All-Island of Ireland Agri-Food Research Ecosystem Mapping Exercise Report

Abbreviations

AFBI	Agri-Food and Biosciences Institute
AMR	Antimicrobial Resistance
CAGR	Compound Annual Growth Rate
CAP	Common Agricultural Policy
DAERA	Department of Agriculture, Environment and Rural Affairs
DAFM	Department of Agriculture, Food and the Marine
DfE	Department for the Economy
EC	European Commission
EI	Enterprise Ireland
EPA	Environmental Protection Agency
EU	European Union
FWCI	Field-Weighted Citation Impact
GB	Great Britain
GERD	Gross Domestic Expenditure on Research and Development
GHG	Greenhouse Gas
GVA	Gross Value Added
HRB	Health Research Board
IRC	Irish Research Council
LULC	Land Use and Land Cover
LULUCF	Land Use, Land Use Change and Forestry
NI	Northern Ireland
NUIG	NUI Galway
PI	Principal Investigator
QUB	Queen's University Belfast
ROI	Republic of Ireland
RPO	Research Performing Organisation
R&I	Research and Innovation
SFI	Science Foundation Ireland
TRL	Technology Readiness Level
UCC	University College Cork
UCD	University College Dublin
UK	United Kingdom
UU	Ulster University
WHO	World Health Organisation

Table of Contents

List of Figures

List of Tables

1. Executive Summary

The Agri-Food sector is the largest indigenous industry in the Republic of Ireland (ROI)[1] and is more important in Northern Ireland (NI) in terms of employment and economic contribution than any other country in the United Kingdom[2]. The sector is a key feature of the island of Ireland's economy, culture and society, exporting food and drink products around the world and contributing to the island's global reputation. The sector is highly complex with a range of actors along the food chain, and is a major future driver for the economic development of the whole island of Ireland. The research and innovation (R&I) scope of this sector is vast - covering topics ranging from food science, health, animal science, crop science, economics and rural development to the environment.

For the first time, the seven most research intensive institutions in Agri-Food on the island of Ireland - University College Dublin (UCD), Teagasc, University College Cork (UCC), the National University of Ireland Galway (NUIG), Queen's University Belfast (QUB), Ulster University (UU), and the Agri-Food Biosciences Institute (AFBI) - have come together to support the *mapping of the Agri-Food research ecosystem across the entire island of Ireland* for publicly funded research awarded from 2015-2020.

This mapping exercise is very timely - the Agri-Food sector on the island is facing some of its greatest challenges due to the COVID-19 pandemic, the geopolitical situation in Ukraine, changing dietary patterns and environmental issues associated with current production practices, and national and international climate mitigation obligations. Food production systems are one of the key drivers of climate change, and the EU has set out a range of ambitious targets to reduce the use of pesticides and antimicrobials, reduce fertilisation, increase organic farming, improve animal health and welfare, and reverse biodiversity loss by 2030. Although the Agri-Food sector is one of the largest contributors to greenhouse gas (GHG) emissions and climate change[3], it is also one of the main sectors that is being most impacted by environmental degradation and is one of the few sectors that can work towards a carbon positive position.

The sustainability of the whole food system, from producer to consumer, is the biggest challenge facing the sector on the island as well as globally. Sustainable agriculture and food systems will require diversification, a building of resilience and a whole system approach. A strong R&I ecosystem is key to supporting Agri-Food primary producers, processors, SMEs, multinationals and research institutions to drive future waves of economic development in the sector to assist the sector to radically transform to produce high quality products that are internationally competitive using environmentally neutral production systems.

There is strong collaborative research taking place across the island of Ireland, and complementary strengths exist both North and South. It is estimated that a total of €680.9M of public investment has been awarded to academic research projects and Centres on the island in the area of Agri-Food between 2015 and 2020. Year-on-year public investment in Principal Investigator (PI)-led individual research projects (n=1,805) has declined annually since 2015, falling from €138.6M in 2015 to €96.2M in 2019. This mirrors the decline in Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP for the ROI from 1.52% in 2014 to an estimated 1.23% in 2019[4,5]. The PI-led funding portfolio experienced an overall negative compound annual growth rate (CAGR) of -8.7% between 2015 and 2019. During this same period, institutions in ROI and NI produced 7,779 research outputs in the Agricultural and Biological Sciences subject area, with a citation impact of 60% above world averages[6].

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[1] Department of Agriculture, Food and the Marine, *Annual Review and Outlook for Agriculture, Food and the Marine 2021*. 2021, Department of Agriculture, Food and the Marine: Dublin, Ireland.

[2] Allen, M*., Northern Ireland's Agri-Food sector – background and possible 'Brexit' considerations*. 2016, Northern Ireland Assembly.

[3] Environmental Protection Agency, *Ireland's Provisional Greenhouse Gas Emissions 1990-2019*. 2020, Environmental Protection Agency: Dublin, Ireland.

[4] OECD*, Main Science and Technology Indicators, Volume 2020 Issue 2*. 2021, Organisation for Economic Cooperation and Development: Paris, France.

[5] It should be noted that the actual amount of R&D investment has increased by 67%, from €2.76 billion in 2012 to an estimated €4.59 billion in 2020.

[6] Figures taken from SciVal, using the "Agricultural and Biological Sciences" subject area from the All Science Journal Classification used in Scopus. This is the default scheme in SciVal.

Summary of Key Findings

Total Public Research Investment:

- It is estimated that a total of €680.9M of public investment was awarded to academic research projects and Centres in the area of Agri-Food on the island of Ireland between 2015 and 2020. This includes:
  - ➤ 1,805 PI-led individual research projects to the value of €608.2M of public investment.
  - ➤ €11.2M awarded by Enterprise Ireland (EI) to ROI RPOs for research commercialisation (i.e. Commercialisation Fund and Commercial Case Feasibility Grant) and public/private collaborations (i.e. Technology Gateways, Innovation Voucher and Innovation Partnership).
  - ➤ The funding and renewal of three EI Technology Centres to the value of €20.8M.
  - ➤ €40.7M public investment awarded to two new Science Foundation Ireland (SFI) Research Centres.

Awards by Region and Funder Type:

- ROI research agencies, public bodies and government departments accounted for nearly 60% of historic public investment for PI-led individual research projects awarded during 2015-2020.
- Public research investment by EU, NI and GB funders accounted for 21.6%, 16.4% and 4.7% of the total €608.2M respectively. Over 40% of the €99.6M NI funding was awarded to projects in the Animal theme.
- Over 70% of public investment in Agri-Food research was awarded to RPOs based in ROI (€428.0M) - this does not include the additional €72.7M public investment for EI R&I awards, EI Technology Centres and SFI Research Centres to ROI institutions. €180.2M (29.6%) was awarded to NI-based RPOs during the same period.

Awards by Research Theme and Topic:

- ROI-based funders awarded the largest amount of funding to the Environment theme (€104.6M). Nearly half (€49.6M) of all Environment projects funded across the island were on the topic of 'Natural Resources & Raw Materials Efficiency'.
- The majority of funding awarded by the EU across the two regions was also to the Environment theme (€45.8M), making up 35% of total EU funding awarded.
- For NI-based funders, the key research area for investment during the period 2015-2020 was in the Animal theme (€40.9M).
- For GB-based funders, the priority theme appears to be Food, where €11.7M was invested during the period 2015-2020.
- Only 11.2% (€68.2M) of PI-led individual research projects were funded in Plant theme, with the majority of these being awarded to projects in the area of 'Crops & Agronomy' (€37.1M).
- The diversity in focus and expertise across the two jurisdictions points to the complementarity of an all-island approach, leveraging investment in diverse and complimentary areas across the five research themes.
- The top five research topics by funding in NI were:
  - ➤ Animal theme: 'Animal Production & Livestock Systems' (€24.8M), 'Animal Health & Welfare' (€22.3M), and 'Fisheries & Aquatic Ecosystems' (€22.2M)
  - ➤ Food theme: 'Food Chain Integrity & Safety' (€16.2M)
  - ➤ Environment theme: 'Ecosystems' (€12.8M)
- In ROI, the top five research topics in terms of funding drawn down were:
  - ➤ Animal theme: 'Animal Production & Livestock Systems' (€60.6M)
  - ➤ Environment theme: 'Natural Resources & Raw Materials Efficiency' (€49.6M), 'Climate / Air / Water' (€29.6M) and 'Soils / Land Use / Mixed Farming & Diversification' (€23.6M)
  - ➤ Plant theme: 'Crops & Agronomy' (€35.2M).

Funding Award Trends:

- The majority of public research investment (63.5%) was awarded to projects to the value of €1M or less. There were a limited number of large scale PI-led individual research awards in the Plant and Environment themes, with the majority of larger awards (€5M or over) funded in the Animal, Food and Sustainability themes.
- The year-on-year trend in public research investment for PI-led individual projects fell significantly from €138.6M in 2015 to €96.2M in 2019.
- The Environment theme experienced the only increase in public investment, with a compound annual growth rate (CAGR) of 9.2% between 2015 and 2019.
- The Food theme experienced a fluctuating, but relatively stable growth of -1.4% CAGR during the period, with €30.0M invested in Food research in 2016.
- There has been a fairly stable growth rate of -3.6% CAGR for the Sustainability theme (decreasing from €16.3M in 2015 to €14.1M in 2019).
- The Animal theme experienced a significant decline in public investment from €52.0M in 2015 to €19.5M in 2019, representing a significant negative CAGR of -21.8%
- The Plant theme experienced the greatest decrease in funding during the period with a large negative CAGR of -26.5%, reducing from a healthy €25.7M in 2015 to just €7.5M in 2019.
- The overall Agri-Food (PI-led) funding portfolio experienced a negative growth rate of -8.7% CAGR between 2015 and 2019.

Research Outputs:

- During the five-year period 2015-2019, institutions in ROI and NI together produced 7,779 research outputs in the Agricultural and Biological Sciences subject area[7].

- The all-island Field-Weighted Citation Impact (FWCI)[8] for Agricultural and Biological Sciences remained very stable year-on-year between 2015 and 2019 and well above world averages, with a citation impact of 1.60.

- The research profiles of NI and ROI institutions are highly complementary and there is a high degree of collaboration between institutions in the two regions. There was strong research output collaboration between RPOs in NI, particularly between AFBI and QUB (n=116). There was also a high number of scholarly output collaborations between Teagasc and UCD (n=410), and Teagasc and UCC (n=342) in ROI. The strongest collaborations between North and South RPOs on research outputs was with Teagasc for AFBI and QUB, and with UCD for UU.

- According to the 2021 QS World University Rankings, UCD is ranked 51st in the world in the Agriculture and Forestry subject area, UCC is ranked 57th, QUB is ranked in the top 151-200, and NUIG is ranked in the top 301-350. UCD is also ranked 23rd in the QS World University Rankings for Veterinary Science.

By analysing historical public research investment and scholarly outputs, and mapping these against the targets and ambitions of national and European Union (EU) strategies and policies as well as market trends and drivers, six recommendations on public investment gaps/misalignments to strategies and policies and future research funding opportunities to 2030 have been identified.

Recommendation 1: The ROI and NI governments must enhance all-island R&I collaboration in Agri-Food by delivering on their commitment of a North-South programme of R&I, including an all-island research hub through Universities Ireland and strategic Agri-Food research awards under the HEA North-South Research Programme. These enhanced partnerships will ensure continued shared advances in R&I and will generate strategic, large-scale and sustained all-island collaborations that will support a transformative Agri-Food sector beneficial to the whole island.

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[7] Figures taken from SciVal, using the "Agricultural and Biological Sciences" subject area from the All Science Journal Classification used in Scopus. This is the default scheme in SciVal.

[8] FWCI is the ratio of citations received relative to the expected world average for the subject field, publication type and publication year.

Recommendation 2: As the largest indigenous industry on the island of Ireland, and pivotal to the continued growth and sustainability of the two regions, year-on-year public investment in Agri-Food research across the 'whole food system' should be increased with a positive CAGR to 2030.

Recommendation 3: National and EU policies and strategies highlight soil quality and health, alternative land uses including forestry, and agricultural diversification as essential to achieving a climate neutral Agri-Food system by 2050. Further research investment in sustainable land use, land use change and forestry must be prioritised to 2030.

Recommendation 4: There are substantial market opportunities in crop and plant innovation that are not being targeted nationally and are currently being met through imports. Research investment in plant innovation should be prioritised in the context of shifting global patterns in consumer preferences, new strategic priorities and the island's research strengths and expertise in plant science.

Recommendation 5: Additional research investment in technology and innovations in Agri-Food will be vital to the economic success and sustainability of the sector, to ensuring the integrity of the food supply chain and to achieving the environmental targets set out in national and EU strategies. A substantial intervention of additional R&I funding in agri-digitalisation is required to further advance and cement the island's position as a global trusted leader in Agri-Food.

Recommendation 6: There is an urgent need to increase expertise, funding and research infrastructure on GHG, ammonia emission and methane science on the island in order to achieve a climate-neutral food system by 2050, with considerable progress towards meeting agreed targets required by 2030.

2. Project Scope

The aim of this project is to ***map the publicly funded Agri-Food research ecosystem across the entire island of Ireland***. By analysing public research investment during the period 2015-2020 and mapping the findings against the targets and ambitions of national and EU strategies and policies, a range of public research investment priorities, funding gaps and misalignments to strategies and policies, and existing research strengths and excellence in research performing organisations (RPO) across the island to potentially address these gaps, are identified.

The objectives of the mapping exercise project are to:

1. Identify the main public funders of Agri-Food research across the island of Ireland.

2. Collate and analyse the historic investment of public funders in Agri-Food research from 2015 to 2020.

3. Categorise and map funding awards against an agreed set of research themes and topics.

4. Summarise and map the research activities of Research and Technology Centres against agreed research themes.

5. Assess the existing research strengths and outputs of academic institutions and other RPOs across the island.

6. Map existing research strengths and excellence against historic research investment.

7. Review and assess the research funding priorities, strategies and policies of national and EU public bodies, funding agencies and government departments.

8. Identify research investment gaps and misalignments with public research funding priorities, strategies and policies.

9. Provide recommendations on public investment needs and priorities in Agri-Food research, and R&I opportunities for RPOs across the island of Ireland that align with existing research excellence and national and EU strategies and policies.

3. Methodology

The All-Island of Ireland Agri-Food Research Ecosystem Mapping Exercise was conducted in 2020 and 2021 by UCD with support from Teagasc, UCC, NUIG, QUB, UU and AFBI. This section provides an overview of the methodologies used in the mapping exercise project.

3.1 Ecosystem map of public funders

The first stage of the project was to develop a comprehensive all-island map of public research funding bodies across the entire Agri-Food research ecosystem, including relevant government departments and State agencies/public bodies in the Republic of Ireland (ROI), Northern Ireland (NI), Great Britain (GB) and the European Union (EU). Public research funders vary in terms of funding type, research focus areas, frequency of funding calls, size of awards, and research strategy. A repository of public funders was created which summarises the following information:

- Name of funding body

- Link to online funding award database (if available)

- Funding period covered

- List of research themes and topics

- List of award data fields available (e.g. funding programme, host institution, Principal Investigator, collaborators/partners, project title, start and end date, award value)

A repository of relevant national and EU research strategies and policies published since 2015 was also developed (see Appendix C). These publications were reviewed to assess the degree of alignment of historic public investment in Agri-Food research to funding body and government research strategies and priorities.

3.2 Development of research funding taxonomy

A research funding taxonomy was developed for this mapping exercise to categorise and analyse the collated historic funding award data against a set of agreed parameters. There were a number of stages in the development of the final agreed Agri-Food taxonomy. The research themes and topics of four national funding bodies in the Agri-Food sector on the island of Ireland – the Department of Agriculture, Food and the Marine (DAFM), the Environmental Protection Agency (EPA), Teagasc, and AFBI - were reviewed and assessed for relevance, duplication, and overlapping focus areas, and were subsequently re-classified where necessary.

There were three development phases of the taxonomy - the first iteration included 99 potential research topics. These were re-classified and re-grouped to a second list of 33 research topics, which were then further refined to a final list of 21 research topics under the 5 research themes of Animal, Environment, Food, Plant and Sustainability. The evolution of the agreed taxonomy is presented in Appendix A, where a series of re-classifications, consolidations, and alignments of research topics was carried out. Table 3.1 outlines the final agreed taxonomy for the mapping exercise.

Table 3.1: Agri-Food Mapping Exercise Taxonomy

No.	Research Theme	Research Topic	Research Areas Covered in Research Topic
1	**Animal**	Animal Health & Welfare	Animal welfare; Animal wellbeing; Viruses; Infectious diseases; Zoonoses; Antimicrobial resistance (AMR); Animal nutrition; Dietary intervention; Vaccinations; Animal gut health and microbiome
2		Animal Production & Livestock Systems	Animal production; Livestock systems; Livestock sustainability; Anaerobic digestion; Pig development; Beef; Poultry; Sheep; Dairy production systems; Grazing strategies; Reducing use of antimicrobials; Meat products
3		Fisheries & Aquatic Ecosystems	Freshwater catchment management; Freshwater ecosystem management; Marine ecosystems management; Sustainable mariculture; Marine nutrient management; Fishing gear/equipment; Fish tagging; Fishing capacity; Seaweed; Aquaculture
4	**Environment**	Agri-Environment	Environmental monitoring; Environmental protection; Anaerobic digestion; Methane emissions; Agricultural climate solutions
5		Climate, Air & Water	Water quality; Air quality; Air science; Greenhouse gas (GHG) emissions; Carbon stocks; Sinks and management options; Climate adaptation; Climate mitigation; Safe water; Drinking water; Innovative water technologies; Integrated water management; Atmospheric ammonia deposition monitoring and modelling; Ammonia mitigation measures
6		Ecosystems	Ecosystem services and sustainability; Biodiversity; Natural capital; Protection and expansion of forest resource; Resilient ecosystems; Marine ecosystems
7		Natural Resources & Raw Materials Efficiency	Bioeconomy; Circular economy; Renewable energy; Sustainable management of natural resources; Adding value; Understanding, managing and conserving our water resources; Resource efficiency; Food waste/loss; Waste stream; Minimising waste; Waste management; Biomass; Valorisation; Biorefinery; Phosphorus
8		Soils, Land Use & Mixed Farming/Diversification	Soil health; Soil quality; Soil carbon sequestration; Forest utilisation; Agroforestry; Land use; Land management; Land diversification; Bogs; Land nutrient management; Land use emissions and sequestration

9	Food	Food Chain Integrity & Safety	Food safety; Food supply chain; Value chain; Food systems; Food authenticity; Food traceability; Food fraud; Integrity of supply chain; Food regulation; Food toxins
10		Food Processing Technology & Engineering	Food processing; Food chemistry; Chemical food safety; Food hygiene; Food microbiology; Novel food processing technologies
11		Food Product Development & Formulation	Food formulation; Food industry development; Food industry sustainability; Food biosciences; Food microbiology
12		Food Quality & Sensory Science	Food quality; Food sensory; Eating quality; Improved food flavour
13		Functional Food, Nutrition, Health & Diet-Related Disease	Human nutrition; Diseases; Chronic diseases; Food function; Functional food for optimal nutrition; Biomarkers; Personalised nutrition; Diets; Food supplements; Functional additives; Organic food; Nutrigenomics; Dietary determinants of health; Food for health
14	Plant	Crops & Agronomy	Arable and fibre crops; Pesticides; Crop breeding; Plant pests; Plant diseases; Pest management; Arable weeds; Indigenous crops; Endophytes; Plant stressors
15		Grassland Science	Grass; Clover; Forages; Forage grass breeding; Pesticides; Grass sequestration
16		Horticulture Development	Food horticulture; Enhancing grass nutritive value and efficiency
17		Plant Protein	Plant-based diet; Plant food sources; Animal protein supplements
18	Sustainability	Agri-Food Economics & Consumer Behaviour	Agricultural economics; CAP; Socioeconomics of a sustainable environment; Farm surveys; Agri-Food business and market; Market resilience; Brexit; Trade and exports; Economics of natural environment; Consumer choices; Consumer behaviour; Consumer trust; Food promotion; Food labelling

19		Farm Management & Rural Development	Farm management; Farm safety; Rural development; Rural employment; Entrepreneurship, business innovation and diversification at the farm level
20		Health & Wellbeing	Human wellbeing; Improvement of health; Health impacts; Human microbiome; Gut-brain axis
21		Smart Agriculture	Precision farming; Precision fisheries management; Drones; Decision support systems; Remote sensing; Earth observation

3.3 Historic funding award data collection and analysis

Following the development of the public funder ecosystem map and taxonomy, all publicly available data on Agri-Food research funding awards that have commenced since the start of 2015 were manually sourced and collated into a Master File over the period May-November 2020. Due to the nature of data access in the two jurisdictions, different data collection approaches were adopted in ROI and NI.

Detailed funding award data for all the main public funders in ROI, except for Enterprise Ireland (EI) and Teagasc (internally funded and Walsh Scholarship awards only), were collated from publicly available and searchable databases. EI and Teagasc were contacted by UCD to source a copy of their Agri-Food award data. The strategic focus and main research activities of relevant SFI Research Centres and EI Technology Centres were also collated and summarised (see Appendix B). In NI, the three RPOs active in Agri-Food research (QUB, AFBI and UU) were contacted by UCD to get permission to access a copy of their academic institutions' Agri-Food funding award data for 2015-2020 from their internal research grant databases. Due to the different data collection approaches in each jurisdiction and period of data collection, award data for the year 2020 is incomplete (see Section 3.6.1 for project limitations).

Extensive verifications and checks were undertaken on all collated data to identify and remove any duplicate awards (e.g. for projects involving collaborators or multiple funding agencies and listed more than once in the Master File) and awards deemed not to be within the scope of Agri-Food research (e.g. wind energy, tidal power, flood management). Table 3.2 illustrates the range of award data collated in the Master file.

Table 3.2: Historic Funding Award Data Collected

Award Data	Data Field
Lead RPO	AFBI; AIT; CIT; DAFM; DCU; DDUH; DIT; DKIT; ESRI; GMIT; IPA; ITS; ITT; LIT; MI; MIC; MU; NUIG; QUB; RCSI; TCD; Teagasc; TNI; TUD; UCC; UCD; UL; UU; WIT
Year Start	2015; 2016; 2017; 2018; 2019; 2020
Funder Region	EU; GB; NI; ROI
Funder Type	Academic NI; Academic ROI; Govt NI; Govt ROI; Govt GB; Public Body NI; Public Body ROI; Public Body GB; Research Agency NI; Research Agency ROI; Research Agency GB; EC; Other
RPO Region	ROI; NI
Research Theme (Tier 1)	Animal; Environment; Food; Plant; Sustainability
Research Topic (Tier 2)	Food Chain Integrity & Safety; Food Product Development & Formulation; Food Processing Technology & Engineering; Food Quality & Sensory Science; Functional Food / Nutrition / Health / Diet-Related Disease; Animal Production & Livestock Systems; Fisheries & Aquatic Ecosystems; Animal Health & Welfare; Crops & Agronomy; Plant Protein; Grassland Science; Horticulture Development; Agri-Environment; Soils / Land Use / Mixed Farming & Diversification; Ecosystems; Climate / Air / Water; Natural Resources & Raw Materials Efficiency; Agri-Food Economics & Consumer Behaviour; Farm Management & Rural Development; Smart Agriculture; Health & Wellbeing

Award Data	Data Field
Award Range	€0.03-0.2M; €0.2-0.5M; €0.5-1M; €1-2M; €5M+
Award Amount (€)	
Award Amount (£)	*If applicable*
Lead RPO & Partners	
Funding Body	Agriculture and Horticulture Development Board; AgriSearch (NI Agricultural Research & Development Council); Agri-Food Quest; BBSRC; BIM; British Council; DAERA; DAFM; DfE; EPA; EPSRC; ESRC; EU Horizon 2020; EU Interreg; European Food Safety Authority; Food Safety Authority of Ireland; Health and Social Care NI; HRB; Innovate UK; Invest NI; IRC; Marine Institute; NERC; NI Environment Agency; Northern Ireland Water; Sea Fish Industry Authority; Seafood; SFI; Teagasc; Wellcome Trust
Project Title	
Project Summary	*If available*
Start Date	
End Data	*If available*
Principal Investigator	*If available*
Principal Investigator Scopus ID	*If available*

During the data collection phase of the mapping exercise project, a total of 1,805 Principal Investigator-led (PI-led) funding awards in ROI and NI Agri-Food academic institutions and RPOs were collated, checked and verified in the Master File. Each award was then categorised against the agreed taxonomy (Tier 1 and Tier 2). It should be noted that many Agri-Food research projects are multi-disciplinary and span more than one research area. For analytical purposes, each award was mapped to one research theme and one research topic based on the deemed strongest alignment to the taxonomy categories.

In-depth analysis and thematic mapping of the data by funder type, funder region, start year, award size, and research theme and topic was conducted. The results of this analysis and overarching insights are presented in Section 5.1, which provides a picture of retrospective funding patterns in the Agri-Food research sector for the whole island of Ireland from 2015-2020.

3.4 Research output analysis

The Agri-Food research strengths, expertise and publication outputs of RPOs in ROI and NI were analysed using Elsevier SciVal[9] and Elsevier Scopus[10].

3.4.1 Bibliometrics

Bibliometric analysis was conducted to provide a picture of the island of Ireland's research performance relative to other countries and institutions. Bibliometrics is a well-established method of analysing research performance. It is based upon statistical analysis of articles, reviews and other publication types. The volume of publication output is a good proxy for the levels of research activity in a country. It is generally agreed that more frequently cited papers are associated with other measures of excellent research and can be used as a proxy indicator for research quality. Analysing where co-authors of papers are located provides an insight into the collaboration networks of the island of Ireland's research system.

3.4.2 Data sources

Bibliometric data was drawn from Elsevier Scopus and Elsevier SciVal. Scopus was launched in 2004, and is the largest abstract and citation database of peer-reviewed literature in the world. It indexes scientific journals, books and conference proceedings.

Scopus delivers a comprehensive overview of the world's research output in the fields of science, technology, medicine and to a lesser extent in the fields of social sciences and arts and humanities. Table 3.3 illustrates the coverage per discipline in Scopus.

Table 3.3: Coverage Per Discipline in Scopus

Discipline	Approximate % coverage of all outputs in Scopus
Health Sciences	80%+
Natural and Physical Sciences	70% to 80%+
Engineering	40% to 60%
Social Sciences, Business and Management	<= 30%
Arts and Humanities	<= 15%

Elsevier SciVal is a reporting tool for Scopus data that enables evidence-based strategic decision making on research performance. SciVal consists of four modules:

1. Overview - provides an overview of the research performance of institutions and others based on output, impact, and collaborations.

2. Benchmarking – Helps determine research strengths and weaknesses by comparing research institution and teams to others based on performance metrics.

3. Collaboration – Identifies and analyses existing and potential collaboration opportunities. Identifies suitable collaboration partners.

4. Trends - Analyses research areas to find top performing universities, authors and publication channels.

SciVal was used extensively in this mapping exercise to profile the island of Ireland's research outputs.

3.4.3 Indicators

For national and institutional comparisons, relatively high-level, generic indicators should be used. These are simple, transparent and accessible to a general audience. Once the findings of initial studies have been absorbed and accepted, it may then be valuable to move into more detailed areas and more complex analyses with confidence.

The methodological process for this mapping exercise project can be best described as a combination of input (i.e. funding awards), activity and output variables. However, only output variables can lead directly to an index of quality. While the ability to acquire research funding is clearly a reflection of track record and good ideas, there is great variation in cost and in access to funding between different fields and jurisdictions, and this can skew any direct comparisons.

Consequently, most international comparative studies make extensive use of bibliometrics. The basic elements in bibliometrics are counts of journal articles and counts of citations to those articles. Citations are references made subsequently to earlier publications. More highly cited work is regarded as having greater influence or 'impact' on its field and citation impact is, in large samples, equated with relative quality.

Citation rates vary between fields and citations increase over time. For this reason, the count of citations for any single article is meaningless. However, if citation counts for an article are compared to the average for the year and the field to which the journal is assigned, then they can provide information through context. By rebasing or 'normalising' individual citation counts against relevant world averages for large samples of articles, good indicators for strategic purpose can be obtained. This index is the Field-Weighted Citation Impact (FWCI) referred to in this report.

Definitions of the main bibliometric indicators used in this report are provided in Table 3.4.

Table 3.4: Bibliometric Indicator Definitions

Indicator	Definition
Publication volume (also referred to as research output)	The total number of publications of all types in SciVal per calendar year for the country, institution or group selected.
Field-Weighted Citation Impact	FWCI (Field-Weighted Citation Impact over a five-year interval, e.g. 2012-2016) is an indicator of mean citation impact and compares the actual number of citations received by an article with the expected number of citations for articles of the same document type, publication year and subject field in SciVal. Where the article is classified in two or more subject fields, the harmonic mean of the actual and expected citation rates is used. The indicator is therefore always defined with reference to a global baseline of 1.00 and intrinsically accounts for differences in citation accrual over time, differences in citation rates for different document types (reviews typically attract more citations than research articles, for example) as well as subject-specific differences in citation frequencies overall and over time and document types.
Citations	The total number of citations received by publications of all types per given time interval from the SciVal database.
Citations per publications	The total number of citations divided by the total number of publications of all types from the SciVal database (i.e. the average number of citations received per publication).
Subject Area	Subject areas are used to categorise Scopus Sources (and the publications in those Scopus Sources) into scientific disciplines. The All Science Journal Classification is the default scheme in SciVal and is used in this report. It has 27 main categories and 334 subcategories.
Collaboration	The extent of international, national and institutional co-authorship of publications.
Academic-Corporate Collaboration	Publications whose affiliation information contains both academic and corporate organisation types. Scopus is biased toward large corporate

Indicator	Definition
	entities. Some smaller companies may not always register as Academic-Corporate Collaboration in Scopus.

3.5 Gap analysis

Once the data collection and analysis phase was completed, the key findings from the historical public research investment and research output analyses were assessed and mapped against national and EU strategies, targets and policies. Informed by this analysis, Section 6 presents a range of Agri-Food research investment gaps, future needs and priorities, and opportunities for RPOs across the island of Ireland.

Section 7 of this report presents six recommendations for future public research investment in Agri-Food to 2030 that align with existing research strengths and excellence on the island and national/EU strategic and policy priorities and drivers.

3.6 Project limitations and key assumptions

This report provides a comprehensive map and analysis of historic public investment in Agri-Food research across the island of Ireland from 2015-2020. There are a number of limitations to this project which are summarised below. In addition, some assumptions were made in relation to data gathered from public funding bodies and RPOs in order for the mapping exercise to be effectively undertaken.

3.6.1 Project limitations

1. Historic public investment awarded exclusively to industry (e.g. EPA's Green Enterprise programme) for Agri-Food research were not included in this mapping exercise. Projects that were led by an RPO in collaboration with, or receiving co-funding by an industry partner, were deemed within the scope of this project.

2. Disaggregate funding award data for PI-led individual research projects were publicly accessible or provided by all public funding bodies and RPOs except for EI. EI provided aggregate Agri-Food funding spend for the years 2015-2019 for their R&I programmes (i.e. Technology Centres, Commercialisation Fund, Commercialisation Case Feasibility Grant, Technology Gateways, Innovation Vouchers and Innovation Partnerships). For this reason, disaggregate funding award data is analysed and presented in Section 5.1 for PI-led individual funding awards only, excluding EI R&I awards. The total historic public investment in Agri-Food research in ROI, including EI R&I programmes, EI Technology Centres and SFI Research Centres, is provided at an aggregate level only.

3. Research projects funded by funding agencies outside of the UK and EU (e.g. China, US) were not included in the scope of this project. In cases where a project is co-funded by a public funding body outside of the EU and UK (e.g. US-Ireland Research and Development Partnership Programme), the funding award was included in the mapping exercise if the body awarding and administering the fund to the RPO is based within the EU or UK.

4. Research awards allocated by ROI and NI funding agencies to RPOs that are not based on the island of Ireland were not included in the scope of this project (for example, Teagasc Walsh Scholarships awarded to RPOs based in other European countries).

5. PI-led individual funding award data for the year 2020 is incomplete. Publicly available funding award data in ROI were collated for the period January 2015 to November 2020. Data provided by Teagasc on their internally funded and Walsh Scholarship awards cover the full year from January to December 2020. Funding award data provided by AFBI and QUB for 2020 is to April 2020, and data provided by UU is to May 2020. Some analysis provided in Section 5.1 covers the period 2015-2019 only due to the incomplete data set for 2020.

6. The PI name associated with some project awards was not available (e.g. EU Horizon 2020 awards).

7. The Technology Readiness Level (TRL) of funding awards was not included in the data provided by RPOs or publicly available and is therefore not mapped or analysed in this report.

3.6.2 Key assumptions

1. Funding awards were categorised against the agreed taxonomy based on the subjective interpretation of best alignment by the authors.

2. In the case where a funded project could be alignment to more than one research theme or research topic, the award was aligned to the deemed strongest research theme/topic in the taxonomy.

3. For projects co-funded by a funding body based on the island of Ireland and one outside of ROI/NI (e.g. BBSRC-SFI Joint Funding Programme), the funding body administering the award on the island of Ireland was recorded as the funding award body.

4. In cases where a funding award involves multiple collaborators and RPO partners, the lead/host institution was recorded as the receiving institution.

5. Similarly, in cases where a funding award involves multiple academics (from one or more RPOs), the PI was recorded as the receiving awardee.

6. In the case of one RPO, funding awards are recorded by financial year (e.g. over two consecutive years from 1st August to 31st July) rather than by start date. An assumption was made that the latter of the two years was the project start date for the purposes of this project (for example, a project awarded during the financial year 2015-2016 was recorded as starting in 2016).

7. In some cases, the year a funding call was announced is different to the start date of the award (for example, a funding call could have opened in 2015 but the successful PI/RPO was awarded funding and the project commenced in 2016). In these instances, the year the funding was received by the host institution was recorded as the start year.

8. Funding amounts in Sterling (£) were converted to Euro (€) using the annual average exchange rates for GBP and EUR based upon information published by the Central Bank of Ireland[11]. The GBP/EUR exchange rate on 5th October 2020 was used for funding awards that started in 2020.

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[11] http://www.edwinfoley.ie/Revenue-euro-sterling-exchange-rate

4. All-Island Agri-Food Sector

4.1 Strategic importance of agriculture and the food industry

The Agri-Food sector - which is classified as primary production (agriculture, fishing and forestry), food and beverages, and the wood processing sector - is the largest indigenous industry on the island of Ireland, playing a crucial role in the economy of both jurisdictions. The sector is highly complex, from individual home-stead producers of raw product through to multi-national processing companies. The global reach of the sector is extensive, with food produced in ROI being exported to over 180 markets worldwide including the UK, Europe, the Americas, Asia and Africa[12]. The sector spans livestock and crop production, food processing, manufacturing and engineering, consumer marketing, pharmaceuticals, and human and animal healthcare.

Some of the key trends for the ROI Agri-Food market in 2020 include[13]:

- The value of Agri-Food products remained relatively stable in 2020 despite Brexit and the COVID-19 pandemic. The sector had an annual turnover of €14.2 billion in 2020 (down 2.7% on 2019 figures but up 60% on 2010 values) and accounted for 3.7% of Gross Value Added (GVA) at factor cost.

- Agri-Food exports represented 8.8% of Irish merchandising exports in 2020.

- The UK remained the largest trading partner for ROI with 37% (€5.3 billion) of Agri-Food products exported within the year, down 4% from the previous year. The overall proportion of exports to the UK has been steadily declining since 2010 (from 45%).

- Agri-Food accounted for 12% of ROI's total imports in 2020. Imports of Agri-Food sector products totalled €10.2 billion, increasing by 2% on the previous year and by 68% since 2010. There was a trade surplus in products of €4 billion in 2020.

- 137,500 farms produced over €8.2 billion in output during the year, and the sector employed 7.1% of the national working population (between 10-14% of employment in rural and coastal areas).

- The top five Agri-Food exports in value terms were dairy produce, beef, beverages, pigmeat, and cereal and cereal preparation, and accounted for 73% of total Agri-Food sector exports (or €10.3 billion).

- Fish has been ROI's fifth largest Agri-Food export for a number of years, but exports were significantly impacted by COVID-19 in 2020 and the value decreased by 8% despite volume decreasing by less than 1%.

Agriculture is more important in NI, in terms of employment and economic contribution, than any other part of the UK and is a key future driver for the future economic development of the country[14]. The key market trends for the NI Agri-Food sector in 2020 include[15]:

- Approximately 79% of the total NI land area of 1.35 million hectares is used for agriculture, including common rough grazing.

- The agricultural income of farms increased in 2020, with total income from farming growing by 34% to £456 million (from £342 million in 2019).

- Gross output of agriculture was estimated at £2.23 billion (a 4.2% increase from 2019).

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[12] Department of Agriculture, Food and the Marine, *Annual Review and Outlook for Agriculture, Food and the Marine 2021*. 2021, Department of Agriculture, Food and the Marine: Dublin, Ireland.
[13] ibid.
[14] Allen, op. cit.
[15] Department of Agriculture, Environment and Rural Affairs, *Statistical Review of Northern Ireland Agriculture 2020*. 2021: Belfast, Northern Ireland.

- There were increases in the output of the milk, cattle, sheep, pigs, and eggs sectors, although these were somewhat offset by decreases in output from the poultry, crops and horticultural sectors.

- GVA increased by 15.0% in 2020 to £673 million.

- The gross turnover of the food and drinks processing sector increased by 7% to £5.2 billion in 2018.

- The total agricultural labour force in 2020 was 51,301 persons.

- NI has the smallest average farm size in the UK, and the dominance of grass-based cattle (beef and dairy) and sheep within NI agriculture accounts for almost 90% of total farms[16, 17].

It is clear that the Agri-Food sector is of vital importance to both the ROI and NI economies. Its geographical spread across the whole island of Ireland means that it particularly supports socio-economic development in rural areas. Dairy and meat exports currently underpin the current agri-economy of the island of Ireland. Brexit is posing huge challenges for the Agri-Food and fisheries sectors, due to both ROI and NI's exposure to the UK market. Nearly 40% of ROI Agri-Food exports are to the UK, and conversely ROI is the UK's largest export destination. The most immediate impact of Brexit to date has been the volatility in the value of the Sterling (£) against the Euro (€).

The COVID-19 pandemic and geopolitical situation in Ukraine have brought new challenges and volatilities to the sector, both for the island of Ireland and globally. The macroeconomic shocks as a result of these crises are putting pressure on Agri-Food commodity prices. Food supply chains on the island are facing some of the greatest challenges in history. The sustainability and resilience of food supply is dependent on the structure, management, transparency, and innovativeness of the food chain. In the short-term, there is a need to ensure continuity of the food supply chain on the whole island, particularly in the context of Brexit, COVID-19 and Ukraine.

4.2 Global challenges, drivers and megatrends

4.2.1 Global challenges and drivers

We are at the cusp of a global revolution in food production systems. The key drivers of this change are:

- the negative effects of climate change and increased GHG emissions on our global environment;

- the need to feed an increasing global population, with finite natural resources, and the increasing move towards plant-based diets and biological crop inputs to complement or replace chemical farm inputs;

- the deleterious effects of food producing and processing practices on ecosystems and biodiversity;

- the need to produce food that enhances health, not food that causes ill health;

- declining consumer trust in the safety and authenticity of the food they buy and consume; and

- the need to develop new value chain models globally that appropriately reward food producers.

The global Agri-Food sector is facing substantial challenges due to changing dietary patterns and environmental issues associated with current production practices, and meeting national and international climate mitigation obligations. Such issues have contributed to a growing negative perception towards current agricultural systems and are driving shifting consumer preferences. A background of political and economic uncertainty and changes, including Brexit, CAP reform, the invasion of Ukraine by Russia, and the COVID-19 pandemic, are exacerbating many of these challenges for the food industry, not least in terms of trade of meat, dairy, and other food commodities. The COVID-19 pandemic has highlighted the vulnerability of global food systems and

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[16] Allen, op. cit.
[17] Department of Agriculture, Environment and Rural Affairs, op. cit.

the need for resilience to shocks. The World Health Organisation (WHO) has identified healthy, sustainable food systems as an important factor in a global recovery from the pandemic[18]. These national and global challenges are placing a premium on the sector's ability to diversify its portfolio to include higher value products and services and to enter new international markets.

4.2.2   Megatrends

The European Parliament AGRI Committee published a report in 2019 on megatrends in the Agri-Food sector[19] which provides an analysis of the megatrends that are influencing the way food is being produced, distributed and consumed. The report provides an outlook of global production needed to sustain a global population of 10 billion people by 2050, and outlines a 'state of play' of the global forces affecting the food chain in the future. The key Agri-Food sector megadrivers identified in this report include:

Technology

- Technological progress and innovation could have the potential to increase production more than land expansion. Innovation can enhance the Total Factor Productivity of the agricultural industry (i.e. increase crop and livestock output without increasing input).

- Technology has the potential to enable the development of precision agriculture solutions, which can increase yields by up to 30%.

- As one of the main causes of GHG emissions, new technologies in the Agri-Food sector's processes can enhance ecological efficiency (e.g. new land and water conservation techniques, improved biodiversity preservation technologies, enhanced production technologies, and integrated pest management).

- Technological solutions can help modernise agriculture by increasing the efficiency of its processes, foster innovation, and also create new business models.

- Technology can support the sustainable and efficient use of land and water by increasing crop yields without expanding the use of agricultural land.

- Biotechnology could also benefit the future of the Agri-Food sector (e.g. disease-resistant plants will decrease the volatility of the yield, increase production, and reduce the usage of chemical pesticides).

Consumption patterns and preferences

- Convenience and health are the two most important factors that affect consumption behaviour and patterns.

- Urbanisation is affecting consumption patterns, with people taking less time to buy and prepare their food. With an increase in demand for convenience products, food processing will play an increasingly important role in the Agri-Food value chain.

- In the last decade, there has been a growing demand for healthier, environmentally friendly and ethical diets. Veganism, vegetarianism and flexitarianism have become more popular – it is estimated that nearly 22% of the world's population is vegetarian. These changes in consumption patterns and preferences are mainly due to animal welfare concerns and the health implications of animal-based diets.

- Consumers, particularly those living in high-income countries, are also purchasing more high-value organic food.

- There has also been an increasing consumer demand for alternative protein sources (e.g. laboratory created meat or plant-based alternatives).

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[18] Global Panel on Agriculture and Food Systems for Nutrition, *COVID-19: Safeguarding food systems and promoting healthy diets.* 2020, Global Panel on Agriculture and Food Systems for Nutrition: London, UK.
[19] Kirova, M., Montanari, F., Ferreira, I., Pesce, M., Albuquerque, J.D., Montfort, C., Neirynck, R., Moroni, J., Traon, D., Perrin, M., Echarri, J., Arcos Pujades, A., Lopez Montesinos, E., Pelayo, E., *Research for AGRI Committee – Megatrends in the Agri-Food sector: global overview and possible policy response from an EU perspective.* 2019: Brussels, Belgium.

Food waste and loss

- One-third of the world's food is currently being lost or wasted, which can cause a loss of land, water, energy and agricultural inputs, and the emission of tonnes of GHGs.

- Food waste is when food that is 'fit for consumption' is wasted at the retail level. There is a growing consumer awareness of food waste, with consumers becoming more mindful of food waste along the food value chain and supporting suppliers committed to the circular economy.

- Food loss occurs along the food chain (e.g. during transportation, storage). Food loss can be caused by inadequate technology, a lack of knowledge and skills, poor logistics, and inefficient markets.

Natural resources

- Competition between food and non-food uses of biomass is increasing the interdependence between food, feed, and energy markets. This competition could have harmful effects on local food security and access to land resources.

- Biofuels are increasingly being used as an alternative to fossil fuels. Cereals and oilseeds are being used to make biofuels, and biomass is starting to be used to substitute petrochemicals.

Food production

- In order to meet the future food and feed demands of the projected world population of 10 billion by 2050, agricultural production levels will need to increase by almost 50%.

- If the trend of a reduction in the consumption of meat continues, it is projected that a 40% increase in global cereal production to 2050 could be required. The production of wheat should increase by 24%, rice by 33%, and corn by 34%.

- Based on the scenario of consumption patterns continuing to shift away from meat-based diets, global meat production could increase by less than 30% by 2050 compared to 2012. It is projected that the herd size of poultry would need to increase by 40%, cattle by 34%, and pigs by 10%.

- The production of sugar cane could increase by up to 35%, soybeans by 33%, and the cassava by 54% by 2050[20].

Research, development and innovation will be vital to reshaping the sector. The challenge for the world, and in particular the island of Ireland where agriculture contributes so significantly to the economy and global reputation, is to radically transform current food production systems. Systemic fundamental and translational research that maximise the potential of the island of Ireland is needed to contribute innovative solutions that overcome the massive and growing global challenges in sustainable food production, climate change, and the increasing incidence of diet-related illnesses, whilst engaging all stakeholders along the supply chain in the process of change.

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[20] Kirova et al., op. cit.

5. Key Findings

5.1 Historical public research investment

This section provides an overview of historical public investment in Agri-Food research in ROI and NI from 2015-2020. As noted in Section 3.4.1, Agri-Food funding spend for the years 2015 to 2019 for Enterprise Ireland's (EI) R&I programmes was not available by research theme or topic. Due to this limitation, the total historical public investment in Agri-Food research across the island of Ireland from 2015-2020 is provided at the aggregate level only in Section 5.1.1. Deeper analysis of the funding award data by funding region (NI and ROI), funder type, start year, award size, and research theme and topic is presented in Sections 5.1.2.2 to 5.1.6 for PI-led individual funding awards only (i.e. not including EI R&I awards, EI Technology Centres and SFI Research Centres).

5.1.1 Total historical public research investment

It is estimated that a total of €680.9M of public investment has been awarded to academic research projects and Centres in the area of Agri-Food across the whole island of Ireland between 2015 and 2020. A breakdown of this total public research investment is provided below:

- 1,805 PI-led individual research projects have been awarded to ROI and NI RPOs from 2015-2020, totalling €608.2M of public investment. The analysis presented in Sections 5.1.2.2 to 5.1.7 focus on this investment, as outlined above.

- In addition to this €608.2M, EI awarded a further €11.2M to ROI RPOs for research commercialisation (i.e. Commercialisation Fund and Commercial Case Feasibility Grant) and public/private collaborations (i.e. Technology Gateways, Innovation Voucher and Innovation Partnership) between 2015 and 2019.

- Further to this €619.4M, 3 EI Technology Centres and 2 SFI Research Centres in ROI (totalling €20.8M and €40.7M public investment respectively) in the area of Agri-Food were awarded funding or renewed between 2015 and 2020, bringing the total estimated public investment during the period to €680.9M:
    - Food for Health Ireland Technology Centre
    - Dairy Processing Technology Centre
    - Meat Technology Ireland
    - BiOrbic SFI Bioeconomy Research Centre (formerly BEACON)
    - VistaMilk SFI Research Centre[21]

5.1.2 Summary

An aggregate analysis of Agri-Food funding awards from 2015-2020 (including the EI R&I awards, 3 EI Technology Centres and 2 SFI Research Centres) by funder location is provided in Section 5.1.2.1. Due to the data limitations outlined above, Sections 5.1.2.2 to 5.1.7 provide an analysis of the 1,805 PI-led individual research projects only, which account for 89% (or €608.2M) of total awards. The analysis presented below begins by looking at where funding comes from on an aggregate basis, then, based on funder location, how it is spread across the five research themes. Findings are then presented on how the funding is distributed across the two jurisdictions (ROI and NI) by research theme. Trends in funding for the five-year period 2015-2019 are then presented (2020 data was incomplete at the time of data collection and analysis). Deeper analysis by funder group, research theme and research topic are then provided to understand how investment is awarded to RPOs across the island. Finally, funding award size distribution across the five research themes is presented.

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[21] The VistaMilk SFI Research Centre is jointly funded by SFI and DAFM.

5.1.2.1 PI-led and Centre awards by funder location

Figure 5.1A illustrates the distribution by funder type and location (ROI, EU, NI and GB) of the total €680.9M public research investment from 2015-2020 on the island of Ireland. Nearly 62% (€421.8M) of total public research investment for the island of Ireland was awarded by ROI research agencies (e.g. IRC, HRB, SFI), public bodies (e.g. Teagasc, EPA, SafeFood) and government departments (e.g. DAFM), compared to just 14.6% by NI funding bodies (€99.5M). The funding and renewal of a number of large EI Technology Centres and SFI Research Centres in ROI in part explains this significant proportion of funding by ROI funding bodies (similar research centres do not exist in NI). However, it should be noted that NI government departments (e.g. DAERA, DfE) awarded slightly more funding to Agri-Food research projects between 2015-2020 than government departments in ROI (€84.1M and €82.3M respectively). European funding (e.g. through programmes such as EU Horizon 2020, Interreg, European Food Safety Authority, European Institute of Innovation and Technology) accounted for 19.2% of total historic awards during the six-year period.

A more detailed analysis of the 1,805 PI-led individual research projects funded (i.e. excluding EI R&I awards, EI Technology Centres and SFI Research Centres) - totalling €608.2M of public investment - is summarised in the remainder of Section 5.1.

In summary, as might be expected considering the relative sizes of the two jurisdictions, ROI-based funders provided the majority of Agri-Food research funding on the island from 2015-2020. This analysis also shows the importance of EU funding to both jurisdictions and in the current context, suggests that it is more important than ever to maintain this key pipeline of funding.

5.1.2.2 PI-led (only) awards by funding region and research theme

Figure 5.1B provides a visual breakdown of the source (ROI, EU, NI and GB) of PI-led individual Agri-Food research awards by the five research themes from 2015-2020 for the whole island of Ireland.

ROI-based funders provided the greatest amount of funding to the Environment theme (€104.6M). Nearly half (47.4% or €49.6M) of all Environment projects funded across the island were on 'Natural Resources & Raw Materials Efficiency' – i.e. projects on the bioeconomy; circular economy; renewable energy; sustainable management of natural resources; understanding, managing and conserving water resources; food waste and loss; valorisation; and biorefinery etc.

The majority of funding awarded from the EU across the two regions (ROI and NI) was also to the Environment theme (€45.8M), making up 35% of the total €130.8M EU funding awarded. Looking at NI-based funders, the key research area for investment has been in the Animal theme, with €40.9M funded over the same period. Moving to GB-based funders, the priority theme appears to be Food, where €11.7M was invested during 2015-2020.

In stark contrast, only 11.2% (€68.2M) of PI-led individual research projects were funded in the Plant theme, with the majority of these being awarded to projects in the area of 'Crops & Agronomy' (€37.1M). Looking across the four funder locations, the theme that attracted the least amount of investment in all locations except the ROI was the Plant theme - €10.5M (EU), €7.3M (NI) and €1.7M (GB). In ROI, the theme that received the least public investment was the Sustainability theme (€44.0M compared to €48.7M for the Plant Theme).

ROI research agencies, public bodies and government departments accounted for 57.4% (or €349.0M) of historic public investment for PI-led individual research projects awarded over the period. Public research investment by EU, NI and GB funders accounted for 21.6%, 16.4% and 4.7% of the total €608.2M respectively. Nearly €41M (40.4%) of the €99.6M NI funding was awarded to Animal projects.

In summary, there are clear themes that have attracted greater public research investment from 2015-2020 than others. This diversity of investment direction and focus is a strength of the all-island approach and will be further examined in subsequent sub-sections.

5.1.2.3 PI-led (only) by awardee region

The distribution of public research investment awarded by ROI, NI, EU and GB funders to PIs in ROI and NI institutions is presented in Figure 5.1C. Over 70% of public investment in Agri-Food research was awarded to RPOs based in ROI (€428.0M), and this does not include the additional €72.7M public investment for EI R&I awards, EI Technology Centres and SFI Research Centres to ROI institutions. €180.2M (29.6%) was awarded to NI-based RPOs during the same period.

The allocation of funding awards by research theme varies significantly between the two regions. Figure 5.1C below clearly shows that ROI RPOs were awarded more public funding under each of the five research themes than NI RPOs during the period 2015-2020. Both ROI and NI RPOs are strong in the theme of Environment (accounting for nearly one-third of the total €608.2M). Over two-thirds of funding for projects in Food were awarded to PIs in ROI institutions, demonstrating research excellence and strength in this research area on the island. Similarly, the majority (85.5%) of funding awards for Plant projects were to PIs based in ROI institutions. 40.7% (€69.3M) of awards in the Animal theme were awarded to NI RPOs, demonstrating their excellence in this field.

A more in-depth analysis of funding awarded by research theme and topic in the two jurisdictions is provided in Section 5.15.

Figure 5.1: All-Island Agri-Food Public Research Investment (2015-2020). A: PI-Led and Centre Awards by Funder Location. B: PI-Led (only) Awards by Funding Region and Research Theme. C: PI-Led (only) by Awardee Region.
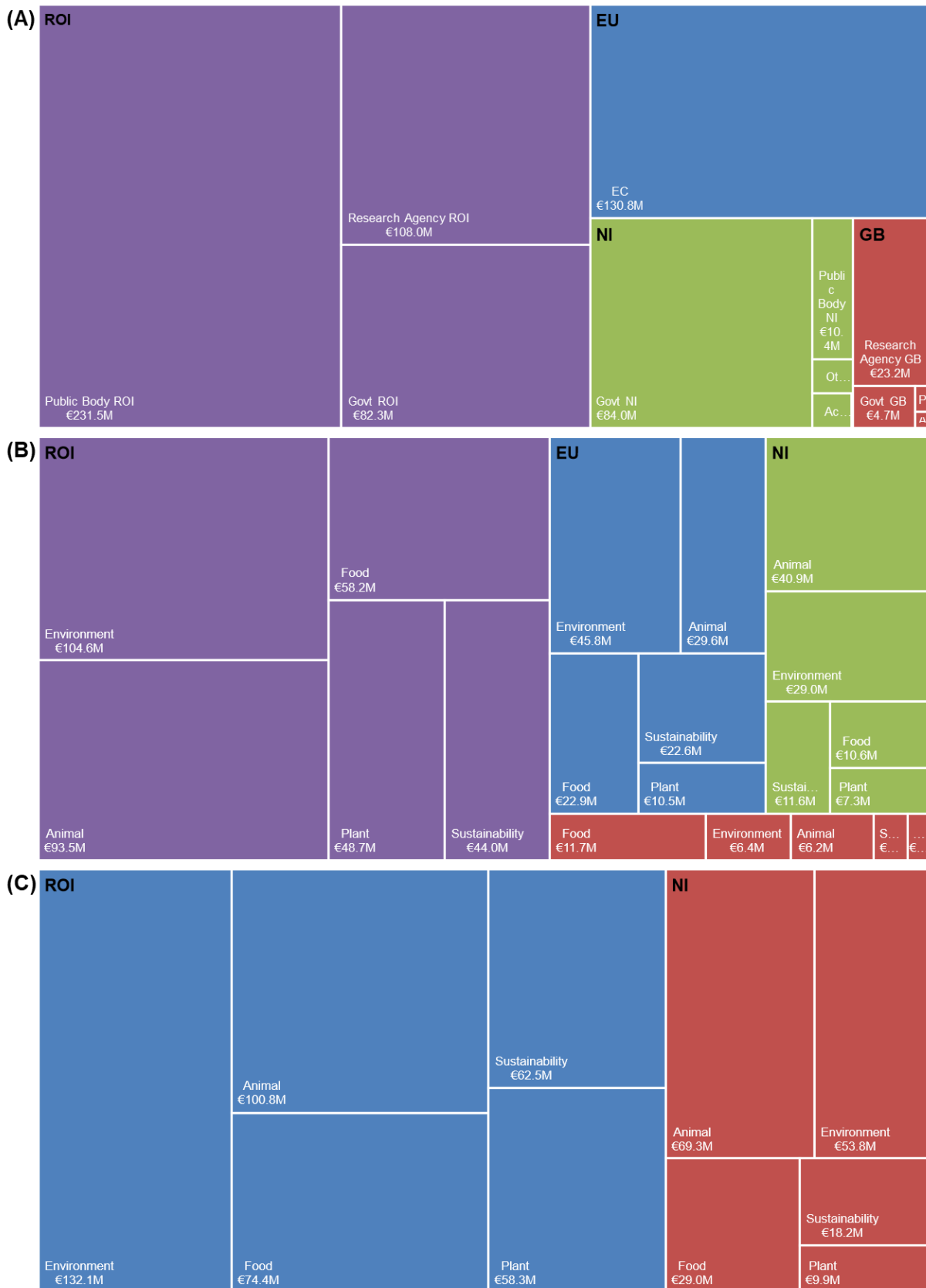
5.1.3   Research funding trends

Figure 5.2 illustrates the overall year-on-year trend in public research investment for PI-led individual research projects, decreasing from €138.6M in 2015 to €96.2M in 2019 (2020 data was incomplete at the time of data collection and analysis). Year-on-year public investment for Agri-Food research decreased annually during the five-year period, reflecting the decline of Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP for Ireland from to 1.52% in 2014 to an estimated 1.23% in 2019. Ireland's GERD is well below the estimated average of 2.10% for the EU27 countries in 2019[22], however it is important to note that the total actual amount of R&D investment in Ireland increased by 67% from €2.76 billion in 2012 to an estimated €4.59 billion in 2020[23].

It is important to interpret these year-on-year public investment trends with caution, as not all Agri-Food public funding programmes are run on an annual basis (e.g. DAFM Competitive Research Call), and therefore trends will vary depending on when a call is announced and when awards are made to an RPO.

The Environment theme experienced the only increase in public investment over the period, with a compound annual growth rate (CAGR) of 9.2%. The largest increase in this theme was in 2019 (with an additional investment of €10M), signalling potential future growth for this theme. The Food theme experienced a fluctuating, but relatively stable growth of -1.4% CAGR during the same period, with €30.0M invested in Food research in 2016. The Plant theme has experienced the greatest decrease in funding during the period with a large negative CAGR of -26.5%, reducing from a healthy €25.7M in 2015 to just €7.5M in 2019. The biggest drop was from €25.7M in 2015 to €9.9M in 2016, marking the beginning of a relatively stable annual investment of under €10M. There was a fairly stable growth rate of -3.6% CAGR for the Sustainability theme, decreasing from €16.3M in 2015 to €14.1M in 2019. The Animal theme experienced a significant decline in public investment from €52.0M in 2015 to €19.5M in 2019, representing a significant negative CAGR of -21.8%

The overall Agri-Food (PI-led) funding portfolio experienced a negative growth rate of -8.7% CAGR between 2015 and 2019. The distribution of this funding between research themes has shifted significantly over the period with a greater focus on the Environment, perhaps driven by new national and EU targets relating to climate change shaping funders' portfolios.

In summary, funding totals across the five research themes over the period 2015-2019 have varied significantly with markedly differing trajectories. It is clear that the Environment theme is a priority as might be expected given the global environmental crisis. However, key areas of importance such as the Plant and Animal themes, which have the potential to have a significant positive impact on the global climate crisis, experienced large negative CAGRs of -26.5% and -21.8% over the same period. These important findings will be discussed in further detail in Section 6.

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[22] OECD, *Main Science and Technology Indicators, Volume 2020 Issue 2*. 2021, Organisation for Economic Cooperation and Development: Paris, France.

[23] Department of Further and Higher Education, Research, Innovation and Science, *The Research and Development Budget 2020-2021*. 2021, Government of Ireland: Dublin: Ireland.

Figure 5.2: All-Island Agri-Food Public Research Funding (2015-2020), PI-Led (only) Awards by Research Theme and Project Start Year
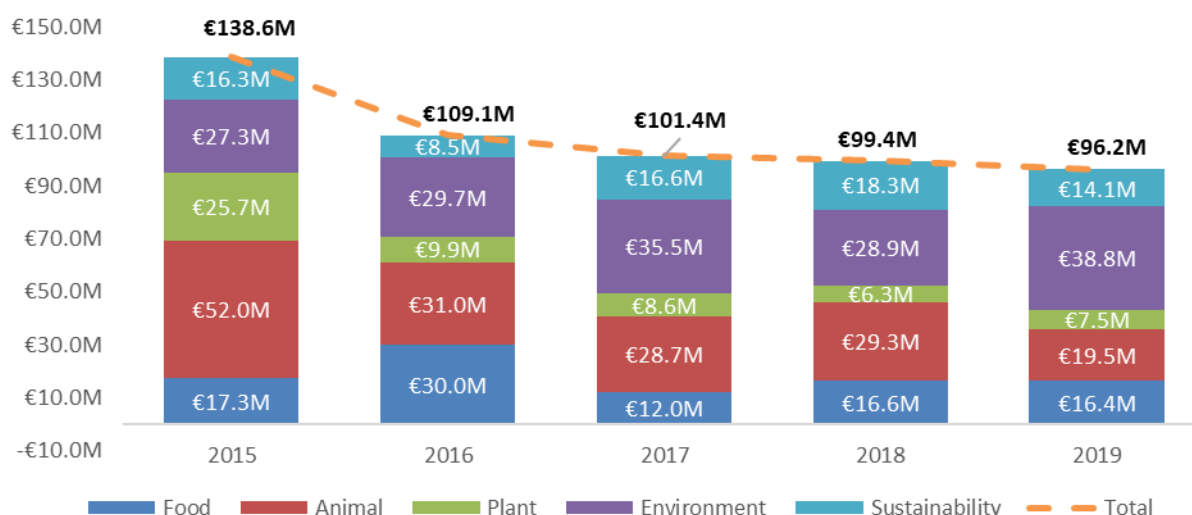
5.1.4 Investment by funder

Building on the findings illustrated in Figure 5.1A, Figure 5.3 provides a deeper dive into the sources of funding from across ROI, NI, EU and GB. This data shows where the money is coming from in more detail, rather than where it is awarded to. The largest cohort of funders by a large margin was public bodies in ROI (e.g. EPA, Teagasc), providing 32.8% (or €199.4M) of total funding for PI-led individual research projects for the period 2015-2020. This compares to €10.4M of total investment provided by NI public bodies during the same period. The most significant theme in terms of investment by ROI public bodies is the Environment theme, accounting for 32.9% of total PI-led awards during this period.

Next in terms of total funding provided is the EU at 21.5% (€130.8M). The NI government (e.g. DAERA, DfE) provided 13.8% of total funding (€84.0M) during the period, with the bulk of this being awarded to the Animal (€37.5M) and Environment themes (€22.8M). The ROI government (e.g. DAFM) provided a similar amount of funding – 13.5% (€82.3M) – with most of this being allocated to the Environment (€26.1M) and Food (€29.3M) themes. Following this is ROI research agencies (e.g. IRC, HRB, SFI), which accounted for 11.1% of total funding and was reasonably well balanced across the five research themes.

Excluding EU funding, the ROI-based funders accounted for the majority (57.4%) of investment across the five themes, accounting for €349.1M of total funding over the period. NI-based funders accounted for €99.4M of total funding, with GB-based funders providing just €29.0M of funding across the five themes.

In summary, there is strong diversity in funding sources driving research in Agri-Food on the island across the five themes. This diversity of funding is a clear strength of the all-island Agri-Food research ecosystem, with different national funders prioritising areas to the wider benefit of the research community.

Figure 5.3: All-Island PI-led Funding Awards by Research Theme and Funder Type (2015-2020)
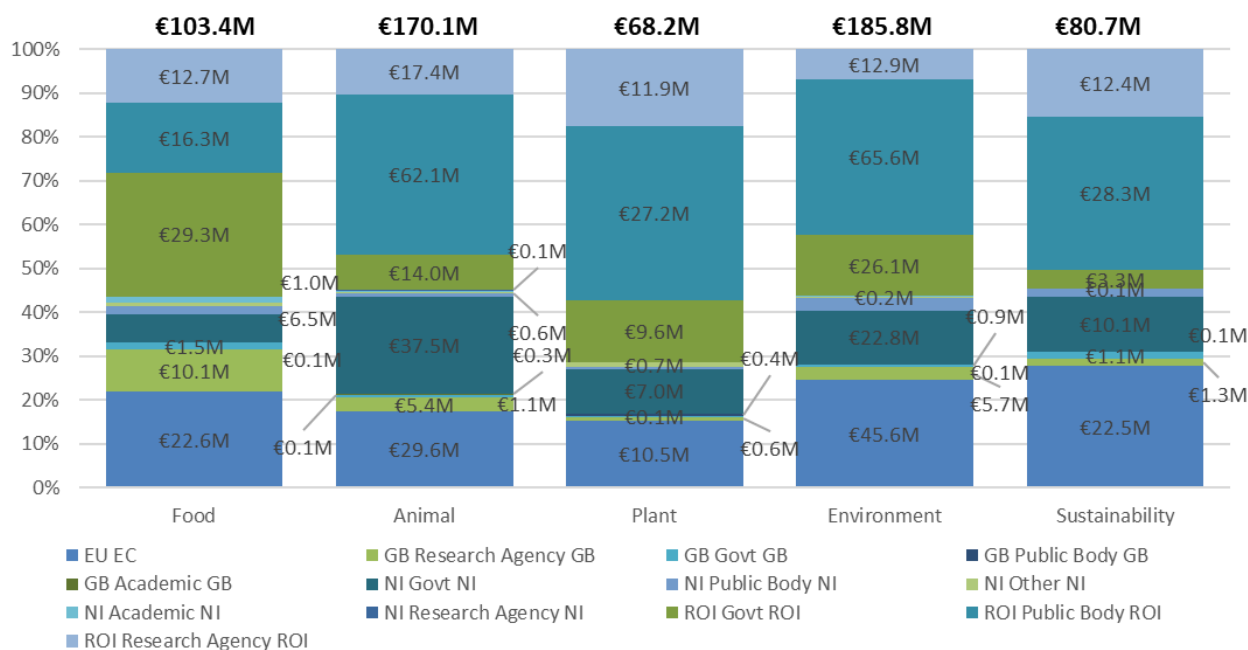
5.1.5 Investment by research themes/topics by region

It is clear from the analysis above that public investment in Agri-Food research is not evenly distributed across the five research themes. As outlined in Section 5.1.3, funding fluctuates from year to year depending on the timing of large funding calls and Centre investments, and the distribution can in some cases be driven by changing strategic priorities at the funder or government level. In this section we examine where the funding is being spent, how this varies across the five themes and, digging deeper what are the key research topics within these themes that have attracted funding.

Starting with the Environment theme, as clearly illustrated in Figure 5.4 there is a disproportionate allocation of public investment between the five research topics. The majority of the €185.8M (€132.0M - ROI; €53.8M - NI) for Environment projects was awarded to projects in the areas of 'Natural Resources & Raw Materials Efficiency' and 'Climate, Air & Water' (33.5% and 19.6% respectively). Only €21.6M (11.6%) was allocated to projects on the 'Agri-Environment'.

Turning to the Animal theme, the distribution of PI-led individual funding awards between the three research topics (€170.1M in total) varies significantly – 50.2% for 'Animal Production & Livestock Systems', 30.8% for 'Animal Health & Welfare' and 19.0% for 'Fisheries & Aquatic Ecosystems'. Over 40% of all projects were awarded to NI RPOs, clearly demonstrating research strength and excellence of this field in this region.

For the Food theme, a total of €103.4M (€74.3M - ROI; €29.1M - NI) was awarded during the period, with over 38% of projects being funded in the area of 'Food Chain Integrity & Safety' (€39.5M) and a further 27.9% in 'Functional Food, Nutrition, Health & Diet-Related Disease'. The remaining three research topics received €35.0M (33.8%) of total funding for the Food theme.

A total of €80.7M was awarded to the Sustainability theme, with less than 12.0% (€9.7M) of this allocated to the research topic 'Farm Management & Rural Development'. PI-led individual research projects in 'Smart Agriculture', which is a growing global R&I area, received over one-third (€25.7M) of funding. Furthermore, the addition of over €25M for the VistaMilk SFI Research Centre substantially increases the share of public funding for this developing research area[24]. Equally, €25.3M was awarded to projects in the area of 'Agri-Food Economics & Consumer Behaviour' (31.4%). Finally, 'Health and Wellbeing' research was also well funded during the period with €19.7M (24.4%) awarded to projects in areas such as: human wellbeing, health impacts, human microbiome, and the gut-brain axis.

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[24] Note: the VistaMilk SFI Research Centre funding is not included in the data in Figure 5.4 as per Section 5.1

It is clear from Figure 5.4 that the majority of Plant awards, totalling €68.2M (€58.3M - ROI; €9.9M - NI) were in the areas of 'Crops & Agronomy' (54.4%) and 'Grassland Science' (25.5%). €7.7M was awarded to 'Plant Protein' projects, but it is important to note that this was for a small number of awards (n=6). Very little public investment was awarded to projects in the area of 'Horticulture Development' during the period (€6.0M or 8.8%). It is clear that RPOs across the island of Ireland have particular research expertise and strength in securing funding in the area of 'Crops & Agronomy' (e.g. research on arable and fibre crops; pesticides; crop breeding; plant pests and diseases; arable weeds; indigenous crops; endophytes; plant stressors etc.).

In summary, the top five research topics by funding in NI were:

- Animal theme: 'Animal Production & Livestock Systems' (€24.8M), 'Animal Health & Welfare' (€22.3M), and 'Fisheries & Aquatic Ecosystems' (€22.2M)
- Food theme: 'Food Chain Integrity & Safety' (€16.2M)
- Environment theme: 'Ecosystems' (€12.8M)

In ROI, the top five research topics in terms of funding drawn down were:

- Animal theme: 'Animal Production & Livestock Systems' (€60.6M)
- Environment theme: 'Natural Resources & Raw Materials Efficiency' (€49.6M), 'Climate / Air / Water' (€29.6M) and 'Soils / Land Use / Mixed Farming & Diversification' (€23.6M)
- Plant theme: 'Crops & Agronomy' (€35.2M)

This divergence in focus and expertise across the two jurisdictions again points to the complementarity of an all-island approach, leveraging investment in diverse and complimentary areas across the five research themes.

Figure 5.4: All-Island Agri-Food Public Research Funding (2015-2020), PI-Led (only) Awards by Research Theme and Topic

- **Environment**
  - Natural Resources & Raw Materials Efficiency, €49.6M
  - Climate / Air / Water, €29.6M
  - Soils / Land Use / Mixed Farming & Diversification, €23.6M
  - Ecosystems, €12.8M
  - Natural Resources & Raw Materials Efficiency, €12.7M
  - Agri-Environment, €12.4M
  - Soils / Land Use / Mixed Farming & Diversificati... €9.0M
  - Ecosystems, €19.9M
  - Agri-Environment, €9.2M
  - Climate / Air / Water, €6.9M

- **Animal**
  - Animal Production & Livestock Systems, €60.6M
  - Animal Health & Welfare, €30.1M
  - Animal Production & Livestock Systems, €24.8M
  - Animal Health & Welfare, €22.3M
  - Fisheries & Aquatic Ecosystems, €22.2M
  - Fisheries & Aquatic Ecosystems, €10.0M

- **Food**
  - Functional Food / Nutrition / Health / Diet-Related Disease, €23.5M
  - Food Chain Integrity & Safety, €23.3M
  - Food Chain Integrity & Safety, €16.2M
  - Food Product Development & Formulation, €9.4M
  - Food Process... Technol... &...
  - Functi... Food / Nutriti... Health...
  - Food Processing Technology & Engineering, €15.6M
  - Food...
  - F...
  - F...

- **Sustainability**
  - Smart Agriculture, €20.2M
  - Health & Wellbeing, €17.9M
  - Agri-Food Economics & Consumer Behaviour, €17.2M
  - Agri-Food Economics & Consumer Behaviour, €8.3M
  - Farm Manag... & Rural Develo... €7.2M
  - Smart Agricultu... €5.5M
  - Farm Mana...
  - Health...

- **Plant**
  - Crops & Agronomy, €35.2M
  - Grassland Science, €11.8M
  - Grassland Science, €5.6M
  - Horticulture Developm... €4.7M
  - Plant Protein, €6.6M
  - Cr... &...
  - Hor...
  - Plan...

34

5.1.6 Investment size distribution

In this section we examine the distribution of the size of awards across the island. Nearly two-thirds (€386.0M) of the 1,805 PI-led individual research projects were under €1M in award value. Most projects with an award size of under €1M fell within the Environment theme (34.9%). However, as shown in Figure 5.5 below, this trend changes as the award size of projects increases. For example, 66.9% of projects with an award size of €5M and over (excluding Centres) were in the Animal theme.

Only €34.4M of public investment (5.7%) was awarded to PI-led individual research projects with a value of €5M or over during the period 2015-2020. This amount substantially increases to €95.9M when the 3 EI Technology Centres and 2 SFI Research Centres in the area of Agri-Food are also included[25]. No PI-led individual Environment research projects with an award value of €5M or over were funded during the period (as illustrated in Figure 5.6 below). It should be noted that the BiOrbic SFI Bioeconomy Research Centre, which is primarily categorised to this research theme, was awarded over €15M in 2017. Finally, no Plant projects with an award size of €5M or over were funded by public research investment, and similarly none of the EI Technology Centres and SFI Research Centres awarded funding during the period are primarily aligned to this research theme. The majority (40.6%) of awarded Plant projects were €1-2M in size.

In summary, as might be expected there is a significant 'tail' in the distribution of funding by award size, with the vast majority of funding being awarded to projects of a smaller value (€1M or less). Although this allows for a wider distribution of funding to more projects, it is only with larger awards that more significant impacts can be achieved in terms of the research themes of greatest strategic importance. The findings point to a limited number of large scale PI-led individual research awards in the Plant and Environment themes, with the majority of larger awards (i.e. €5M or over) being funded in the Animal, Food and Sustainability themes.

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[25] The 3 EI Technology Centres and 2 SFI Research Centres are not included in the data in Figure 5.5. See Section 5.1 for approach and Section 3 for methodology.

Figure 5.5: All-Island Agri-Food Public Research Funding (2015-2020), PI-Led (only) Awards by Research Theme and Award Size

5.2 Research outputs

Bibliometrics is a well-established method of analysing research performance, and is based upon statistical analysis of articles, reviews and other publication types. Bibliometric analysis in Elsevier Scopus and Elsevier SciVal for the five-year period 2015-2019 was conducted to provide a picture of the island of Ireland's research performance relative to other countries and institutions. A summary of these findings for NI and ROI are presented below.

5.2.1   Overview

In this section we analyse the research outputs from the leading RPOs included in this Agri-Food funding analysis. As outlined in the Methodology (Section 3), the Bibliometric analysis does not map exactly to the research themes and topics defined in the taxonomy but represent the best approximation available.

5.2.1.1 Northern Ireland

In the five-year period from 2015 to 2019, NI RPOs produced 1,633 research outputs[26] in the Agricultural and Biological Sciences subject area. These research outputs have a citation impact[27] of 64% above world averages (i.e. 1.64). The 1,633 research outputs are broken down into the sub-areas listed in Figure 5.6 below.

Figure 5.6: NI Research Outputs by Sub-Area (%)
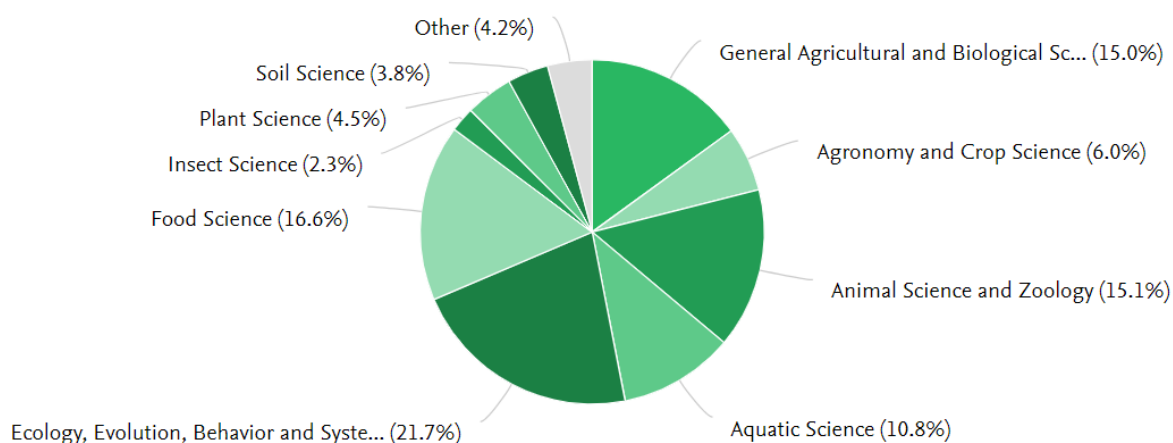
Agricultural and Biological Sciences research in NI is produced primarily by three institutions – QUB, AFBI and UU. As shown in Table 5.1 below, QUB has the greatest scholarly output in this grouping, followed by AFBI and UU. All three institutions are producing Field-Weighted Citation Impact (FWCI) well above the international average.

Table 5.1: Agricultural and Biological Sciences Research Outputs in NI

Institution	Sector	Scholarly Output	Citations	Citations per Publication	Field-Weighted Citation Impact
QUB	Academic	1,153	14,361	12.5	1.69
AFBI	Government	376	3,724	9.9	1.53
UU	Academic	222	2,581	11.6	1.35

In terms of international standing, NI-based RPOs are ranked highly in a range of sub-areas, in particular, QUB is ranked in the top 151-200 in the world in the Agriculture and Forestry subject area according to the QS World University Rankings[28]. A key area of strength within NI, is in the Veterinary Science subject area, where 219 research outputs[29] were produced within the period of analysis. These outputs had citation impacts of 112% above world averages (2.12) and were authored by researchers primarily based in AFBI and QUB.

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[26] Figures taken from SciVal, using the "Agricultural and Biological Sciences" subject area from the All Science Journal Classification used in Scopus. This is the default scheme in SciVal.

[27] FWCI is the ratio of citations received relative to the expected world average for the subject field, publication type and publication year.

[28] QS World University Rankings is an annual publication of university rankings by Quacquarelli Symonds (QS). https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/agriculture-forestry

[29] Figures taken from SciVal, using the "Veterinary" subject area from the All Science Journal Classification used in Scopus. This is the default scheme in SciVal.

5.2.1.2 Republic of Ireland

In the five-year period from 2015 to 2019, institutions in ROI produced 6,513 research outputs in the Agricultural and Biological Sciences subject area. These research outputs have a citation impact of 59% above world averages (1.59). The 6,513 research outputs are broken down into the sub-areas listed in Figure 5.7 below.

Figure 5.7: ROI Research Outputs by Sub-Area (%)
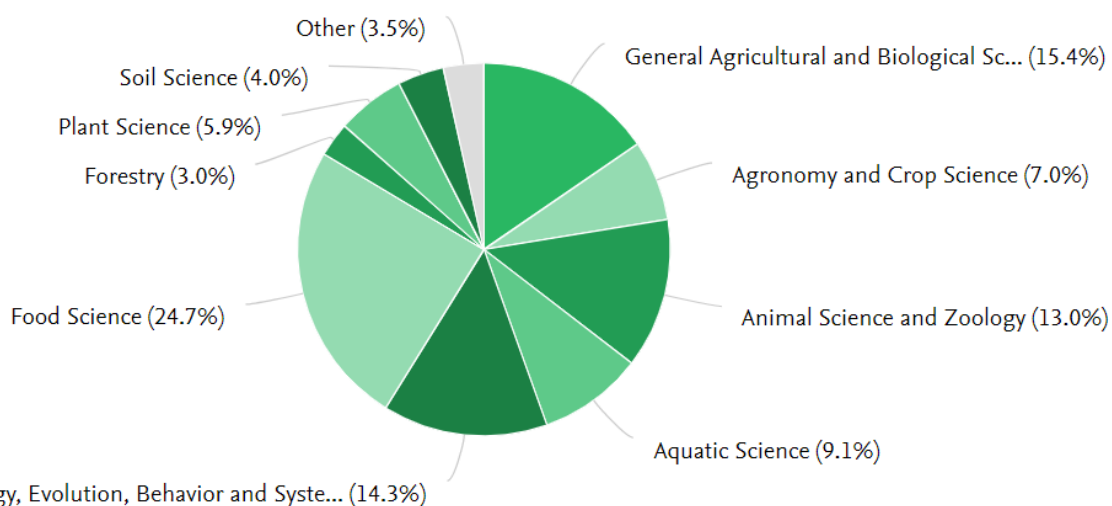
Agricultural and Biological Sciences research in ROI is produced primarily by 8 RPOs, as listed in Table 5.2 below.

Table 5.2: Agricultural and Biological Sciences Research Outputs in ROI

Institution	Sector	Scholarly Output	Citations	Citations per Publication	Field-Weighted Citation Impact
UCD	Academic	1,915	25,329	13.2	1.69
Teagasc[30]	Academic	1,586	17,464	11	1.52
UCC	Academic	1,299	17,427	13.4	1.57
Trinity College Dublin	Academic	732	8,568	11.7	1.58
NUIG	Academic	650	6,658	10.2	1.42
University of Limerick	Academic	307	3,857	12.6	1.73
Technological University Dublin	Academic	192	2,494	13	1.57
Marine Institute	Government	173	1,670	9.7	1.46

The ROI has three institutions ranked in the QS World University Rankings Agriculture and Forestry subject area[31] - UCD is ranked 51st in the world, UCC is 57th, and NUIG is ranked in the top 301-350. 718 research outputs were produced in the Veterinary Science subject area from 2015 to 2019 in

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[30] Teagasc produced a total of 2,685 publications during the period 2015-2019. All of these are in the area of Agri-Food, but many are classified in categories other than Agricultural and Biological Sciences.

[31] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/agriculture-forestry

ROI. These outputs had citation impacts of 61% above world averages (1.61) and were authored by researchers primarily based in UCD and Teagasc. UCD is also ranked 23rd in the QS World University Rankings for Veterinary Science[32].

The Clarivate list of Highly Cited Researchers for 2020 listed 8 researchers from ROI in the category of Agricultural Sciences[33]. Of these, 5 were located in Teagasc, 3 in UCD and 1 in UCC. Across all institutions worldwide, only Cornell University and Teagasc had 5 researchers in the Agricultural Sciences category (no organisation had more than 5), and only 9 organisations had 3 or more. This placed Teagasc and UCD in the top 9 organisations worldwide as hosts of highly cited researchers in the field of Agricultural Sciences in 2020.

5.2.1.3 All-island

The research profiles of NI and ROI are highly complementary and there is a high degree of collaboration between institutions. In the five-year period from 2015 to 2019, institutions in ROI and NI together produced 7,779 research outputs in the Agricultural and Biological Sciences subject area. These research outputs have a citation impact of 60% above world averages (1.60).

The 7,779 research outputs are broken down into the following sub-areas, as shown in Figure 5.8 below:

Figure 5.8: All-Island Research Outputs by Sub-Area (%)
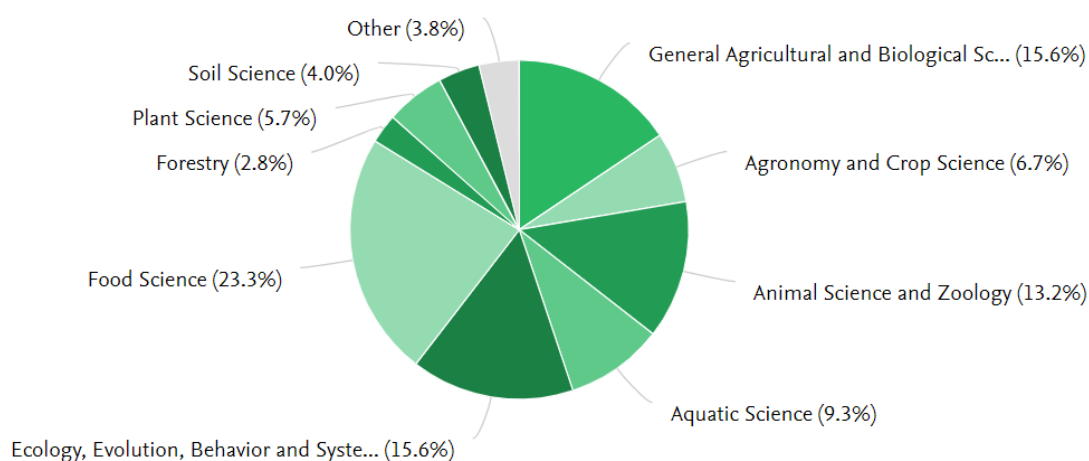
5.2.2   Impact

Combining ROI and NI research outputs over the period of analysis, the All-Island FWCI for Agricultural and Biological Sciences remained very stable year-on-year from 2015 to 2019 and well above world averages, with a citation impact of 1.60. The FWCI for NI and ROI was 1.64 and 1.59 respectively.

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[32] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/veterinary-science
[33] https://recognition.webofscience.com/awards/highly-cited/2020/

Figure 5.9: All-Island Field-Weighted Citation Impact, 2015-2019

All Ireland ☆

2015 to 2019 ⌄   All subject areas ⌄   QS   ◯ 🏛   Data sources ⁑   🔳 Report from template

Summary   Topics & Topic Clusters   Collaboration   Published   Viewed   Cited   Authors   Institutions   More... ⌄

➕ Add Summary to Reporting   Export ⌄

Overall research performance   ➕ Add to Reporting

7,779	34,144	1.60
Scholarly Output ⓘ	Authors	Field-Weighted Citation Impact ⓘ

📄 View list of publications

95,927	12.3
Citation Count ⓘ	Citations per Publication ⓘ

5.2.3   Collaboration – international and industry

Table 5.4 illustrates the collaboration on research papers between the top 10 RPOs across the island of Ireland (n=7,779). We found there was strong research output collaboration between AFBI and QUB in NI (n=116). Similarly, there was a high number of scholarly output collaborations between Teagasc and UCD (n=410), and Teagasc and UCC (n=342) in ROI. The strongest collaborations between NI and ROI, in terms of research outputs, was with Teagasc for AFBI and QUB, and with UCD and UCC for QUB.

Table 5.3: Scholarly Output Collaboration between Top 10 North and South RPOs

	AFBI	NUIG	QUB	TCD	Teagasc	TU Dublin	UCC	UCD	UL	UU
AFBI	**376**	2	116	6	68		6	29	3	14
NUIG	2	**650**	30	27	55		29	31	15	1
QUB	116	30	**1,153**	30	64	5	41	34		24
TCD	6	27	30	**732**	38	12	27	83	7	8
Teagasc	68	55	64	38	**1,586**	36	342	410	58	11
TU Dublin			5	12	36	**192**	5	28	1	
UCC	6	29	41	27	342	5	**1,299**	80	29	5
UCD	29	31	34	83	410	28	80	**1,915**	42	13
UL	3	15		7	58	1	29	42	**307**	5
UU	14	1	24	8	11		5	13	5	**222**

Two-thirds of the 7,779 scholarly outputs have international co-authors (n=5,134), and 6% have co-authors from industry (n=464).

Figures 5.10 and 5.11 clearly illustrate that scholarly outputs with international institutional or industry collaborators have higher citation impact. Research outputs with industry co-authors had a FWCI of 2.00, compared to 1.57 for papers with no academic-industry collaboration.

Figure 5.10: All-Island Scholarly Output by International Institution Co-Author

Collaboration ⓘ

Scholarly Output in All Ireland, by amount of international, national and institutional collaboration

Metric		Scholarly Output	Citations	Citations per Publication	Field-Weighted Citation Impact
■ International collaboration	66.0%	5,134	69,874	13.6	1.74
■ Only national collaboration	17.2%	1,339	13,304	9.9	1.31
■ Only institutional collaboration	13.1%	1,016	10,648	10.5	1.32
■ Single authorship (no collaboration)	3.7%	290	2,101	7.2	1.27
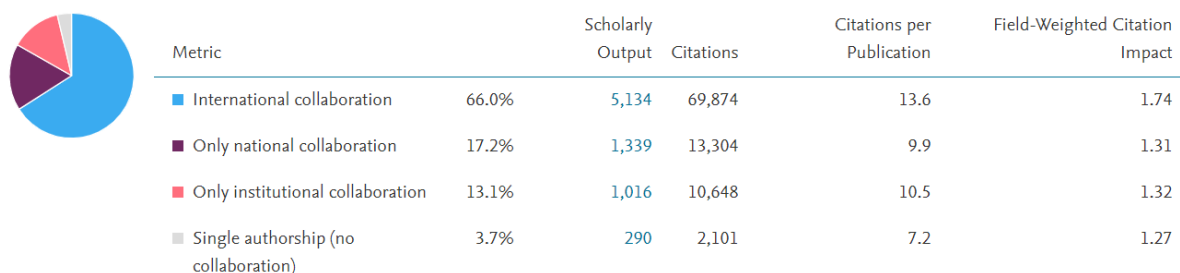
Figure 5.11: All-Island Scholarly Output by Industry Co-Author

Academic-Corporate Collaboration ⓘ

Scholarly Output in All Ireland with both academic and corporate author affiliations

Metric		Scholarly Output	Citations	Citations per Publication	Field-Weighted Citation Impact
■ Academic-corporate collaboration	6.0%	464	7,281	15.7	2.00
■ No academic-corporate collaboration	94.0%	7,315	88,646	12.1	1.57
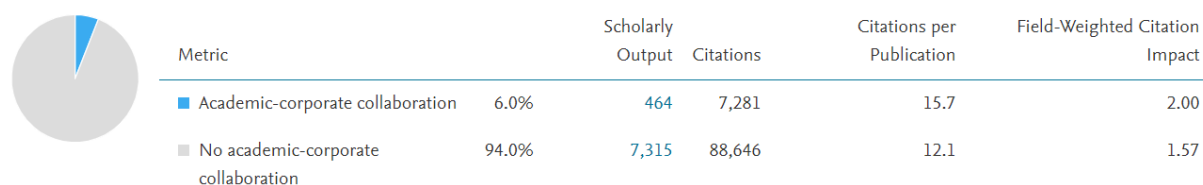
The top 20 industry collaborators for Agricultural and Biological Sciences scholarly outputs are located in 10 countries around the world, with the highest number of collaborations (n=30) with Alltech Inc. in the United States.

Table 5.4: Top 20 Industry Collaborators for Agricultural and Biological Sciences

Industry	Country	Scholarly Output
Alltech Inc.	United States	30
AZTI	Spain	21
Nestle	Switzerland	17
GenProbio S.r.l.	Italy	17
Pfizer	United States	15
Creme Global	Ireland	14
Fera Science Ltd.	United Kingdom	13
INVAS Biosecurity Ltd.	Ireland	13
RSK Group plc	United Kingdom	11
NIZO food research	Netherlands	11
DairyNZ Limited	New Zealand	11
Megazyme Ltd.	Ireland	11
Operation Wallacea Ltd.	United Kingdom	10
Kerry Group	Ireland	8
SINTEF	Norway	7
Arup Group	United Kingdom	7

Bord na Mona Horticulture Ltd	Ireland	7
FishVet Group	United Kingdom	7
ECT Oekotoxikologie GmbH	Germany	7
Merck	United States	6

5.2.4 Summary

In summary, both ROI and NI have significant research strength in a range of subject areas relating to Agri-Food. This strength is condensed in three RPOs in NI and distributed across five key RPOs in ROI. These strengths are complimentary and offer significant complementarity, and again reinforces the clear advantage of supporting greater integration and collaboration between the two groups of RPOS to drive the sector forward on an all-island basis. In this context, and with greater clarity of the UK's involvement in Horizon Europe, and with a ready list of industry collaborators, the potential is significant.

6. Gap Analysis

There are a wide range of national and EU strategies, policy documents, targets and plans that are informing, driving and providing strategic direction for the growth and sustainability of the Agri-Food sector across the island of Ireland (see Appendix C). Global challenges and drivers - including environmental sustainability, global population trends, dietary shifts, market shocks and new disruptive technologies – are shaping these ambitions and targets. There has been a seismic policy shift in recent years from prioritising the economic viability and growth of the Agri-Food sector to ensuring its sustainability and resilience underpinned by an integrated food systems approach. National and European research funding calls are being thematically framed to support R&I activities that address challenges and opportunities linked to policy objectives and sustainable sectoral growth targets.

By assessing the key findings of the historical public research investment and research outputs analyses for Agri-Food presented in Section 5 against the targets and priorities set out in national and EU strategies/policies, within the context of global challenges and drivers impacting the sector, a number of specific research gaps and potential opportunities across the island have been identified that should be prioritised for funding investment to 2030, and these are presented in Section 6.3.

6.1 National strategic priorities

Although preceding Agri-Food strategies on the island of Ireland have recognised that the development of the sector must be undertaken within a framework of sustainability, and that environmental protection and economic competitiveness cannot be achieved at the expense of the other, growth of the Agri-Food sector to further position it as a strategically vital sector of the economy has been the primary objective and driver. *Food Wise 2025* (2015), for example, set out significant growth opportunities across all sub-sectors of the Irish Agri-Food industry, as well as a range of actions that would facilitate this growth through human capital, market development, innovation and competitiveness[34].

The *Sustainable Healthy Agri-Food Research Plan* (2015) provides a framework for a strategic approach to R&I in ROI for the 'Sustainable food production and processing' and 'Food for health' priority areas of the National Research Prioritisation Exercise. Competitiveness, sustainability and consumer orientation are the three guiding principles of the plan, and its eight cross-cutting research pillars have provided a roadmap for research in food production in ROI since 2015:

1) Animal production
2) Grass, clover, forage, crops and food horticulture
3) Sustainable management of natural resources, climate change and trans-boundary gases
4) Food processing technology and engineering
5) Food product development, formulation and sensory science
6) Food chain integrity and safety
7) Functional foods and health
8) Nutrition, health and diet-related diseases[35]

The vision of NI's *Going for Growth* strategy (2013) is 'growing a sustainable, profitable and integrated Agri-Food supply chain, focused on delivering the needs of the market'[36]. The strategy, which was developed by the Agri-Food Strategy Board, set out a range of ambitious growth targets for the Agri-Food sector in NI to 2020, including increasing employment in the sector by 15% and growing industry turnover by 60% to £7 billion. The strategy outlines seven major themes that impact across the whole supply chain and that act as drivers, enablers or barriers to growth: 1) Growing market share; 2) Working together; 3) Sustainable growth; 4) Innovation, entrepreneurship and skills; 5) Better regulation; 6) Financing growth; and 7) Food Fortress.

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[34] Department of Agriculture, Food and the Marine, *Food Wise 2025: Local Roots, Global Reach*. 2015, Department of Agriculture, Food and the Marine: Dublin, Ireland.
[35] Department of Agriculture, Food and the Marine, *Sustainable Healthy Agri-Food Research Plan*. 2015, Department of Agriculture, Food and the Marine: Dublin, Ireland.
[36] Agri-Food Strategy Board, *Going for Growth: A Strategic Action Plan in Support of the Northern Ireland Agri-Food Industry*. 2013, Northern Ireland Executive: UK.

The recently published *Food Vision 2030* (2021) is the fifth Irish Agri-Food strategy since 2000 and succeeds *Food Wise 2025*. The new strategy sets out four high level missions (and 22 targets) to be achieved in order to develop a sustainable food system that is profitable throughout (economic sustainability), has broad-based benefits for society (social sustainability) and has a positive or neutral impact on the natural environment (environmental sustainability):

1) Climate smart, environmentally sustainable Agri-Food sector;
2) Viable and resilient primary producers with enhanced wellbeing;
3) Food that is safe, nutritious and appealing, trusted and valued at home and abroad; and
4) Innovative, competitive and resilient sector, driven by technology and talent[37].

DAERA published the draft *Green Growth Strategy for Northern Ireland* in late-2021, which sets out the long-term vision and a solid framework for tackling the climate crisis by balancing climate action with the need for a clean, resilient environment and economy[38]. The *Future Agricultural Policy Framework Portfolio for Northern Ireland* (2021) has been developed as a Foundation Programme under the umbrella of the developing *Green Growth Strategy*. The policy document outlines a future vision for agricultural support in NI designed around four key outcomes: 1) Increasing agricultural productivity as a means to improved profitability; 2) Environmental sustainability; 3) Improving resilience; and 4) A responsive supply chain.

There is consensus among key stakeholders in the two regions (government, primary producers, industry, researchers etc.) for the need to ensure the economic, social and environmental sustainability and resilience of the sector on the island. Global challenges (e.g. COVID-19, Brexit, climate change, biodiversity loss, consumer trust, growing global population, dietary shifts, malnutrition/obesity etc.) and new EU targets and ambitions are driving this change in strategic direction.

Both the NI Executive in the *New Decade, New Approach* agreement (2020)[39] and the ROI government in the *Programme for Government: Our Shared Future* (2020)[40] and *Climate Action Plan* (2021) have pledged to tackle climate change. The ROI government has committed to reducing agricultural emissions and land use, land use change and forestry (LULUCF) emissions by 22-30% and 37-58% respectively by 2030[41].

Towards delivering on these commitments, DAFM published *Ag Climatise: A Roadmap towards Climate Neutrality* (2020), which sets out a vision for the ROI government to develop a 'climate neutral food system', whereby the climate impact of biogenic methane is reduced to zero and remaining agricultural emissions are balanced by removals through land use and a significant contribution to renewable energy[42]. The six tasks prioritised to achieving this vision are:

1) Reduce GHG emissions from the Agri-Food sector;
2) Increase the carbon sequestration and carbon storage potential of Ireland's land use sector;
3) Reduce nutrient loss to the environment and contribute to improved water quality and biodiversity;
4) Meet ammonia emissions reduction targets;
5) Build sustainable, resilient food production and land use management systems that meet these climate and environmental obligations, while also meeting market expectations; and
6) Transparently communicate progress.

6.2 EU strategic priorities

The EC's goal is for Europe to be the first climate-neutral continent by 2050. The objectives of the *European Green Deal* (2019)[43] are to reconcile the food system with the needs of the planet and to

[37] Department of Agriculture, Food and the Marine, *Food Vision 2030*. 2021, Department of Agriculture, Food and the Marine: Dublin, Ireland.

[38] https://www.daera-ni.gov.uk/consultations/consultation-draft-green-growth-strategy-northern-ireland

[39] Northern Ireland Office, *New Decade, New Approach*. 2020, Northern Ireland Office: UK.

[40] Department of the Taoiseach, *Programme for Government: Our Shared Future*. 2020, Department of the Taoiseach: Dublin, Ireland.

[41] Department of the Environment, Climate and Communications, *Climate Action Plan 2021: Securing Our Future*. 2021, Government of Ireland: Dublin, Ireland.

[42] Department of Agriculture, Food and the Marine, *Ag Climatise: A Roadmap towards Climate Neutrality*. 2020, Department of Agriculture, Food and the Marine: Dublin, Ireland.

[43] European Union, *The European Green Deal*. 2019, European Union: Brussels, Belgium.

produce healthy, equitable and environmentally friendly food for Europeans. There are a range of ambitious targets for the Agri-Food sector set out in the *EU Biodiversity 2030 Strategy* (2020)[44] and *EU Farm to Fork Strategy* (2020)[45], including:

- Ensure sustainable food production - the food chain (covering food production, transport, distribution, marketing and consumption) has a neutral or positive environmental impact;
- Reduce dependency on pesticides and antimicrobials;
- Reduce excess fertilisation;
- Increase organic farming;
- Improve animal welfare;
- Reverse biodiversity loss;
- Reduce emissions by at least 55% by 2030 (Fit for 55 Package);
- Ensure food security, nutrition and public health (i.e. that everyone has access to sufficient, nutritious, sustainable food that upholds high standards of safety and quality, plant health, and animal health and welfare, while meeting dietary needs and food preferences);
- Preserve the affordability of food, while generating fairer economic returns in the supply chain;
- Promote sustainable food consumption and facilitate the shift to healthy, sustainable diets - improve dietary patterns and lifestyles to reduce the incidence of non-communicable diseases; and
- Reduce food waste and loss.

Another pivotal strategic driver of the Agri-Food sector in Europe is *FOOD 2030* (2018), which adopts a systemic approach to connect, scale-up and boost EU R&I in food to provide solutions to four priorities: 1) Nutrition for sustainable and healthy diets; 2) Climate-smart and environmentally sustainable food systems; 3) Circular and resource efficient food systems; and 4) Food systems innovation and empowerment of communities. Key *FOOD 2030* targets include:

- Improve dietary patterns and lifestyles for a 50% reduction in the incidence of non-communicable diseases in 2030, while reducing the environmental impact of food consumption.
- Create a resource-smart food system with 50% lower GHG emissions by 2030.
- Ensure food safety along the entire food chain, among all food system actors, developing and implementing traceability systems all along the food chain supported by available and new safe technologies[46].
- Develop new assessment methodologies, traceability and labelling systems to empower risk assessors, users, innovators and communities, and to address their concerns[47, 48].

6.3 Research gaps and future opportunities

Within a six-year period from 2015 to 2020, a significant shift and re-prioritisation of national Agri-Food strategies and targets has been witnessed – moving away from a producer-led approach and the prioritisation of the economic growth of the sector to ensuring its future sustainability and resilience within the context of a range of global challenges and drivers, namely Brexit, COVID-19, Ukraine, climate change, biodiversity loss, global population growth and diet-related diseases. At a national and EU level, strategies and policies are being underpinned by a 'whole food systems' approach and sustainability (economic, social and environmental). These policies, strategies and targets are in turn informing and driving the strategic direction of R&I funding programmes.

It is estimated that over €680M of public research funding (ROI, NI, EU and GB) has been invested in Agri-Food research (PI-led individual research projects and Centres) on the island of Ireland between 2015 and 2020. Detailed analysis of the 1,805 PI-led individual research projects funded during this period provides additional insights into the research strengths and expertise of RPOs across the island, as well as where funders are directing public research investment in line with R&I strategies and plans.

[44] European Union, *Farm to Fork Strategy*. 2020, European Union: Brussels, Belgium.
[45] European Union, *Biodiversity 2030 Strategy*. 2020, European Union: Brussels, Belgium.
[46] EC FOOD 2030 Independent Expert Group, *Recipe for change: An agenda for a climate smart and sustainable food system for a healthy Europe*. 2018, European Union: Brussels, Belgium
[47] European Union, *FOOD 2030 Pathways for Action: Food Safety Systems of the Future*. 2020, European Union: Luxembourg.
[48] EC FOOD 2030 Independent Expert Group, op. cit.

Year-on-year public investment in PI-led individual Agri-Food research projects declined annually from 2015 to 2019 - falling from €138.6M in 2015 to €96.2M in 2019. This mirrors the 0.29% decline in Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP for the ROI from 1.52% in 2014 to an estimated 1.23% in 2019[49]. The overall PI-led funding portfolio experienced a negative compound annual growth rate (CAGR) of -8.7% between 2015 and 2019.

A deeper dive analysis of the five research themes (and 21 research topics) in Section 5.1 illustrates that the distribution of funding across the themes and topics is not proportionate, with funding being drawn down in ROI and NI RPOs for a diverse range of topics. In addition, this analysis has highlighted a number of specific research topics where public investment has not pivoted in line with the transitioning strategic priorities of the ROI and NI governments and the EU. Figure 6.1 shows the scale of the distribution of funding by research topic and where there are potential gaps in public investment. The total amount of funding awarded (X axis), strategic alignment (Y axis) and CAGR (bubble) for each research topic for the period 2015-2019 are presented in this diagram. Each research topic's strategic alignment was subjectively scored from 1 to 5 based on a high-level assessment of key national and EU strategies and policy documents relevant to the Agri-Food sector. A score of 1 represents 'no/very little strategic alignment', and a score of 5 represents 'significant/very high strategic alignment'. A negative CAGR (decline in funding) is represented by a white bubble, and a positive CAGR (growth in funding) is represented by a blue bubble. A larger bubble symbolises a larger (positive or negative) CAGR.

Figure 6.1: All-Island PI-Led (only) Funding Awards by Research Topic, Total Funding, Strategic Alignment and CAGR (2015-2019)
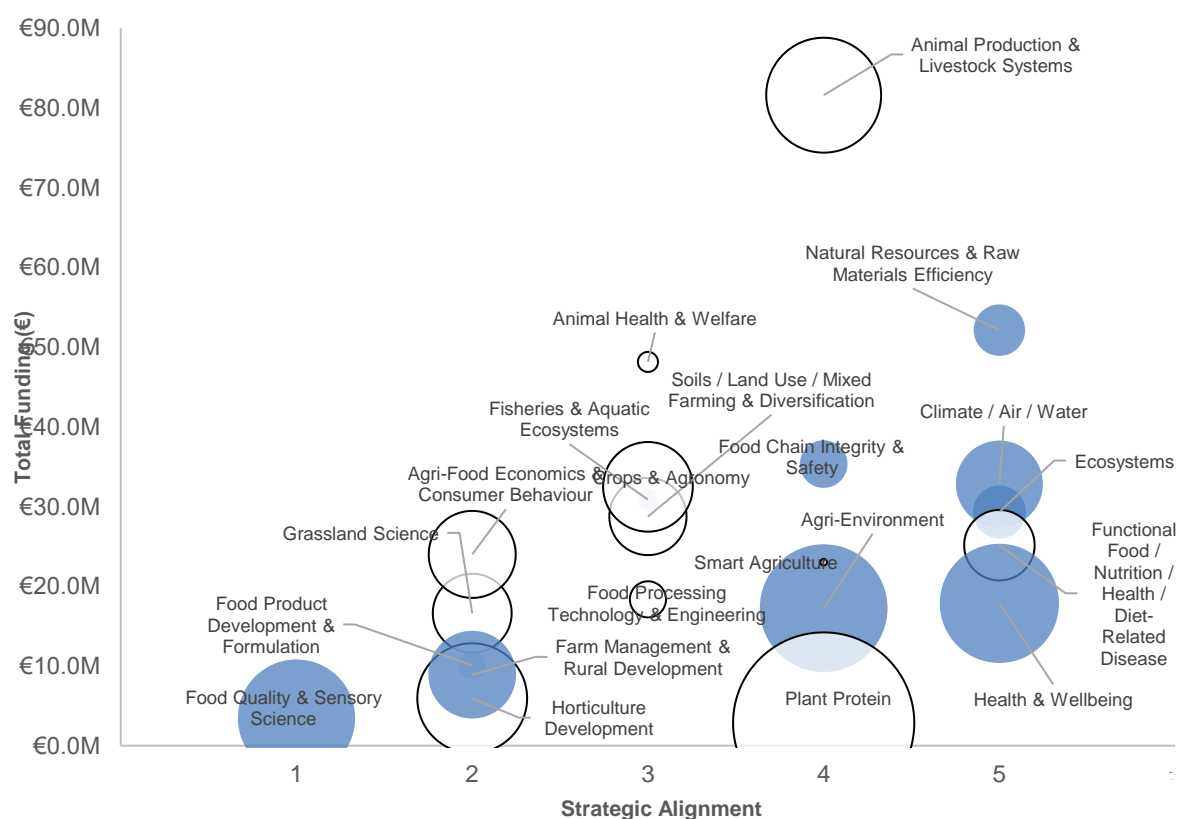
Looking first at the Animal theme, which had a substantial negative CAGR of -21.8% from 2015-2019, it is clear that funding investment for the research topic 'Animal Production & Livestock Systems' significantly declined during the period (CAGR of -40.5%). Although public investment in this research area significantly declined from €36.5M in 2015 to €4.6M in 2019, it is important to note that it fluctuated up and down considerably each year most likely as a result of when certain research

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[49] OECD, *Main Science and Technology Indicators, Volume 2020 Issue 2*. 2021, Organisation for Economic Cooperation and Development: Paris, France.

funding programmes were launched (e.g. DAFM Competitive Research Call opens approximately every 18 months).

The Environment theme witnessed the only increase in public investment during the period, with an overall CAGR of 9.2%. Each of the research topics in this theme experienced funding growth between 2015 and 2019, except for the strategically important research topic 'Soils / Land Use / Mixed Farming & Diversification'. In particular, 'Agri-Environment' had a CAGR of 48.9% but this topic accounts for the smallest proportion of all Environment research (11.6%).

The Food theme had a slightly fluctuating, but overall small negative growth rate of -1.4% CAGR during the period 2015-2019. Again, the CAGR for each research topic within this theme varied. It is clear from Figure 6.1 that the two negative CAGRs for this theme were 'Functional Food, Nutrition, Health & Diet-Related Disease' (-15.5%) and 'Food Processing Technology & Engineering' (-4.2%). Although these two research areas experienced a negative CAGR between 2015 and 2019, total funding for the period 2015-2019 was relatively strong at €28.8M and €21.2M respectively. The greatest increase in growth was for 'Food Quality & Sensory Science' at 41.2%.

The Plant theme experienced the greatest decline in funding from 2015-2019 with a sizeable negative CAGR of -26.5%. It is important to note that all four research topics in the theme experienced a negative growth rate during the five-year period.

Finally, the Sustainability theme had a small negative growth rate of -3.6% CAGR, despite the large positive CAGR of 42.6% for the 'Health & Wellbeing' research topic. 'Smart Agriculture', which is a key driver to ensuring the future sustainability and resilience of the Agri-Food sector, had a fairly consistent year-on-year growth rate (% CAGR).

As the largest indigenous industry on the island of Ireland and essential to the economic growth and sustainability of the two jurisdictions, it is imperative that public investment in Agri-Food R&I across the 'whole food system' (i.e. the five research themes) increases year-on-year to 2030 to ensure the transformation, sustainability and diversification of the sector. Based on a high-level review of national and EU strategies and policies relevant to the sector and the findings presented in Section 5, it is projected that investment will continue to be directed to the Environment theme as a priority, and this area will witness a strong positive CAGR to 2030. It is clear from Figure 6.1 that there are a number of research areas where funding investment has not pivoted in line with new strategic priorities of the ROI and NI governments and the EU. These current research gaps, and consequent future funding opportunities, are discussed in further detail in the sub-sections below.

6.3.1 Sustainable land use

The future of the Agri-Food sector cannot be sustained without preserving and restoring the planet's ecosystems, biodiversity, soil and land. Agriculture is the primary land use and land cover (LULC) type in ROI (67.6%), followed by wetlands (14.9%) and forestry (9.5%)[50]. Soil is a fragile natural resource due to the negative impact of settlement patterns, the generation of slurry and sludge, nutrient loss to water, ammonia emissions to the atmosphere, and soil organic carbon losses[51]. Approximately 33% of global soils are degraded, and erosion is affecting 25% of agricultural land in the EU[52]. In addition, peatland in ROI is in a degraded state due to land drainage, reclamation for agricultural purposes and peat extraction.

There is a growing need for the LULUCF sector to become a long-term sustainable net sink, positively contributing to addressing climate change and supporting a transition to a carbon neutral economy and society by 2050. Land use is a key climate mitigation measure for the island, but there are significant challenges that must be overcome to maximise the potential contribution from land use.

Given its strategic importance both nationally and in the EU, and strong research expertise on the island (particularly in Teagasc, UCD, AFBI and QUB) in soil science, forestry, biodiversity and land use, it is important to note that only €32.6M of public investment was awarded to PI-led individual research projects on 'Soils, Land Use, Mixed Farming & Diversification' between 2015 and 2020. Apart from 2015 and 2017 (€8.8M and €7.8M respectively), the annual allocation of public funding to this research topic was less than €5M. Across the whole island of Ireland this research topic

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[50] RSK Environment Ltd., *Strategic Environmental Assessment (SEA) Scoping Report: Agri-Food Strategy to 2030.* 2020, Department of Agriculture, Food and the Marine: Dublin, Ireland.
[51] ibid.
[52] Mission Board for Soil Health and Food, *Caring for soil is caring for life - Ensure 75% of soils are healthy by 2030 for food, people, nature and climate.* 2020, European Commission: Brussels, Belgium.

witnessed a negative growth of -18.5% CAGR between 2015 and 2019, with a slight decline experienced in NI (-1.8% CAGR) and a significant decline in ROI (-25.2% CAGR)

The expansion of the National Agricultural Soil Carbon Observatory, which was established by Teagasc in 2020, with an additional €2.7M in funding from DAFM in 2021 is welcome[53]. National and EU policies and strategies highlight soil quality and health, alternative land uses including forestry, and agricultural diversification as essential to achieving a climate neutral Agri-Food system by 2050. Further research in these areas should be prioritised for future funding programmes to 2030.

6.3.2   Plant innovation

Crop production supports the Agri-Food sector on the island through the provision of high-quality, low carbon input, traceable feed for dairy and livestock production, and raw material for processing into food and drink products[54]. The ROI tillage sector is estimated to contribute over €1.3 billion per annum to economic output, and supports 11,000 full-time equivalent jobs[55]. Furthermore, tillage has a good environmental footprint with low emissions, and is important for biodiversity and ecosystems. As with the rest of the Agri-Food sector, crop production is facing a number of challenges which currently limit its development (including access to land, loss of effective plant protection products, climate change, new pesticide and fertiliser targets, and restrictions on plant breeding technologies)[56].

DAFM has set out a number of actions and targets for the crop and tillage sector[57] that align with the EU's target[58] to reduce the use and risk of chemical pesticides by 50% and the use of fertiliser by at least 20% by 2030. In addition, Teagasc's report *Crops 2030: A Strategic Plan to deliver environmental and economic sustainability for the Irish Crops Sector* (2020)[59] provides a range of recommendations and actions for the sector, including: supporting the diversification of mainstream and niche crops to generate novel, value added streams (such as food/nutritional ingredients, products to enhance gut microbiome, and protein digestibility etc.) to meet consumer-driven nutritional and health demands; and investigating the potential for development of alternative feed crops such as ensiled protein crops[60].

There are substantial market opportunities in plant innovation, many of which are currently being met through imports, in the areas of food, sustainability and diversified land uses. For example, Ireland is 'protein deficient' with animal feed protein being imported[61]. Despite these opportunities, public funding in this area has been declining year-on-year since 2015 with a substantial negative CAGR of -26.5% for the period 2015-2019. Overall, funding for this theme accounted for just over 11% of all Agri-Food public research investment across the island during the six-year period 2015-2020. In addition, there are no Centres primarily focused on plant or crop science. The analysis in Section 5.1 shows that Teagasc, UCD, AFBI and QUB are strong research leaders in this domain, and funding is mainly being awarded from the EU, IRC and government departments (e.g. DAFM, DAERA).

In particular 'Plant Protein', which has become more important in recent years due to changing consumption patterns and preferences, animal welfare concerns and environmental considerations, received very little to no public research investment in ROI or NI between 2015-2019 (-100% CAGR). It is important to note that €4.8M of funding was allocated to RPOs in ROI in 2020 for research projects in this area.

There is huge potential for crop production and innovation to expand and develop, producing more food and drink products and supporting the sustainability credentials of produce[62]. Future research opportunities in crop and plant innovation, based on national and EU policy targets, global challenges and market drivers, include: indigenous crop production; plant-based protein alternatives for food and animal feed; novel fertilisers; organic farming; and biopesticides for pest and disease control.

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[53] https://www.gov.ie/en/press-release/d7063-mcconalogue-announces-27-million-funding-to-expand-the-national-agricultural-soil-carbon-observatory/
[54] Teagasc Tillage Crop Stakeholder Consultative Group, *Crops 2030 - A strategic plan to deliver environmental and economic sustainability for the Irish Crops Sector.* 2020: Ireland.
[55] Wallace, M., *Economic Impact Assessment of the Tillage Sector in Ireland.* 2020: Dublin, Ireland.
[56] Teagasc Tillage Crop Stakeholder Consultative Group, op. cit.
[57] Department of Agriculture, Food and the Marine, *Ag Climatise: A Roadmap towards Climate Neutrality*, op. cit.
[58] European Union*, Farm to Fork Strategy*, op. cit.
[59] Teagasc Tillage Crop Stakeholder Consultative Group, op. cit.
[60] ibid.
[61] ibid.
[62] ibid.

6.3.3 Agri-digitalisation

Technology is drastically transforming the Agri-Food sector and is a key enabler to its long-term sustainability and resilience. It has the potential to support the development of precision agriculture solutions that could increase yields by up to 30%[63]. Smart agriculture is transforming every aspect of agricultural practice, from farm management to plant genetics, and is driving an evolution from precision agriculture to predictive agriculture. Precision farming, smart technologies and the use of artificial intelligence will enable the sector to deliver on the EU's targets to improve soil management and water quality, reduce the use of fertilisers, pesticides and GHG emissions, improve biodiversity, create a healthier environment for farmers, and ensure consumer trust through food traceability and authenticity.

Disparities across the globe in the uptake and adoption of technology in the Agri-Food sector is striking. Compared to international activity, the pipeline of Agtech start-ups on the island of Ireland is minimal. It is positive that AgTechUCD, a €3M Agtech innovation centre in ROI, was established in 2020 with funding from the Regional Enterprise Development Fund. This hub will be a focal point for the Agtech innovation ecosystem and an innovation showcase for ROI[64].

Teagasc, one of the key research leaders for smart agriculture on the island and host institution of the €25M VistaMilk SFI Research Centre, has identified five technology themes as priorities for R&I to 2035: 1) Plant and animal genomics and related technologies; 2) Human, animal and soil microbiota; 3) Digital technologies; 4) New technologies for food processing; and 5) Transformation in the food value chain system[65].

Public research funding for the Sustainability theme remained relatively stable during the period 2015-2019, with a small decline in growth of -3.6% CAGR. Teagasc, UCD and QUB are leading a number of large research programmes in the area of agri-digitalisation - the two largest research programmes on the island funded in the 'Smart Agriculture' topic are the VistaMilk SFI Research Centre and the CONSUS (Crop Optimisation through Sensing, Understanding and Visualisation) SFI Strategic Partnership. QUB also has strong expertise on the island in food supply chain integrity and food provenance, traceability and authenticity to future proof the Agri-Food sector.

The recent pivoting of public research investment to 'Smart Agriculture' is to be commended, but compared to global activity, R&I in this area it is still marginal on the island. During the period 2015-2019, NI experienced a large negative CAGR of -51.4% in 'Smart Agriculture' compared to the positive growth rate of 11.3% CAGR in ROI. Given the clear fundamental need for agri-digitalisation, data innovations and smart agriculture/precision farming to ensure the sustainability and growth of the Agri-Food sector, an overall CAGR of -0.2% for the island is noteworthy. Further substantial research investment in technology and innovations in Agri-Food will be vital to the economic success and sustainability of the sector on the island, and in achieving the environmental targets set out in *Farm to Fork* and other EU and national strategies. A significant intervention of additional R&I funding in agri-digitalisation will be required to further cement the island's position as a global leader in food safety, quality and production.

6.3.4 Sustainable Animal Production

It is now recognised that the Agri-Food sector is the largest contributor to ROI's GHG emissions (accounting for approximately one-third)[66] and agriculture and forestry, as the main land use on the island, exert the most pressure on water quality[67]. Agriculture is responsible for 99% of ammonia emissions in ROI, with projections that by 2035 increased dairy herd numbers will be a key driver of increased emissions due to their high nitrogen excretion values relative to other livestock[68]. Although bovine numbers have remained relatively stable, the removal of milk quotas has resulted in an expansion of the dairy herd. As animal sourced foods are rich in nutrients, and reducing/removing these from the diet could have significant negative health implications, the consumption of meat, dairy, seafood and eggs (in appropriate evidence-based quantities) will remain as official advice and guidance for a healthy, balanced diet.

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[63] Kirova et al., op. cit.

[64] https://www.ucd.ie/innovation/news-and-events/latest-news/agtech-connector-innovation-hub-kildare/name,479612,en.html

[65] Teagasc, *Teagasc Technology Foresight 2035*. 2016: Ireland.

[66] Environmental Protection Agency, *Ireland's Provisional Greenhouse Gas Emissions 1990-2019*, op. cit.

[67] Department of Agriculture, Food and the Marine, *Food Vision 2030*, op. cit.

[68] Department of Agriculture, Food and the Marine, *Ag Climatise: A Roadmap towards Climate Neutrality*, op. cit.

Given that dairy and meat exports underpin the current agri-economy of the island, the two regions must play a leading role in shaping how GHG emissions from livestock farming are understood and addressed through R&I. DAFM has identified four key areas for prioritisation in *Food Vision 2030*: 1) Novel feed additives to reduce the level of biogenic methane emissions; 2) Grass, herbs and fodder varieties that deliver required sward yields and longevity at lower levels of nitrogen application; 3) Grass biorefining for increased nitrogen and protein use efficiency and lowering of emissions to air, soil and water; and 4) Animal genetics enabling the breeding of livestock with lower emissions[69].

EI Technology Centres and SFI Research Centres such as Food for Health Ireland, VistaMilk and BiOrbic are undertaking research in this area, however there is an urgent need to increase expertise, funding and research infrastructure on GHG, ammonia emission and methane science on the island. Research funding for 'Animal Production & Livestock Systems' fell drastically from €36.5M in 2015 to just €3.8M in 2019 (-40.5% CAGR). This research field has become more important in recent years due to changing consumption patterns and preferences, animal welfare concerns and climate mitigation targets.

The announcement in 2021 of €9M funding by DAFM to Teagasc to establish a National Agricultural Sustainability Research and Innovation Centre is welcome. The Centre will provide practical integrated solutions for farmers and other stakeholders to restore and protect biodiversity, improve water quality, and reduce GHG and ammonia emissions[70]. This is a positive step in increasing the % CAGR and realignment of public investment towards this strategically important research area.

6.4 North-South Collaborations

Academic institutions, research groups and researchers across the island of Ireland share long-standing and deep collaborative links in the Agri-Food domain. There are a number of research programmes that facilitate cross-border collaborations (e.g. DAFM's National Research Call co-funded by DAERA, and the US-Ireland Research and Development Partnership Programme). Over recent decades, with the backdrop of EU R&I framework programmes, ROI has become a valuable research partner for NI institutions, and these all-island ties will become more important than ever now due to Brexit. The findings in Section 5 demonstrate that there are differences in focus and expertise of researchers across the two jurisdictions, pointing to the complementarity of an all-island approach by leveraging investment in diverse and complimentary areas across the 'whole food system'.

Due to the cultural, economic and political interlinkages between ROI and NI, the sustainability of the Agri-Food sector will require a new transitional approach where resources and expertise across the island are pooled together to reduce emissions, increase sustainability, protect biodiversity, and improve health and nutrition. Existing all-island channels will need to be maintained and enhanced through research programmes to continue shared advances in R&I and the development of the research talent pipeline. Partnerships should be further fostered to generate strategic, large-scale and sustained all-island collaborations that will support a transformative and diversified Agri-Food sector through R&I. East-West collaborations should also be further fostered, particularly in the context of Brexit, through cross-border research initiatives. ROI institutions should avail of existing all-island relations to further target GB funding programmes (e.g. BBSRC, NERC) in partnership with NI collaborators.

The NI Executive[71] and ROI government[72] recognise the significant opportunities and benefits of enhanced North-South R&I collaboration and have both committed to a North-South programme of R&I, including an all-island research hub, through Universities Ireland. The new HEA North-South Research Programme announced in 2021, funded by the Shared Ireland Fund[73], is a welcome development that has the opportunity to strengthen the island's reputation as a leader and innovator in Agri-Food research. Over €37M was awarded to 62 projects in the first round of this call, with €1M

[69] Department of Agriculture, Food and the Marine, *Food Vision 2030*, op. cit.
[70] https://www.teagasc.ie/news--events/news/2021/new-nasric-announced.php
[71] Northern Ireland Office, op. cit.
[72] Department of the Taoiseach, op. cit.
[73] https://www.gov.ie/en/press-release/84ef5-taoiseach-micheal-martin-and-minister-simon-harris-award-over-37m-under-shared-island-north-south-research-programme/

(2.7%) being awarded to five projects in the area of Agri-Food[74]. A second round of this call will be announced in 2023.

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[74] The results of the HEA North-South Research Programme call were announced in early 2022 and are therefore not included in this mapping exercise, which covers the period 2015-2020.

7. Recommendations

The All-Island of Ireland Agri-Food Research Ecosystem Mapping Exercise, for the first time, provides an in-depth analysis of publicly funded Agri-Food research across the entire island of Ireland. By analysing historic public research investment (2015-2020) and research outputs (2015-2019) and mapping these findings against the targets and ambitions of national and EU strategies and policies, public research investment gaps and misalignments to strategies and policies, future research funding priorities, and research strengths/excellence in RPOs to address these gaps and opportunities have been garnered.

This mapping exercise is very timely - the Agri-Food sector on the island is facing substantial challenges due to Brexit, the COVID-19 pandemic, the geopolitical situation in Ukraine, the changing dietary patterns and environmental issues associated with current production practices, and national and international climate mitigation obligations. The sustainability of the whole food chain, from producer to consumer, is the biggest challenge facing the sector on the island and globally. Sustainable agriculture and food systems will require diversification, resilience and a 'whole food system' approach. A strong R&I ecosystem is key to supporting Agri-Food primary producers, processors, SMEs, multinationals and research institutions to drive future waves of economic development in the sector to assist the sector to radically transform to produce high quality products that are internationally competitive, using environmentally neutral production systems.

Recommendations for future public investment in Agri-Food research across the island of Ireland to 2030 based on historical public research investment, research outputs, research excellence and strengths in ROI and NI institutions, and national and EU targets and ambitions are provided below.

Recommendation 1: The ROI and NI governments must enhance all-island R&I collaboration in Agri-Food by delivering on their commitment of a North-South programme of R&I, including an all-island research hub through Universities Ireland and strategic Agri-Food research awards under the HEA North-South Research Programme. These enhanced partnerships will ensure continued shared advances in R&I and will generate strategic, large-scale and sustained all-island collaborations that will support a transformative Agri-Food sector beneficial to the whole island.

Recommendation 2: As the largest indigenous industry on the island of Ireland, and pivotal to the continued growth and sustainability of the two regions, year-on-year public investment in Agri-Food research across the 'whole food system' should be increased with a positive CAGR to 2030.

Recommendation 3: National and EU policies and strategies highlight soil quality and health, alternative land uses including forestry, and agricultural diversification as essential to achieving a climate neutral Agri-Food system by 2050. Further research investment in sustainable land use, land use change and forestry must be prioritised to 2030.

Recommendation 4: There are substantial market opportunities in crop and plant innovation that are not being targeted nationally and are currently being met through imports. Research investment in plant innovation should be prioritised in the context of shifting global patterns in consumer preferences, new strategic priorities and the island's research strengths and expertise in plant science.

Recommendation 5: Additional research investment in technology and innovations in Agri-Food will be vital to the economic success and sustainability of the sector, to ensuring the integrity of the food supply chain and to achieving the environmental targets set out in national and EU strategies. A substantial intervention of additional R&I funding in agri-digitalisation is required to further advance and cement the island's position as a global trusted leader in Agri-Food.

Recommendation 6: There is an urgent need to increase expertise, funding and research infrastructure on GHG, ammonia emission and methane science on the island in order to achieve a climate-neutral food system by 2050, with considerable progress towards meeting agreed targets required by 2030.

8. Appendices

In this section we present the various reference material used in the formulation of the mapping exercise report. This includes:

- Appendix A – Taxonomy Development
- Appendix B – Research and Technology Centre Summaries
- Appendix C – List of National and EU Strategies and Policies

A. Taxonomy Development

This Appendix highlights the stages of development of the agreed taxonomy of the research themes and research topics used for the analysis presented in this report. The research themes and topics of four ROI and NI Agri-Food funding bodies (DAFM, EPA, Teagasc and AFBI) were assessed for relevance, duplication, and overlapping focus areas, and subsequently re-classified where necessary. Starting with 99 research topics of interest, 5 research themes and 21 research topics were identified. The development of the taxonomy is presented across the following three tables.

Table A.1: Long List of Agri-Food Research Themes and Topics

No.	Funding Body	Research Theme	Research Topics	Updates
1	Department of Agriculture, Food and the Marine	Agriculture	Animal Production	Renamed theme to 'Animal'. Renamed topic to 'Animal Production & Biosciences'
2			Grass, Clover, Forage, Crops & Food Horticulture	
3			Socio-Economic	Incorporated into topic 'Agricultural Economics & Farm Surveys'
4			Sustainable Management of Natural Resources	Incorporated into topic 'Resource Efficiency'
5		Food	Food Chain Integrity & Safety	
6			Food Processing Technology & Engineering	
7			Food Product Development, Formulation & Sensory Science	Removed "Sensory Science". Listed under 'Food Quality & Sensory Science'
8			Functional Food & Health	Incorporated into topic 'Nutrition, Health & Diet-Related Disease'
9			Nutrition, Health & Diet-Related Disease	Renamed topic to 'Functional Food, Nutrition, Health & Diet-Related Disease'
10			Platform	Renamed topic to 'Food Provisioning Platforms'
11		Forestry	Adding Value	Incorporated into topic 'Resource Efficiency'
12			Climate Change	Incorporated into topic 'Environment, Soils & Land Use'
13			Ecosystem Services	Renamed theme to 'Environment'. Combined & renamed topics 'Ecosystems'
14			Expansion of The Forest Resource	
15			Forest Expansion	
16			Forest Resource Protection	
17			Productivity	Incorporated into topic 'Resource Efficiency'

No.	Funding Body	Research Theme	Research Topics	Updates
18			Resource Utilisation	Incorporated into topic 'Environment, Soils & Land Use'
19	Environmental Protection Agency	Climate	Carbon Stocks, GHG Emissions, Sinks & Management Options	Renamed theme to 'Environment'. Combined & renamed topics to 'Climate & Air'
20			Ireland's Future Climate, Its Impacts, & Adaptation Options	
21			Climate Solutions, Transition Management & Opportunities	
22			Air Science	
23		Water	Safe Water	Renamed theme to 'Environment'
24			Ecosystem Services & Sustainability	Incorporated into topic 'Resource Efficiency'
25			Innovative Water Technologies	Incorporated into topic 'Safe Water'
26			Understanding, Managing & Conserving Our Water Resources	Incorporated into topic 'Resource Efficiency'
27			Emerging & Cross-Cutting Issues	Removed: Out of scope
28		Sustainability	Resource Efficiency	
29			Health & Wellbeing	
30			Natural Capital & Ecosystem Services Including Soils & Biodiversity	
31			Socio-Economic Aspects of a Sustainable Environment	Incorporated into topic 'Agricultural Economics & Farm Surveys'
32		Green Enterprise	Plastics	Removed: Out of scope
33			Construction & Demolition Waste	Removed: Out of scope
34			Food Waste	Renamed theme to 'Environment'
35			Resources & Raw Materials	Renamed theme to 'Environment'
36	Teagasc	Animal & Grassland	Animal & Bioscience	Incorporated into topic 'Animal Production'
37			Grassland Science	Renamed theme to 'Plant'
38			Livestock Systems	Renamed theme to 'Animal'
39			Pig Development	Renamed theme to 'Animal'
40		Crops, Environment & Land-Use	Crops	Renamed theme to 'Plant'. Renamed topic to 'Crops & Agronomy'
41			Agri-Environment	Renamed theme to 'Environment'
42			Forestry Development	Removed: Out of scope
43			Horticulture Development	Renamed theme to 'Plant'
44			Agricultural Catchments	Removed: Teagasc programme as opposed to research theme
45			Environment, Soils & Land Use	Renamed theme to 'Environment'
46		Food	Food Biosciences	
47			Food Safety	Incorporated into topic 'Food Chain Integrity & Safety'
48			Food Chemistry & Technology	Incorporated into topic 'Food Processing Technology & Engineering'
49			Food Industry Development	
50			Food Quality & Sensory Science	

No.	Funding Body	Research Theme	Research Topics	Updates
51		**Rural Economy & Development**	Agricultural Economics & Farm Surveys	
52			Agri-Food Business & Spatial Analysis	
53			Farm Management & Rural Development Knowledge Transfer	
54		**Economics**	Agri-Food Market & Policy Analysis	Incorporated into topic 'Agricultural Economics & Farm Surveys'
55			Rural Development	Incorporated into topic 'Farm Management & Rural Development Knowledge Transfer'
56			Economics of Natural Environment	Incorporated into topic 'Agricultural Economics & Farm Surveys'
57	Agri-Food & Biosciences Institute	**Fisheries & Aquatic Ecosystems**	Freshwater Catchment Management	Renamed theme to 'Animal'. Renamed topic to 'Fisheries & Aquatic Ecosystems'
58			Freshwater Ecosystems Management	
59			Marine Ecosystems Management	
60			Nutrient Management	
61			Sustainable Mariculture	
62		**Grassland & Plant Science**	Agroforestry	Incorporated into topic 'Environment, Soils & Land Use'
63			Arable & Fibre Crops - Oats	Incorporated into topic 'Crops'
64			Arable & Fibre Crops - Potato	
65			Biodiversity	Renamed theme to 'Environment'
66			Control Measures for Mushroom Pests	Removed: Out of scope
67			Enhancing Nutritive Value & Efficiency	Incorporated into topic 'Horticulture Development'
68			Renewable Energy	Incorporated into topic 'Resource Efficiency'
69			Environmental Monitoring	Incorporated into topic 'Agri-Environment'
70			Forage Grass Breeding	Incorporated into topic 'Grassland Science'
71			Grass & Forages	
72			Horticultural Crops	Incorporated into topic 'Horticulture Development'
73			Mushroom Research	
74			Nutrient Management	Incorporated into topic 'Environment, Soils & Land Use'
75		**Environmental Protection**	Anaerobic Digestion	Incorporated into topic 'Agri-Environment'
76			Biogeochemistry Research	
77			Environmental Monitoring	
78			Renewable Energy	Incorporated into topic 'Resource Efficiency'
79			Nutrient Management	Incorporated into topic 'Environment, Soils & Land Use'
80			Water Quality	Incorporated into topic 'Safe Water'
81		**Sustainable Livestock**	Anaerobic Digestion	Incorporated into topic 'Animal Production'
82			Beef	

No.	Funding Body	Research Theme	Research Topics	Updates
83			Dairy	
84			Pigs	
85			Poultry	
86			Sheep	
87			Nutrient Management	Incorporated into topic 'Environment, Soils & Land Use'
88			Animal Welfare	Renamed theme to 'Animal'. Renamed topic 'Animal Health & Welfare'
89			Ruminant Nutrition	
90		Animal Health & Welfare	Animal Welfare	
91			Infectious Diseases & Viruses	
92			Agri-Food Economics & Consumer Behaviour	Incorporated into topic 'Agricultural Economics & Farm Surveys'
93			Chemical Food Safety	Incorporated into topic 'Food Processing Technology & Engineering'
94			Food Hygiene	
95			Food Microbiology	
96		Food Quality & Safety	Food Processing	
97			Food Function & Nutrition	Incorporated into topic 'Nutrition, Health & Diet-Related Disease'
98			Food Industry Sustainability	Incorporated into topic 'Food Industry Development'
99			Eating Quality	Incorporated into topic 'Food Quality & Sensory Science'

Table A.2: Short List of Agri-Food Research Themes and Topics

No.	Research Theme	Research Topics	Updates
1	Agriculture	Grass, Clover, Forage, Crops & Food Horticulture	Incorporated into topics 'Grassland Science', 'Crops & Agronomy', and 'Horticulture Development'
2	Animal	Animal Health & Welfare	
3	Animal	Animal Production & Bioscience	Renamed topic to 'Animal Production & Livestock Systems'
4	Animal	Fisheries & Aquatic Ecosystems	
5	Animal	Livestock Systems	Incorporated into topic 'Animal Production & Bioscience'
6	Animal	Pig Development	
7	Environment	Agri-Environment	
8	Environment	Biodiversity	Incorporated into topic 'Ecosystems'
9	Environment	Climate & Air	Renamed topic to 'Climate, Air & Water'
10	Environment	Ecosystems	
11	Environment	Environment, Soils & Land Use	Renamed topic to 'Soils, Land Use & Mixed Farming/Diversification'
12	Environment	Food Waste	Incorporated into topic 'Resources & Raw Materials'
13	Environment	Resources & Raw Materials	Renamed topic to 'Natural Resources & Raw Materials Efficiency'
14	Environment	Safe Water	Incorporated into topic 'Climate & Air'
15	Food	Food Biosciences	Incorporated into topic 'Food Product Development & Formulation'
16	Food	Food Chain Integrity & Safety	
17	Food	Food Industry Development	Incorporated into topic 'Food Product Development & Formulation'
18	Food	Food Processing Technology & Engineering	
19	Food	Food Product Development & Formulation	
20	Food	Food Provisioning Platforms	Removed: Out of scope
21	Food	Food Quality & Sensory Science	
22	Food	Functional Food, Nutrition, Health & Diet-Related Disease	
23	Plant	Crops & Agronomy	
24	Plant	Grassland Science	
25	Plant	Horticulture Development	
26	Plant	Plant Protein	New addition based on megatrends and market drivers
27	Rural Economy and Development	Agricultural Economics & Farm Surveys	Renamed theme to 'Sustainability'. Renamed topic to 'Agri-Food Economics & Consumer Behaviour'
28	Rural Economy and Development	Agri-Food Business & Spatial Analysis	Incorporated into 'Agri-Food Economics & Consumer Behaviour'
29	Rural Economy and Development	Farm Management & Rural Development Knowledge Transfer	Renamed theme to 'Sustainability'. Renamed topic to 'Farm Management and Rural Development'
30	Sustainability	Health & Wellbeing	
31	Sustainability	Natural Capital & Ecosystem Services Including Soils & Biodiversity	Incorporated into topic 'Ecosystems'
32	Sustainability	Resource Efficiency	Incorporated into topic 'Resources & Raw Materials'
33	Sustainability	Smart Agriculture	New addition based on disruptive technologies and digitisation

Table A.3: Final Taxonomy of Agri-Food Research Themes and Topics

No.	Research Theme	Research Topics
1	Animal	Animal Health & Welfare
2	Animal	Animal Production & Livestock Systems
3	Animal	Fisheries & Aquatic Ecosystems
4	Environment	Agri-Environment
5	Environment	Climate, Air & Water
6	Environment	Ecosystems
7	Environment	Natural Resources & Raw Materials Efficiency
8	Environment	Soils, Land Use & Mixed Farming/Diversification
9	Food	Food Chain Integrity & Safety
10	Food	Food Processing Technology & Engineering
11	Food	Food Product Development & Formulation
12	Food	Food Quality & Sensory Science
13	Food	Functional Food, Nutrition, Health & Diet-Related Disease
14	Plant	Crops & Agronomy
15	Plant	Grassland Science
16	Plant	Horticulture Development
17	Plant	Plant Protein
18	Sustainability	Agri-Food Economics & Consumer Behaviour
19	Sustainability	Farm Management & Rural Development
20	Sustainability	Health & Wellbeing
21	Sustainability	Smart Agriculture

Food   Animal   Plant   Environment   Sustainability

APC Microbiome Institute

The APC Microbiome Institute (APC) is a gastrointestinal health research centre exploring the role that gastrointestinal bacteria (microbiota) play in health and disease. The microbiota is a target for treatment and prevention of disease, and a source of functional food ingredients, new drugs, and disease biomarkers.

Research at the APC Microbiome Institute is relevant to many different industry sectors: food, pharma, biotechnology, infant nutrition, medical foods and veterinary. APC investigators are global research leaders in how the microbiome plays a crucial role in these areas. The APC has also developed a number of technology platforms that can be of significant benefit to industry clients in furthering their own R&D agenda, such as culture-to-product, pre-clinical models, next generation sequencing, bioIT, bioprocessing and human studies.

APC is very experienced in managing industry interactions and welcomes industry partners through a variety of flexible modalities. The benefits of partnership include the ability to undertake collaborative research with leading experts, access to our technology platforms and our extensive databases, and the reservoir of expertise held by APC investigators.

APC works closely with State agencies and can support clients in accessing appropriate State funding mechanisms.

TAXONOMY ALIGNMENT

- Food   ◉
- Animal   ○
- Plant   ○
- Environment ○
- Sustainability ●

BUDGET

€80 over 6 years

RESEARCH AREAS

- Microbes to Molecules
- Diet and Microbes at the Extremes of Life
- Brain-Gut-Microbiota Axis
- Host-Microbe Dialogue

RPO PARTNERS

- **University College Cork (Host)**
- Teagasc
- Cork Institute of Technology
- NUI Galway
- University College Dublin
- University of Limerick
- NIBIRT

INDUSTRY PARTNERS

- AbbVie
- Adare Pharma
- Alimentary Health
- Cremo SA
- Danone

- DuPont
- Janssen Pharmaceuticals
- Kerry Group
- Mead Johnson Nutrition

- Nutricia
- Second Genome
- Sigmoid Pharma
- Trino Therapeutics4D Pharma

Food · Animal · Plant · Environment · Sustainability

BiOrbic

BiOrbic is Ireland's national bioeconomy research centre, established to promote and develop Ireland's bioeconomy through excellent research and innovation

The modern world is dependent upon fossil resources to produce everyday items that we consume. Since these resources are finite and depleting, it is essential to develop alternative technologies based on renewable biological resources. The future economy must use biological resources sustainably to produce valuable goods, such as bioactive molecules, chemical building blocks, plastics, fuels, and energy. This future economic activity is referred to as the bioeconomy. In Ireland, the agri-food and marine sectors produce high volumes of residues during food production. The conversion of these residues to higher value products will create new business opportunities. New value chains will allow these industries to diversify and add value to the sector, increase resource efficiency and complementing food production activities. 80% of agri-food companies are in rural Ireland; thus, the bioeconomy will be a key driver to stimulate rural and agricultural redevelopment. BiOrbic addresses multiple scientific, technological, and social challenges to convert this vision into reality.

TAXONOMY ALIGNMENT

- Food ◯
- Animal ◯
- Plant ◯
- Environment ●
- Sustainability ◉

BUDGET

€18m over 6 years

RESEARCH AREAS

- Bioeconomy
- Agri-Food
- Marine
- Advanced Materials
- Renewable biological resources Biotechnology/Biologics
- Resilient and Resource-Efficient Value Chains
- Rural Renaissance

RPO PARTNERS

- **University College Dublin (Host)**
- Trinity College Dublin
- University of Limerick
- NUI Galway
- Teagasc

INDUSTRY PARTNERS

- BHSL
- Commercial Mushroom Producers
- Glanbia
- Nutramara
- Nucleus VP Energy
- Monaghan Mushrooms Ltd.

NuritasCarbery

Food   Animal   Plant   Environment   Sustainability

Dairy Processing Technology Centre (DPTC)

The Dairy Processing Technology Centre (DPTC) is an industry–academic collaborative research centre, hosted by the University of Limerick, with a research agenda driven by the long-term growth opportunities for the dairy sector created by the removal of milk quotas in 2015.

DPTC has been established as a centre of excellence for dairy processing research and innovation. The Centre will help to fuel growth in the Irish dairy sector by performing research focused on cost-efficient processing, facilitating a step-change in environmental sustainability and creating, validating and commercialising a pipeline of science and technology-based manufacturing platforms for dairy ingredients.

The foundation of the DPTC is a strong, long-term industry–academic collaborative partnership that will develop, build and translate the knowledge and capabilities in dairy processing that are needed today and for the long-term growth development of the sector.

TAXONOMY ALIGNMENT

- Food ●
- Animal ◉
- Plant ○
- Environment ○
- Sustainability ○

RESEARCH AREAS

- Efficiencies – cost competitiveness in dairy processing
- Process development – next generation dairy processing science and technology
- Product innovation – innovating for value through dairy processing
- Quality and safety – product quality and safety by design
- Energy and environment – Environmental sustainability towards a zero emissions Irish dairy industry

INDUSTRY PARTNERS

- Arrabawn
- Aurivo
- Carbery
- Dairygold
- Glanbia
- Kerry
- Lakeland Dairies
- Tipperary COOP

RPO PARTNERS

- University of Limerick (Host)
- Teagasc
- University College Cork
- University College Dublin
- NUI Galway
- Dublin City University
- Trinity College Dublin
- Technology University Dublin

TAXONOMY ALIGNMENT

- Food ●
- Animal ◉
- Plant ○
- Environment ○
- Sustainability ○

BUDGET

€21.6m over 5 years

RESEARCH AREAS

- Healthy Cheese
- Irish Grass-fed Dairy
- Fermented Dairy Ingredients
- Science to Market

RPO PARTNERS

- **University College Dublin (Host)**
- Teagasc
- University of Limerick
- University College Cork
- Dublin City University
- Trinity College Dublin

Food for Health Ireland (FHI)

Food for Health Ireland (FHI) unites world-class science and industry expertise to improve health through innovation in food. Its purpose is to identify novel ingredients coming from milk to develop functional food ingredients that will offer health benefits to consumers.

FHI links world-class academic research with industry vision for the potential of successful market innovations. The industry-focused research strategy within FHI includes the identification, development and exploitation of novel milk-derived bioactive compounds for improving health and wellbeing. FHI also provides a pipeline for the development of new functional food ingredients and products with validated health benefits for consumers.

The FHI approach is to work with Irish food industry partners and in close connection with scientists. FHI has built a unique bridge between high-class research organisations and industry needs.

FHI also provides a contract research facility for small and large global food companies utilising our competencies, resources and technologies. This service provides a gateway to academic research in Ireland and supports open innovation. FHI has completed over 60 projects of this kind since 2008.

INDUSTRY PARTNERS

- Carbery
- Kerry
- Dairygold
- Glanbia
- Bord Bia
- National Dairy Council

MaREI

TAXONOMY ALIGNMENT

- Food ●
- Animal ◉
- Plant ○
- Environment ○
- Sustainability ○

RESEARCH AREAS

- Offshore Renewable Energy
- Materials & Structures
- Observations and Operations
- Coastal Marine Systems
- Adv. Fuels in the Circular Economy
- Energy Policy & Modelling
- Energy Management

RPO PARTNERS

- **University College Cork (Host)**
- University of Limerick
- NUI Galway
- Maynooth University
- University College Dublin
- Dublin City University
- Cork Institute of Technology
- Trinity College Dublin
- Dundalk Institute of Technology
- Technology University Dublin
- Dublin Institute for Advanced Studies
- Tyndall National Institute
- Economic and Social Research Institute

MaREI

MaREI undertakes research related to the energy transition, climate action, and blue economy and uses this research to empowers business, shift policy and support society. MaREI helps small energy and marine companies to develop thereby harnessing the economic opportunities of the low carbon energy transition. MaREI research increasingly underpins energy and climate policies of the Irish Government and the European Union. Through engaged research and dialogue with communities, MaREI also supports the human and societal dimensions of climate action and marine conservation.

MaREI is the SFI Research Centre for Energy, Climate and Marine research and innovation, coordinated by the Environmental Research Institute (ERI) at University College Cork. The Centre comprises over 200 researchers working with over 50 industry partners, focusing on defined global challenges such as the Energy Transition, Climate Action and the Blue Economy. MaREI delivers excellent research with societal impact by supporting business, informing policy and empowering society, resulting in the development of a dynamic research ecosystem that is responsive to the needs of all its stakeholders. As a driver of collaboration, our researchers engage with stakeholders across more than 36 countries, and have a proven track record of academic excellence.

INDUSTRY PARTNERS

- Aer Lingus
- Analog Devices International
- ARUP Ireland Trust
- Automsoft International
- B9 Power
- BriToinne
- Bureau Veritas
- CAPACITÉS
- Commissioners of Irish Lights
- DePuy Synthes
- DP Energy Ireland
- ÉireComposites
- Enervo Energy
- Ervia
- ESB
- ESRI Ireland
- Gas Networks Ireland
- GKinetic Energy
- GRSI Energy
- Henkel Ireland
- IDS Monitoring
- Irish Aviation Authority
- Johns Manville
- KOSMOS Energy Ireland
- MAFIC Black Basalt
- Marine Harvest Ireland
- MYMIC
- National Space Centre
- NTR Foundation
- Open Ocean Energy
- Open Hydro
- Pure Marine Gen
- Qualitas Instruments
- Resilience Energy
- Resolve Marine
- RPS
- RSK Ireland
- Shannon Foynes Port Company
- Shell E&P Ireland
- SkySails
- SonarSim
- Technology From Ideas
- Techworks Marine
- Teledyne BlueView
- Teledyne RESON
- WECCA

Meat Technology Ireland (MTI)

Meat Technology Ireland is an industry-led initiative that will build a strategic research and innovation base in beef and sheepmeat processing in Ireland. The Centre will be a 'one-stop shop' for meat processing research and technology, serving as a hub to co-ordinate all beef and sheepmeat processing research needs.

Meat Technology Ireland is an €8.1 million five-year research and innovation programme, developed by industry and co-funded by Enterprise Ireland and a consortium of nine beef and sheepmeat processing companies. MTI is hosted by Teagasc at its Ashtown Food Research Facility in Dublin with TU Dublin, Dublin City University, University College Cork and the Irish Cattle Breeders Federation involved as research providers. The companies behind the initiative are ABP Ireland, Ashbourne Meat Processors, Dawn Meats Group, Dunbia (Ireland), Hilton Foods Ireland, Irish Country Meats, Kepak Group, Liffey Meats, and Slaney Foods International.

The programme is delivered through 6 strategic research pillars which have been defined by the commercial requirements of the MTI member companies.

TAXONOMY ALIGNMENT

- Food ◉
- Animal ●
- Plant ○
- Environment ○
- Sustainability ○

BUDGET

€8.1m over 5 years

RESEARCH AREAS

- Genomic predictions
- Meat tenderness management
- Meat safety and shelf life extension
- Meat characterisation technologies
- Meat and health
- Future market opportunities

RPO PARTNERS

- **Teagasc (Host)**
- Technological University Dublin
- University College Cork
- Dublin City University
- Irish Cattle Breeders Federation

INDUSTRY PARTNERS

- ABP Ireland
- Ashbourne Meat Processors
- Dawn Meats Group
- Dunbia (Ireland)
- Hilton Foods Ireland
- Irish Country Meats
- Kepak Group
- Liffey Meats
- Slaney Foods International.

Food   Animal   Plant   Environment   Sustainability

VistaMilk

The VistaMilk SFI Research Centre represents a unique collaboration between Agri-Food and information communications technology (ICT) research institutes and leading Irish/multinational food and ICT companies. Funded by Science Foundation Ireland (SFI) and the Department of Agriculture Food and the Marine (DAFM)

TAXONOMY ALIGNMENT

- Food ◉
- Animal ○
- Plant ○
- Environment ○
- Sustainability ●

BUDGET

€40m over 6 years

RESEARCH AREAS

- Agri-Food
- Human health, Animal welfare & Environmental sustainability
- High granularity, real-time sensing technologies in the Agri-Food domain
- Integrated communication technologies
- Advanced multi-level analytics
- Value-creating decision support tools

RPO PARTNERS

- Teagasc (Host)
- Dublin City University
- NUI Galway
- Telecommunications Software and Systems Group (TSSG)/Waterford Institute of Technology
- Tyndall National Institute
- University College Dublin

The centre is hosted by Teagasc, in partnership with the Tyndall National Institute, Ireland's national microelectronics institute, the Telecommunications Software & Systems Group (TSSG) at Waterford Institute of Technology, the Insight Centre for Data Analytics, and the Irish Cattle Breeding Federation (ICBF).

The centre will facilitate the development and deployment of new knowledge, new technologies and new decision support tools to maximise the efficiency and effectiveness of the entire dairy production chain. Sustainability, food security, prosperity and societal enrichment are core strategic goals for the centre, in alignment with the UN Sustainable Development Goals.

The research programme will develop new, and advance existing electronic monitoring and actuation technologies to transform an already world-class dairy sector into a global leader in sustainable Agri-Tech. It will specifically address pasture-based dairy production, improved processability and the generation of novel, higher-value-added products. In addition to the creation of new sensing and actuation paradigms, particular focus will be given to developing state-of-the-art analytical techniques applied to large scale, sensor datasets delivered by advanced network and communication technologies.

CENTRE/TAXONOMY ANALYSIS

Centre	Type	Food	Animal	Plant	Environment	Sustainability
APC Microbiome Institute	SFI Research Centre	◉	○	○	○	●
BiOrbic	SFI Research Centre	○	○	○	●	◉
Dairy Processing Technology Centre (DPTC)	Enterprise Ireland Tech. Centre	●	◉	○	◉	○
Food for Health Ireland	Enterprise Ireland Tech. Centre	●	◉	○	○	○
MaREI	SFI Research Centre	○	◉	○	●	○
Meat Technology Ireland (MTI)	Enterprise Ireland Tech. Centre	◉	●	○	○	○
VistaMilk	SFI Research Centre	◉	○	○	○	●

C. List of National and EU Strategies and Policies

There are a wide range of national and EU strategies, policy documents, targets and plans relevant to the Agri-Food sector, including[75]:

- Harnessing Our Ocean Wealth: An Integrated Marine Plan for Ireland (2012)
- EU Forest Strategy: For forests and the forest-based sector (2013)
- The Common Agricultural Policy 2014-2020
- The Common Fisheries Policy 2015-2020
- UN Sustainable Development Goals (2015)
- National Strategic Plan for Sustainable Aquaculture Development (2015)
- Food Wise 2025 (2015)
- Going for Growth: A Strategic Action Plan in Support of the Northern Ireland Agri-Food Industry (2015)
- Closing the Loop - An EU Action Plan for the Circular Economy (2015)
- Sustainable Healthy Agri-Food Research Plan (2015)
- Delivering Our Future, Valuing Our Soils: A Sustainable Agricultural Land Management Strategy for Northern Ireland (2016)
- Agricultural Research and Development Scheme (Northern Ireland) 2016-2020 (2016)
- Teagasc Technology Foresight Report 2035 (2016)
- Forest Research Ireland - A Strategic Agenda for Forest Research in Ireland (2016)
- UN Climate Change – Paris Agreement (2016)
- National Farmed Animal Health Strategy 2017-2022 (2017)
- National Biodiversity Action Plan 2017-2021 (2017)
- Ireland's National Action Plan on Antimicrobial Resistance 2017-2020 (2017)
- Report on the Blue Growth Strategy – Towards more sustainable growth and jobs in the blue economy (2017)
- National Mitigation Plan (2017)
- FOOD 2030 - Recipe for Change (2018)
- Realising Our Rural Potential: Action Plan for Rural Development (2018)
- Research Priority Areas 2018 to 2023 (2018)
- National Raised Bog Special Areas of Conservation (SACs) Management Plan 2017-2022 (2018)
- National Adaptation Framework: Planning for a Climate Resilient Ireland (2018)
- National Policy Statement on the Bioeconomy (2018)
- Animal Health Ireland Strategic Plan 2018-2020 (2018)
- EU Bioeconomy Strategy (2018)
- Climate Action Plan (2019)
- Healthy Ireland Framework 2019-2025 (2019)
- Changing the Culture 2019-2024: One Health Tackling Antimicrobial Resistance in Northern Ireland (2019)
- Strategy for the Development of the Organic Sector 2019-2025 (2019)
- Code of Good Agricultural Practice for reducing Ammonia Emissions from Agriculture (2019)
- Northern Ireland's Climate Change Adaptation Programme 2019-2024 (2019)
- Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan (2019)
- Biodiversity Climate Change Sectoral Adaptation Plan (2019)
- Ag Climatise: A Roadmap towards Climate Neutrality (2020)
- Climate Action Amendment Bill 2020 (2020)

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[75] This is a comprehensive, but not exhaustive, list of national and EU strategies and policy documents relevant to Agri-Food.

- Strategic Environmental Assessment (SEA) Scoping Report: Agri-Food Strategy to 2030 (2020)
- EPA Air Quality Report (2020)
- Towards A Resource Efficient Ireland (2020)
- Crops 2030: A Strategic Plan to deliver environmental and economic sustainability for the Irish Crops Sector (2020)
- State of the Environment Report 2020 (2020)
- A New Circular Economy Action Plan (2020)
- The EU Blue Economy Report (2020)
- EU Biodiversity 2030 Strategy (2020)
- EU Farm to Fork Strategy (2020)
- Food Vision 2030: A world leader in sustainable food systems (2021)
- Future Agricultural Policy Framework Portfolio for Northern Ireland (2021)
- Climate Action Plan 2021: Securing Our Future (2021)