is to consolidate, synthesise and reconcile existing data.

As profiled in **Annex 1**, a variety of programmes and initiatives in Ireland, both 'top down' and 'bottom up' support the implementation of sustainable practices at farm level. The diversity of practices – some of which are promoted through national, mainstream programmes, and others which are designed on the ground in specific regions by farmers – holds implications for how data are and can be collected in relation to their implementation.

Where quantitative data are concerned, as reviewed in Section 2.1 of this report, data available from a national inventory accounting perspective shed light on the extent to which some sustainable farm practices are implemented at farm level. For instance, changes at farm level in substituting chemical N fertiliser sources are reflected in national inventories through reduced sales of chemical fertilisers nationally. These insights from national inventories are valuable for directing the attention of policy and extension prioritisation, for instance, toward areas where data indicate that there is less practice change at farm level.

Beyond data available from national inventories providing insights to practices at farm level, survey instruments such as the NFS provide insights in relation to the extent of implementation where some practices are concerned, as identified in Section 2.1 of this report. However, a range of diverse factors influence the feasibility of how survey instruments may be expanded to assess the implementation of a wider range of practices. While gaps, i.e. practices in relation to which no data are routinely collected are easy to identify, factors complicating the feasibility of collecting data currently in relation to specific practices relate to 'unknowns'. For instance, in relation to practices such as improved animal health/less animal replacements, the 'rebound effect' (increase in animal numbers due to higher productivity) is currently unknown. In relation to some practices, research is outstanding regarding their efficacy at systems level. For example, where feed additives are concerned, additional research is required to ensure there are no harmful residues in final products. Where other practices are concerned, their implementation is interrelated with the implementation of other practices. For instance, the practice of optimising soil pH though liming is interrelated with the practice of soil sampling. Similarly, the establishment and maintenance of clover requires optimising soil pH and P/K levels. Such inter-dependencies can be taken into account in survey design, but at farm-level, the necessary 'bundling' of practices can have implications for farmers' willingness and capabilities to implement them. Some of these and other factors - relating specifically to contextual (economic, social and cultural factors) that shape the environment of farmers' decision-making processes - are reviewed in this report with a view to identifying the orientation of research questions to guide data collection where farmers' implementation of practices are concerned.

Where behavioural and attitudinal data in relation to farmers' implementation practices are concerned, sample approaches are reviewed in this report (Section 2.2)[24]. These approaches are not routinely implemented in Ireland through national survey instruments but offer to provide statistically

[24] Behavioural economics is not included in the review of this report.

significant data in relation to factors that shape farmers' dispositions towards and willingness to implement sustainable practices now and in the future. Similarly, Section 2.3 identifies approaches to assess resilience at farm-level and system-level, neither of which are routinely implemented in Ireland. Planned questions in relation to farm-level resilience for inclusion in Teagasc's NFS are highlighted, and potential approaches for assessing system-level resilience are highlighted.

Qualitative approaches, such as narrative interviewing (Wengraf, 2001), focus groups and ethnographic techniques (involving field observation of e.g. farmers implementing practices) combine to generate evidence and insights that have wide-reaching relevance where multi-actor, approaches are concerned but also where top-down extension and policy implementation approaches are concerned. Qualitative approaches serve to verify actual occurrences and practices on farms rather than relying on actors' reporting of occurrence and practices. In-depth and observational qualitative approaches are preferred over techniques such as semi-structured interviewing in the case of identifying opportunities to expand the national dataset on sustainability practices at farm level, because also the latter overlap with survey approaches suggested in Section 2.2.

Qualitative approaches (detailed in Section 2.4) can be applied and coordinated systematically to assess the national picture where implementation of sustainable practices at farm-level is concerned. The particular focus of such qualitative approaches is to explain how and why policy and extension approaches are to various extents effective. Such approaches provide important information for policy and extension design. Purposively selected cases of programmes/initiatives supporting the implementation of sustainability practices at farm-level could be analysed qualitatively to provide important evidence for strategic improvement of programmes/initiatives nationally.

Considering the range of data types reviewed in this report (the extent to which they are collected as well as gaps and opportunities), there exists significant potential to establish a national database or source of data – oriented to social science data – to complement existing initiatives such as the Sustainability Digital Platform. Adding to the need to count carbon emissions and removals is the need to use social science data – targeting behavioural issues underlying trends in emissions and removals data – to inform how policy and extension efforts may address important behavioural challenges / exploit behavioural opportunities at farm level to support and accelerate the realisation of targets. The gendered dimensions of socio-cultural, economic, technical and behavioural aspects of issues regarding climate change at farm-level also need to be urgently considered (Akram-Lodhi, A. H., 2018).

A sought after requirement in the context of the EU Green Deal are data platforms that provide evidence-based decision-making tools. Such a platform in the Irish case requires a 'dashboard' through which both quantitative and qualitative data can be accessed, providing comprehensive evidence for policy and extension decision-making purposes. There is an urgent need to harvest and make accessible data beyond which are collected through national inventories and by national survey instruments such as the CSO Census of Agriculture and Teagasc's National Farm Survey. A range of ad-hoc studies are conducted by myriad European and nationally funded research projects and smaller scale postgraduate studies. The proportion and adoption by Research Performing Organisations of Open Science and FAIR (Findable, Accessible, Interoperable, Reusable) data principles is an urgent concern in creating an environment and, ideally, a platform where comprehensive social science data are made available for policy and extension design. While gaps and opportunities for new data collection requirements are identified in this report, gaps and opportunities can only be reliably

identified once all data collected are synthesised and ‘misunderstandings’ or inconsistencies between different disciplinary/theoretical/methodological approaches are reconciled to create a comprehensive, holistic understanding of sustainability problems. On that basis, cost-effective data collection opportunities can be pursued that avoid duplication and maximise potential for informing more impactful policy and extension strategies at farm-level.

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Annex 1

Sustainable agriculture in Ireland
Devenish; Agrinewal
Origin Green
Bord Bia Sustainable Beef and Lamb Assurance Scheme (SBLAS)
Agri-Climate Rural Environment Scheme (ACRES)
The 'Areas of Natural Constraint' (ANC) Schem
Targeted Agricultural Modernisation Scheme (TAMS 3)
Low Emission Slurry Spreading (LESS) under TAMS
Solar Capital Investment Scheme (SCIS) under TAMS
FarmPEAT Project
Legacy4LIFE Advancing Farm to Fork Project
The Farming for Nature (FFN) initiative
The Burren Programme
SUAS
Glanbia/Tirlán and Baileys/Sustainable Farming Academy
Tirlán Sustainability Action Payment
Results Based Environment Agri Pilot Programme (REAP)
Woodland Support Fund 2021/22
Organic Farming Scheme
FOOD-I initiative
Protein-I project
Cill Ulta: Northwest Bioeconomy Hub
Corncrake Grant Scheme (CGS)
The Living Bog Project
AranLIFE project
Farm4More project
Teagasc BETTER Farm Programmes for Beef and Sheep
Kerry Group Evolve dairy sustainability programme
Agricultural Sustainability Support and Advisory Programme (ASSAP)
The BRIDE Project (Biodiversity Regeneration In a Dairying Environment)
Agri-Environment Training Scheme (AETS)
Beef Environmental Efficiency Programme Sucklers (BEEP-S) as part of the Beef Sector Efficiency Programme
Suckler Carbon Efficiency Programme
Dairy Beef Calf Programme as part of Beef Sector Efficiency Programmes - Beef Sector Efficiency Programme 2022
Enable Conservation Tillage (ECT) - Wider Adoption of Sustainable Conservation Tillage Systems
Danú Farming Group - Project Plan for a Biological Farming Transition Programme
North Connemara Locally Led Agri-environmental Scheme
Mulkear EIP-Innovation, Technology & KT for Farmer Led Enhancement of Water Quality, Instream Habitat and Riparian Management in the Mulkear Catchment
Farming Rathcroghan Project- Sustainable Farming in the Rathcroghan Archaeological Landscape
Inishowen Upland Farmers Project
Blackstairs farming Futures (BFF) Sustainable farming project in the Blackstairs Mountains
Duallow Project - Duhallow Farming for Blue Dot Catchments

Cúlra Créafóige - Cultivation Renewal Programme
Hen Harrier Project
Protecting Farmland Pollinators
Pearl Mussel Project – Farming for nature in a vibrant rural economy.
TEAGASC CLIMATE ACTION STRATEGY (2022-2030)
BIA Innovator
Dingle Hub - Living Lab
Farm Zero
Integrated anaerobic digestion and green biorefining demonstration initiative
Organic Capital Investment Scheme
Slurry storage scheme
Proposed dairy reduction scheme
Propose beef reduction scheme
Temporary Business Energy Scheme (TBESS)
Protein Aid Scheme
Protein Cereal Mix Scheme
Straw Incorporation Measure (SIM)
New €60m scheme to help farmers improve water quality (announced Nov 22 as an EIP OG)
Tillage Incentive Scheme
Microgeneration Support Scheme
Support Scheme for Renewable Heat
Lough Carra LIFE Project
Sustainable Fertiliser for professionals training course
Forestry Programme 2023-2027
Sustainable Food Systems Ireland
Ag-Climatise
Agricultural Catchments Programme
Talamh Beo Soil Biodiversity Project
Irish Seed Savers Association
Knowledge Transfer (KT) Programme
Wild Atlantic Nature LIFE IP
GAEC 8
Eco-Scheme Space for Nature
Terrain-AI

Annex 2: The Intergovernmental Panel on Climate Change (IPCC) reporting framework: practices (or 'measures') at farm-level

Greenhouse gas emissions from the agricultural sector are captured underneath a number of heading under the Intergovernmental Panel on Climate Change (IPCC) reporting framework:

- Agricultural based emissions (IPCC Category 3)
- Land Use and Land Use change emissions (IPCC Category 4)
- Energy emissions (IPCC Category 1).

Emissions are estimated based on activity data multiplied by an associated emissions factor.

Mitigation of Agricultural based emissions (IPCC Category 3)

1. Efficiency Measures: All other things remaining constant one route to mitigating GHG emissions is to produce product more efficiently i.e. same level of output with fewer inputs. For a given volume of agricultural output, this has the potential to reduce GHG emissions. Established technologies that promote efficiencies and lower the carbon footprint of agricultural products include:

- Higher animal productivity (e.g. higher yields, better animal health, higher fertility, higher grass growth)
- Changes to production techniques (e.g.) extending the ruminant animals grazing season
- Improved soil nutrient management (more selective application of synthetic fertilisers)
- Improved genetic merit
- Use of sexed semen to increase the proportion of dairy-sourced beef production

While efficiency measures will decrease the GHG intensity of agricultural production (i.e. Reduce the carbon footprint of milk or meat production), these measures will not necessarily decrease total sectoral emissions.

2. Absolute emissions reduction: The main current technologies that have proven scientific potential to reduce greenhouse gas emissions revolve around reduction the quantity and type of chemical nitrogen fertiliser (and associated nitrous oxide) applied on farms. These include:

- Achievement of good soil nutrient and pH status
- Optimal use of animal manures and digestates
- Related to the above, the development of bio-based fertilisers
- The development of low-emission mineral nitrogen fertilizers.
- Reducing N excretion by optimising crude protein content in livestock diets

In addition, reducing chemical N fertiliser will also contribute to achieving improved water quality and fulfilling obligations under the EU Nitrates Directive.

Emergent technologies for reducing methane emissions revolve around feed additives, such as 3-NOP or fatty acid supplementation, chemical amendments to reduce manure pH, or reducing the age of slaughter of livestock (thus reducing lifetime methane/N2O from these animals). In the future, breeding for low methane animals may hold promise, and indeed higher Economic Breeding Index (EBI) dairy cows have been shown to have lower than expected enteric methane emissions (Lahart et al. 2021).

2.2.2 Mitigation of Land use and land use change (LULUCF) emissions (IPCC Category 4)

LULUCF revolves around land management and mitigation measure under this category tend to reduce direct CO_2 emissions or enhance CO_2 removals from the atmosphere in terms of land management or change in land use e.g. planting of tress or hedgerows on land previously used in agricultural production. While LULUCF has yet to be allocated a target, a reduction of between 37% and 58% was proposed in the Climate Action Plan 2021.

LULUCF measures considered under the Teagasc MACC consisted of peatland, grassland, cropland and forest management based measures. These include:

- Land-use mitigation strategies to enhance carbon (C) sinks or reduce C loss from agricultural soils include pasture nutrient management (optimising pH, fertilisation, etc.), cover crops and straw incorporation in tillage and water table manipulation in organic soils,
- Forestry based measures include afforestation, reduced deforestation, extending forest rotations, replanting of former afforested peats with birch and agroforestry.

Even though it might be economically rational for some farmers to engage in land use change (e.g. planting of forestry) the historical evidence would suggest that non-economic factors tend to be a constraint.

2.2.3 Mitigation of Energy based emissions associated with agricultural production (IPCC Category 1)

The capacity for offsetting fossil fuel emissions is highly uncertain. At a farm level micro scale farmers could investment in micro generation wind turbines of solar panels to transition to green energy for on-farm activity. On a macro scale the 2018 Teagasc MACC bioenergy was estimated to deliver 1.37 to 2.05 Mt CO2-e yr-1, yet much of this has remained unrealised as both the land area of biomass crops and anaerobic digestion uptake is very low.

Annex 3: Examples of Value Belief Norm, Theory of Planned Behaviour and Segmentation Questionnaires

Table 1 Hypothetical questionnaire based on the VBN to access farmer behaviour regarding adopting protected urea as a mitigation measure

	Not at all	**Low**	**Slightly**	**Moderately**	**Considerably**	**Very**	**Extremely**
Biospheric Values (How important is….)							
Protecting the environment and preserving nature							
Respecting the earth and living in harmony with other species							
Preventing pollution and protecting natural resources							
Altruistic Values (How important is….)							
Equality: Equal opportunity for all							
Social justice: Correcting injustice, care for others							
A world at peace: A world free of war and conflict							

Egoistic Values (How important is….)							
Being influential and having an impact on other people and events							
Creating wealth and striving for a financially profitable business							
Having power and being able to lead others							
	Strongly disagre	**Disagree**	**Somewhat disagree**	**Unsure**	**Somewhat agree**	**Agree**	**Strongly agree**
New Environmental Paradigm (NEP) (How strongly to you disagree/agree…)							
We are approaching the limit of the number of people the earth can support.							
Humans have the right to modify the natural environment to suit their needs.							
When humans interfere with nature it often produces disastrous consequences.							
Human ingenuity will insure that we do NOT make the earth unliveable							
Humans are severely abusing the environment							
The earth has plenty of natural resources if we just learn how to develop them.							
Plants and animals have as much right as humans to exist.							
The balance of nature is strong enough to cope with the impacts of modern industrial nations							

Despite our special abilities humans are still subject to the laws of nature							
The so–called ‘‘ecological crisis’’ facing humankind has been greatly exaggerated.							
The earth is like a spaceship with very limited room and resources.							
Humans were meant to rule over the rest of nature.							
The balance of nature is very delicate and easily upset							
Humans will eventually learn enough about how nature works to be able to control it							
If things continue on their present course, we will soon experience a major ecological catastrophe.							
Awareness of consequences (How strongly to you disagree/agree…)							
The modern agriculture production system can cause greenhouse gases and climate change							
The production and use of synthetic fertiliser can generate huge							
The use of protected urea will greatly benefit the environment							
The use of synthetic fertiliser can cause pollution of the local environment							
Ascription of Responsibility (How strongly to you disagree/agree…)							

Minimising my climatic impacts from fertiliser application is in part my responsibility							
Every farmer must take responsibility for the greenhouse gases caused by fertiliser production							
It is my responsibility to minimize my impacts on the environment as a farmer							
Personal norms (How strongly to you disagree/agree…)							
I feel a personal obligation to do whatever I can to reduce my greenhouse gases from fertiliser application							
I feel morally obligated to use protected urea regardless of what other farmers are doing							
I would feel guilty if I were responsible for damage to the environment as a farmer							
Using protected urea would make me feel like I am being a better farmer							
Behaviour (How strongly to you disagree/agree…)							
I intend to use protected urea in the foreseeable future							
I plan to use protected urea in the near future							
There is a high likelihood that I will use protected urea within the foreseeable future							
I will use protected urea within the next 12 months							

Example of a TPB based Questionnaire

Table 2 Hypothetical questionnaire based on the TPB to access farmer behaviour regarding adopting protected urea as a mitigation measure

	Strongly disagree	**Disagree**	**Somewhat disagree**	**Unsure**	**Somewhat agree**	**Agree**	**Strongly agree**
Attitudinal Items (How strongly to you disagree/agree…)							
I think using protected urea is beneficial							
I think using protected urea is good							
I think that using protected urea is wise							
I think that using protected urea is worthless							
Subjective Norms (How strongly to you disagree/agree…)							
My family suggest using protected urea							
Friends who influence my behaviour think I should use protected urea							
Other farmers recommend using protected urea							
Perceived Behavioral Control (PBC) Items (How strongly to you disagree/agree…)							
I am not confident that I could use protected urea even if I wanted to							
Protected urea is widely available for me to purchase							
I don't know how to distinguish between protected urea and other fertiliser types							
Intention (How strongly to you disagree/agree…)							
I expect to use protected urea in the next year							
I want to use protected urea in the next year							

I intend to use protected urea in the next year							

Example of a Segmentation based Questionnaire

Table 3 Hypothetical questionnaire that could be used to segment farmers based on their perceptions of a broad range of climate change issues [adapted from Hyland et al. (2016)]

(How strongly to you disagree/agree…)	**Strongly disagree**	**Disagree**	**Somewhat disagree**	**Unsure**	**Somewhat agree**	**Agree**	**Strongly agree**
Livestock farming contributes to climate change							
Climate change will affect Irish farming in the next 10 years							
I accept that man-made climate change is happening							
Livestock farmers should share responsibility towards the industry's impact on climate change							
Climate change is an important global issue							
It is possible to reduce GHG emissions from my farm without lowering production levels							
Environmental regulations are important for the future of farming							
Others in my family think that I should farm as environmentally friendly as possible							
I want to farm as environmentally friendly as possible							
Switching to a more environmentally friendly farming methods would not require much change from my current operation							
As a farmer I have an obligation to maintain or improve the environment for future generations							

I am interested in trying different technologies and/or systems to reduce my farms' GHG emissions							
The way farming colleagues think about my farm is important to me							
The government should encourage food production in Ireland to reduce reliance on imports							
The government should financially support farmers in adapting to climate change							
Other industries pollute more than livestock farmers and should therefore be penalised more							
Any climate change reduction strategies must make economic sense to the individual farmer							
Being seen as primarily as a food producer is important to me							
The best climate change mitigation strategies are too costly to adopt							
Climate change poses more of a threat to farming in the next 10 years than that of a general recession							
Climate change will lead to lower productivity on my farm due to disease and pests							
Uncertainty due to variable weather patterns caused by climate change will negatively influence my ability to farm in the future							
Beef or lamb produced with low emissions should be sold at a higher price							

Annex 4 Resilience questions included in Teagasc National Farm Survey 2022 Small Farms Survey – based on approach of Spiegl et al. (2021).

(a) As a farmer it is hard to manage my farm in such a way that it recovers quickly from shocks.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(b) Personally, I find it easy to get back to normal after a setback.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
(c) A big shock will not heavily affect me, as I have enough options to deal with this on my farm.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(d) If needed, my farm can adopt new activities or technologies in response to challenging situations.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(e) In times of change, I am good at adapting myself and facing up to agricultural challenges.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(f) My farm is not flexible and cannot easily be adjusted to deal with a changing environment.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(g) I am in trouble if external circumstances would drastically change, as it is hard to reorganise my farm.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(h) If needed, I can easily make major changes that would transform my farm.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(i) After facing a challenging period on my farm, I still have the ability to radically reorganise my farm.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

(j) I am optimistic about the future of this farm
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Disagree Strongly Strongly Agree

Annex 5: Explanatory notes on sample qualitative data collection approaches for conducting case-studies.

Data collection instrument	Analytical purchase/use of data	Approximate resources/time to implement
Social Network Analysis	To identify and map the connections between different actors in the Agriculture Knowledge Information System in order to gain evidence of who is involved programmes/initiatives and to what extent/how actors are connected to each other. SNA also identifies those who are absent from/marginalise in networks and can be used as tool for visioning more inclusive and innovative networks, that	Social Network Analysis can be evidence-based, using secondary data such as official reports that document the nature of actors' involvement in programmes/initiatives. The extent of the exercise depends on the vastness and complexity of the network. Participatory Social Network Analysis, used to build impressionistic models, involve participatory exercises where actors who key informants in relation to a particular network build a network (identifies actors and connections) on the basis of their knowledge and experience of the network. This approach, which is workshop-based, takes less time than an evidence-based networking exercise. Sample approach: Pages 145-166 of https://liaison2020.eu/wp-content/uploads/2021/09/LIAISON-Assessment-Tools.pdf

	involve a greater diversity of actors and connections between them.	
Agri-Food Systems Mapping	Agri-food systems mapping involves the facilitation of diverse actors/key informants involved in a system to identify variables within a system; identifying the connections between them; and positive or negative relationships between them for sustainability. It can be used as a diagnostic tool, to assess the sustainability of a particular system (and to identify areas in need of intervention); and as a scenario-	Agri-food systems mapping is an exercise that is typically workshop based. The length of the workshop/s depends on the number and types of actors involved, but a single map of a system and constituent variables can by typically constructed within 1.5 hours. Agri-food systems mapping is often then followed by evidence-based data-gathering to verify the indicators and to measure impacts of interventions identified and implemented on the basis of the original mapping exercise. Sample approaches: Participatory/workshop based mapping: https://www.cecan.ac.uk/wp-content/uploads/2020/09/PSM-Workshop-method.pdf Evidence based mapping: https://www.jstor.org/stable/pdf/resrep17139.pdf?refreqid=excelsior%3A3e956022cb199e50bb70469e4fdd97c3&ab_segments=&origin=&initiator=&acceptTC=1

	building tool, modelling more sustainable agri-food systems.	
Narrative interviewing	Understanding actor-specific value systems and actor-specific experiences of particular programmes/initiatives, to assess how programmes/initiatives may become more relevant to actors	Approx. 4 hours to conduct each interview & 4 hours to analyse each interview. For each multi-actor/bottom up initiative, at least one actor type interviewed per multi-actor project, and additional interviews undertaken with end-users For top-down programmes, actors involved in implementing the programme are interviewed. At least one interview with each end-user is conducted Sample approach: Wengraf (2010) https://www.jiscmail.ac.uk/cgi-bin/webadmin?A3=ind0812&L=BIOGRAPHIC-NARRATIVE-BNIM&E=base64&P=890501&B=------%3D_NextPart_000_003F_01C961CD.F2E03660&T=application%2Fmsword;%20name=%22B%20-%20Summary%20of%20BNIM.4.doc%22&N=B%20-%20Summary%20of%20BNIM.4.doc&attachment=q&XSS=3
Focus groups	To understand group perspectives on particular issues/topics, eliciting the views of a group on their shared experiences of a programme	Focus groups take 4 hours to implement and approximately 5-6 hours to analyse. Focus groups are customised to specific research needs. A seminal paper on the purpose/analytical purchase of focus groups is: Then, Karen L.; Rankin, James A.; Ali, Elena **Focus Group Research: What Is It and How Can It Be Used?** Canadian Journal of Cardiovascular Nursing . Winter2014, Vol. 24 Issue 1, p16-22. 7p. 3
Formative evaluation techniques	A range of formative evaluation techniques are used to evaluate/assess the	A handbook detailing various tools and the resources/time to implement them are detailed in: https://liaison2020.eu/wp-content/uploads/2021/09/LIAISON-Assessment-Tools.pdf

	impact of programmes/initiatives so that features of the programmes can be enhanced/ made mode effective (where possible) in response to user feedback.	
Ethnography and participant observation	Ethnographic research, using conversational based interviewing and participant observation (observing what actors actually do, when and the implements they use (materialities) etc.) can be used to gain evidence in relation and verify what actors do (rather than relying on actors' reports of	Ethnographic research/participant observation can require long periods of time when researchers are exploring cultures in an open-ended way. However, when implementation of specific practices are concerned, participant observation and conversational interviews can be conducted relatively quickly. The number of cases chosen (purposively) for inclusion determines the time required for field research and analysis.

	what they do).	