A methodological review of UK food ecolabels

Final report

4 December 2024

Agriculture and Environment Research Unit (AERU)
School of Life and Medical sciences
University of Hertfordshire
United Kingdom

CLEAR

University of Hertfordshire

Report information

Title:	A methodological review of UK food ecolabels
Subtitle:	Final report
Date:	4 December 2024
Report to:	Consortium for Labelling for the Environment, Animal welfare, and Regenerative farming (CLEAR)
Written by:	Agriculture and Environment Research Unit School of Life and Medical Sciences, University of Hertfordshire, UK.
Website:	https://sitem.herts.ac.uk/aeru/
Status:	FINAL (Embargoed copy: till March 2025)
Please cite as:	Tzilivakis, J., Taylor, J.L., Green, A., Warner, D.J and Lewis, K.A. (2024) *A methodological review of UK food ecolabels. Final report.* Prepared for the Consortium for Labelling for the Environment, Animal welfare, and Regenerative farming (CLEAR) by the Agriculture and Environment Research Unit (AERU), University of Hertfordshire, United Kingdom.
Acknowledgements:	Thank you to the steering committee members: Lisa Norton (Chair), Agroecologist & Senior Scientist, Centre for Ecology and Hydrology (CEH); Adam Thompson, Advisor & Investor, Wildfarmed; Catherine Chong, Engagement Lead, The Consortium for Labelling for the Environment, Animal Welfare and Regenerative Farming (CLEAR); Dana Wilson, Senior Policy Officer, Farm Animal Investment Risk & Return (FAIRR); Ed Ayton, Sustainability & Communications Officer, Abel & Cole; Jake White, Head of Legal, World Wide Fund for Nature (WWF); Joanna Trewern, Independent Sustainable Food Specialist; Laurence Smith, Lecturer in Agricultural Business Management, University of Reading; Natalia Nicholls, Eco-Labelling Team Leader, Food Data Transparency Partnership, Department for Environment, Food & Rural Affairs (Defra); Lucas Daglish, Sustainability Manager, British Meat Processors Association; Niamh Noone, Senior Marketing Manager, Soil Association; Richard Osborn, Chief Executive, Equilibrium Markets; and William Selbourne, Farmer, Blackmoor Estate.
Photo (front cover):	Courtesy of Dr John Tzilivakis

Contents

List of Tables

List of Figures

Glossary

Acronym	Description
25-YEP	UK 25 Year Environment Plan (HMG, 2018 & 2023)
ADEME	Agence de l'Environnement et de la Maîtrise de l'Énergie. French Agency for Ecological Transition
AERU	Agriculture and Environment Research Unit (at UH)
AGW	A Greener World
AI	Artificial Intelligence
AONB	Areas of Outstanding Natural Beauty
Background system	A term used in LCA when defining system boundaries to refer to processes which the producer has little or no direct control over (e.g. consumed materials, energy carriers, services, etc.), usually drawing upon secondary data
BOD	Biochemical Oxygen Demand
C	Carbon
CBD	Convention of Biological Diversity
CEF	Characterisation and Evaluation Framework
CH_4	Methane
CLEAR	Consortium for Labelling for the Environment, Animal welfare, and Regenerative farming
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
Defra	Department for Environment, Food & Rural Affairs
Endpoint	Used in reference to the end outcome of an environmental impact (e.g. GHG emissions and climate change are midpoints whilst the health effects on humans and wildlife species are endpoints).
Environmental impact metric or indicator	A measurement that is used to assess environmental impacts. These might be direct measurements, indirect or surrogate measurements, or outputs from models (e.g. that use data on activities to calculate impacts). They can include measures of environmental effects (midpoints) and/or environmental outcomes (endpoints).
EPD	Environmental Product Declaration
ES	Eco-Score
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FDTP	Defra's Food Data Transparency Partnership
FE	Foundation Earth
FS	Foodsteps
Foreground system	A term used in LCA when defining system boundaries to refer to processes which the producer has direct control over, and for which specific primary data should be gathered
FtN	Fair to Nature
GBF	Global Biodiversity Framework
GHG	Greenhouse gas
GWP	Global Warming Potential
IFM	Integrated Farm Management
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management

Acronym	Description
ITAB	French Organic Food and Farming Institute
IGD	Institute of Grocery Distribution
K	Potassium
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LEAF	Linking Environment And Farming
Midpoint	Used in reference to a middle or intermediate environmental effect (e.g. GHG emissions and climate change are midpoints whilst the health effects on humans and wildlife species are endpoints).
N	Nitrogen
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NH_3	Ammonia
NO_3^-	Nitrate
P	Phosphorus
PEF	EU Product Environmental Footprint
PES	Payments for Ecosystem Services
PfL	Pasture for Life
PO_4^{3-}	Phosphate
PS	Planet-Score
RAG	Red, Amber and Green colour categorisation, sometimes referred to as a traffic light system
RSPB	Royal Society for the Protection of Birds
RSPCA	Royal Society for the Prevention of Cruelty to Animals
RUSLE	Revised Universal Soil Loss Equation
SA	Soil Association
Scope 1 emissions	Direct emissions, usually associated with GHG reporting. Covers emissions from sources that an organisation owns or controls directly, e.g. from burning fuel fleet vehicles
Scope 2 emissions	Indirect energy emissions, usually associated with GHG reporting. Covers emissions that a company causes indirectly and come from where the energy it purchases and uses is produced, e.g. the emissions caused when generating the electricity used in buildings
Scope 3 emissions	Other indirect emissions, usually associated with GHG reporting. Covers emissions that are not produced by the company itself and are not the result of activities from assets owned or controlled by them, but by those that it is indirectly responsible for up and down its value chain, e.g. when buying, using and disposing of products from suppliers. Scope 3 emissions include all sources not within the Scope 1 and 2.
SOM	Soil Organic Matter
UH	University of Hertfordshire
UV-B	Ultraviolet-B radiation
VOCs	Volatile Organic Compounds
WFLDB	World Food LCA Database
WRAP	Waste and Resources Action Programme

Executive summary

Introduction

The environmental impacts of agriculture have been the focus of considerable public concern for several decades, with the climate and biodiversity crises being at the forefront. Hence there has been an increasing demand for food production systems to transition to an approach based on agroecology and demonstrate that multiple environmental and socio-economic objectives are being met. The pressures and drivers of change within food systems are multiple, complex and connected, and includes the personal values and preferences of food producers, government policies and initiatives, and market demands from retailers and consumers. With respect to the latter, environmental labelling (ecolabelling) has a potential role in influencing the evolution towards sustainable food production. They include simple green claims on packaging with no verification; assurance labels where production standards are required; and those which attempt to quantify environmental impacts and outcomes. Therefore, labelling schemes potentially impact production practices directly (through required production standards) or indirectly via increased retailer and/or consumer demand for products with green credentials. A common methodology for ecolabelling of food is yet to emerge, so the methods, techniques and sources of data that underpin different ecolabels are variable. Hence, there is a need to investigate the approaches and data being used to understand their relative strengths and weaknesses within the context of a transition to sustainable production.

Pressures and drivers of change within food production systems are multiple, complex and connected

This report is a methodological review of food ecolabels that are currently operating or are expected to operate in the UK. It does not aim to explore the effectiveness of ecolabels as tool for changing consumer or business purchasing behaviour, but rather that if ecolabels have the potential to have any impact in this respect, to what extent do their methodologies provide a true and fair view of environmental impacts and the implications for a transition to agroecology; food sovereignty; and meeting national environmental targets. This could help identify any potential synergies and conflicts between different approaches to ecolabelling and other initiatives, such as policies, agri-environment schemes, etc., that also aim to facilitate a transition to sustainable food production.

A methodological review of food ecolabels

Identify any potential synergies and conflicts between different approaches

Ten ecolabelling schemes that are relevant to the UK were selected and placed into two groups: (1) product-based; and (2) farm assurance-based. Each scheme was systematically reviewed, characterised and evaluated using a framework that encompassed true and fair principles including avoidance of bias; consistency; pragmatism; recognition of subjective elements; faithful representation of environmental impacts; and transparency. Information and data were collated for each scheme from publicly available sources and included a general description; environmental impact coverage; data sources, data quality and verification (incl. the use of primary and secondary data); impact communication; and transparency. With respect to environmental impact coverage, a bespoke classification was developed and applied that encompasses Life Cycle Assessment (LCA) impact categories, ecosystem services and planetary boundaries, to provide a classification that is both holistic and independent from any particular scheme.

Two types of scheme:
(1) Product-based
(2) Farm assurance-based

The findings of the review, within the context of providing a true and fair view of environmental impacts; the transition to agroecology; food sovereignty; and

meeting national environmental targets, are summarised below across five topics: (i) aims and objectives of the schemes; (ii) environmental impact coverage; (iii) impact communication; (iv) fit for purpose; and (v) further research and development, with associated key messages and conclusions shown on the right.

Aims and objectives of the schemes

It is important to acknowledge that the schemes differ in their aims and objectives, both between and within the two groups of schemes examined. Product-based schemes are consumer-focused with the aim of helping them make more sustainable choices, and three of the schemes also focus on food businesses as part of their drive is to impact the wider food industry. The product-based schemes also differ slightly in their environmental focus reflecting a sector where climate change is often the single focus, but increasingly additional environmental impacts are being utilised. Farm assurance-based schemes are largely farmer-focused. The driver is that the schemes will enable and support changes in farming practice to those which have more positive environmental impacts. There are differences in focus amongst the farm assurance-based schemes including integrated, regenerative and organic production; and biodiversity.

Product-based schemes are consumer-focused

Farm assurance-based schemes are farmer-focused

There is a clear difference between the product-based and farm assurance-based schemes with respect to governance (incl. accountability and transparency) in that they are 'top-down' and 'bottom-up' respectively. Product-based schemes have largely been driven by the priorities and motivations of those developing food products. Whereas farm assurance-based schemes have largely been driven by the priorities and motivations of primary producers, which has resonance with respect to the principles of food sovereignty, i.e. greater empowerment of farmers within the food system.

Governance of the two types of schemes is top-down and bottom-up respectively

Taking a wider perspective, it is important to understand how ecolabelling could contribute to the development of sustainable food production systems, i.e. those that are viable in the long-term with respect to the environmental and socio-economic outcomes that society desires. For example, do ecolabel methodologies only report potential impacts of food or do they also support the adoption of agroecological practices. This is an inherently complex topic, much of which is beyond the scope of this review, however some elements are explored below with respect to the coverage of environmental impacts by the schemes, their interpretation and communication, and whether the schemes are 'fit for purpose'.

How could ecolabelling contribute to the development of sustainable food production systems?

Environmental impact coverage

With respect to product-based schemes, the omission of biosphere related impacts, such as biodiversity; and poor accounting of site-specific impacts, including air, soil and water quality, soil provision and water flow regulation, which are all critical for agroecology (and more so with climate change), are notable omissions. Some schemes acknowledge these omissions, while others only focus on the impacts they do cover. There is also a tendency for reliance on secondary and/or modelled data rather than primary data from farmers and food producers. Advances are being made in developing databases, but concerns remain with respect to how well they reflect variability within different production systems and practices; transparency; and whether a product-oriented perspective creates issues for data governance and control within the context of food sovereignty.

Product-based schemes omit biosphere related impacts & poorly account for site-specific impacts

With respect to the farm assurance-based schemes, these potentially cover a wider range of environmental impacts, especially those relating to the biosphere. They are based on primary farm data and account for local conditions and circumstances that can greatly influence environmental effects and impacts. However, certification is based on practices adopted and not achieved environmental outcomes. Thus, the delivery of environmental benefits is unverified and their contribution to national environmental targets uncertain.

Farm assurance schemes cover a wider range of impacts but are based on practices adopted not achieved environmental outcomes

The use of primary data is desirable with respect to providing a true, fair and reliable picture where at the very least primary data for food production activities should be used to feed into models to derive secondary data on environmental impacts. However, taking a product-based perspective often demands data for thousands of activities and processes which leads to many activities and processes in the food system being considered part of the background system, for which databases of secondary data are considered adequate. However, such data should not be used for problem- and case-specific foreground data. Thus, the use of secondary and/or modelled data for key life cycle stages in food production, such as pre-farmgate, is a significant issue with respect to providing a true, fair and reliable picture, especially with respect to accounting for the impact of different methods of production, including many agroecological practices designed to address problem- and case-specific issues. It is beyond the scope of this review to determine all the uncertainties this introduces into the picture, but there is potential for them to be significant.

Use of secondary and/or modelled data is a significant issue for accounting for different methods of production

Some of the product-based schemes are seeking to utilise more primary data and some have attempted to extend the scope of the impacts covered with novel metrics. Similarly, there is a desire amongst the farm assurance-based schemes to gather evidence to verify environmental outcomes. In both instances, progress has been limited, however further development and innovation should be encouraged. Technologies and scientific understanding are rapidly evolving, for example in direct measurement of emissions and remote sensing, alongside methods for handling data to develop advances to facilitate a true and fair view of environmental impacts. Additionally, the collection of more primary data can feed into improvements to secondary data sources. Taking a wider perspective, environmental data is often collected for more than one purpose. There are many other uses, such as demonstrating the delivery of ecosystem services, or trading schemes for carbon, nutrients and biodiversity. A consistent picture of environmental impacts needs to be presented across all these use cases, including ecolabels. Any inconsistences or contradictions due to different perspectives, metrics or data could damage the credibility of all the schemes concerned and thus the perception of their reliability, which could be counterproductive with respect to achieving progress towards environmental targets.

Science, technologies & data on environmental impacts are rapidly evolving

A consistent picture of environmental impacts needs to be presented

Impact communication

A common challenge for all ecolabels is communication; how to convey environmental benefits and burdens within the confines of a label. As outlined above, it was beyond the scope of this review to explore the psychology of behaviour change amongst different businesses and consumers. Thus, communication has not been explored from this perspective, but more from a factual perspective, i.e. what should be communicated to consumers to present a fact-based picture of the environmental impacts arising or relating to how the

food was produced. The two key challenges for product-based schemes are placing impacts in context (normalisation) and how to communicate multiple impacts.

Placing impacts in context and communicating multiple impacts are key challenges

With respect to normalisation, some schemes attempt to utilise the planetary boundaries concept, which has the most resonance for agroecology, but this is problematic as boundaries have not been defined for all impacts. Other schemes benchmark the impact of a product against others, but this only places it within the context of the population of products, thus has little bearing on sustainability.

With respect to handling multiple impacts, the product-based schemes tend to adopt an approach of aggregating the outputs from all the impact metrics in a single score or rating. This is problematic in terms of potentially hiding detail, which is exacerbated by the omissions outlined above, and conveying impacts relative to benchmarks such as planetary boundaries. Additionally, when LCA is applied in other contexts, aggregation is not usually undertaken due to its problematic nature. Aggregating the data to aid communication to consumers can result in something that is meaningless, which does not align with a true and fair picture.

Aggregating the data to aid communication to consumers can result in something that is meaningless

With respect to the farm assurance-based schemes, communication centres around the adoption of good practices and their associated environmental benefits. In some instances, monitoring of environmental effects and outcomes is encouraged as part of good practice, but it does not form the basis of certification, thus there is no verification of any outcomes that are delivered.

Certification is not based on verified environmental impacts

Fit for purpose

A fundamental issue is whether the ecolabelling schemes, and their associated methods and processes, are 'fit for purpose' with respect to facilitating a transition to agroecology; ensuring food sovereignty; and meeting national environmental targets. Different approaches are giving rise to a 'perspective disparity' driven by different data demands and purposes, due to different stakeholders and motivations, which conflict with respect to understanding what is fit for purpose for food ecolabelling and food sovereignty. This is clearly manifested when considering system boundaries and where primary and secondary data are utilised. In a product-oriented perspective, pre-farmgate emissions and impacts, which are usually the largest for food products, are categorised as part of the background system and/or as Scope 3 emissions, i.e. they are outside the direct control of the assessed entity for which secondary data is often assessed to be adequate. However, from a farm-oriented perspective, pre-farmgate emissions and impacts are considered part of the foreground system, and/or as Scope 1 emissions, for which primary data should be sought and used. In the context of the transition to agroecology, changes in practices on farms are required that deliver environmental outcomes. If ecolabelling is to be used as a tool to support this transition, alongside other initiatives and schemes, then it must respond to changes at the farm level and farmers should have the power and tools to govern and control this data to enhance food sovereignty. Thus, a product-oriented approach is potentially flawed with respect to providing an ecolabelling scheme fit for this purpose, unless the approach can be adapted to utilise more primary data from farms, and in so doing enable more equitable governance.

Different approaches are giving rise to a 'perspective disparity'

Ecolabelling must respond to changes at the farm level to support the transition to agroecology

Agricultural production systems need to adopt practices that have a lower environmental footprint and transition to a system based on agroecological principles. The drivers for this transition are complex and include scientific understanding, social, cultural and personal values, government regulation, environmental pressures, and market forces. Ecolabelling as a tool overlaps with many of these as a mechanism to communicate impacts. The picture that is communicated must be a true and fair view of the environmental impact of food. If it is not, then it risks skewing the picture, creating perverse incentives or trade-offs with other issues, and driving the system in the wrong direction. Businesses demand efficient and economic solutions, and hence why standardised methods and databases of impacts are appealing, but this must not be pursued at the expense of creating a true and fair picture of the environmental impacts of food production. There is a risk of externalising important impacts, such as biodiversity, in pursuit of a standardised and/or simplified approach to ecolabelling, which could be counterproductive with respect to its aims. The complexity needs to be embraced to truly resolve the challenges society faces.

Externalising impacts in pursuit of a standardised or simplified approach could be counterproductive

The scope of the environmental impacts needs to be extended for all schemes, but especially for the product-based schemes. Issues such as wildlife species populations and biodiversity cannot be overlooked simply because they are difficult to measure in a standardised way. The need for more outcome-based metrics, to demonstrate progress towards environmental targets desired by society was a finding over a decade ago and this need remains. The practices adopted on farms to improve environmental performance must deliver that performance, and this can only be determined by measuring the outcomes. Additionally, many impacts are site-specific, so the demand for metrics that capture this detail persists. Product-based and farm assurance-based schemes can have a positive role despite the weaknesses outlined in this study. In many respects, they have opposite attributes. Product-based schemes use more outcome metrics, but with significant omissions; a lack of accounting for site-specific factors; and largely using secondary and/or modelled data. Whereas farm assurance-based schemes have greater coverage of environmental impacts; account for site-specific factors; and use primary data, but rely on practice-based metrics. Thus, neither approach is currently providing a comprehensive ecolabelling solution that provides a true and fair view of environmental impacts, supports the transition to agroecology, and supports meeting national targets.

Practices to improve environmental performance must demonstrate delivery by measuring the outcomes

A comprehensive ecolabelling solution is lacking

There is a push by many organisations to develop a more unified approach to ecolabelling, but this is largely from product-based perspectives and motivations. There appears to be an assumption that a product-based approach is the only solution which is possibly driven by the EU Unfair Commercial Practices Directive and the Product Environmental Footprint (PEF) approach. This could be interpreted as accepted practice, rather than establishing what is acceptable to provide a true and fair view of the environmental impact of a food product. There is also a risk that a product-based approach becomes interpreted as synonymous with outcome-based metrics, which is potentially misleading, more so if farm assurance-based schemes continue to encourage the measurement of environmental outcomes on farms. Many product-based schemes also utilise LCA as a methodological framework for environmental impact assessment, but as outlined above, key environmental impacts are omitted from LCA due to a lack of standardised metrics. Metrics for other environmental outcomes do exist, and the technology for measuring and handling the data are evolving at a rapid pace, so

The opportunity to gather primary data on environmental outcomes should be exploited

the opportunity to gather primary data on environmental outcomes in the future should be exploited, rather than relying on secondary and/or modelled data. The transition to sustainable production and consumption systems will rely on having the most accurate and reliable picture of the environmental impacts of food, which in turn will facilitate the adoption of agroecological practices that deliver the outcomes desired. This needs to be coupled with appropriate governance to ensure primary producers are empowered and incentivised to engage with this transition, ranging from those just embarking on this journey to those regarded as advocates. Food production systems are socio-ecological; hence this must be an integral part in any ecolabelling scheme.

The transition to sustainable production needs the most reliable picture of the environmental impacts of food

Further research and development

There is scope for further research and development on ecolabelling with respect to providing a true and fair view of the environmental impacts and more effectively supporting the transition to agroecology, food sovereignty and meeting national environmental targets. This includes identifying novel environmental impact metrics to plug gaps in coverage; seeking practical options for measuring environmental outcomes on farms; exploring new technologies to generate data; exploring the utilisation of data collected within assurance schemes to improve data in other supply chain initiatives; enhanced systems for data governance and control to improve food sovereignty; exploring benchmarks or targets for all metrics within the context of what needs to be achieved for the transition to agroecology; exploring alternative approaches to aggregation that do not hide important detail and/or avoid the issue of burden shift; and explore the viability of multi-component (environmental profile) labels. This work needs to be undertaken by ecolabel developers and practitioners, be that industry; government, regulators, academic institutions, or third sector organisations, in a collaborative fashion to ensure a harmonised solution emerges.

Scope for further R&D on environmental metrics; data generation, handling & governance; benchmarks & impact communication

Collaboration between ecolabel practitioners is needed to ensure a harmonised solution emerges

Drawing upon the ideas above, there is an opportunity to explore hybrid approaches across the schemes. This could be a combination of a farm assurance-based approach to encourage the adoption of best practices and utilisation of its primary farmgate data to feed into a product-based approach to support the quantification of outcome-based metrics; thus providing an improved basis to confirm whether the practices are delivering the environmental outcomes society demands. This could result in a picture of the environmental impacts of food that is true and fair, which supports the transition to agroecology and meeting national environmental targets, and, if coupled with enhanced systems for data governance and control, has the potential to improve food sovereignty by improving the connections between producers and consumers.

There is an opportunity to explore hybrid approaches across the schemes

1 Introduction

1.1 Background and rationale

The environmental impacts of agriculture have been the focus of considerable public concern for several decades. They include the pollution of surface and ground waters from the use of fertilisers (Skinner *et al*., 1997) and pesticides (Warren *et al*., 2003), declines in biodiversity (Chamberlain *et al*., 2000; Goulson *et al*., 2008; Stoate *et al*., 2001), emissions of greenhouse gases (GHGs) (Cooper *et al*., 2009; O'Mara, 2011; Rey Benayas and Bullock, 2012; Vermeulen *et al*., 2018; Woods *et al*., 2010;), pollution from the use of veterinary products (Kay *et al*., 2005), damage to soils and increased erosion (Pimentel and Kounang, 1998; Louwagie *et al*., 2009), and increased demand for water for irrigation (Hart *et al*., 2013). Hence there has been an increasing demand for food production and consumption systems to transition to an approach based on agroecology and demonstrate that multiple environmental and socio-economic objectives are being met.

The pressures and drivers of change within food production systems are multiple, complex and connected, and can include the personal values and preferences of food producers, government policies, and market demands from retailers and consumers. There are also many initiatives and schemes that aim to encourage a transition and/or deliver environmental objectives. Some examples include the concept of 'public money for public goods' that underpins the governments agricultural policy and the new Environmental Land Management schemes (ELMs) (Case, 2023; Defra, 2022); payments for ecosystem services (PES) schemes, such as the one announced by Severn Trent Water to encourage farmers to adopt regenerative farming practices (Impey, 2022); trading schemes for carbon, nutrients and biodiversity benefits (Abram, 2022; EB, 2023; Fraser, 2023; SCM, 2023); environmental data for corporate and/or supply chain reporting (Kamble *et al*., 2020; Kumar *et al*. , 2022; Yakovleva *et al*., 2012); and data to meet consumer demands for information or to promote products with green claims for marketing and/or ecolabels. This review explores the latter within the context of its potential role in influencing the evolution towards sustainable food production.

What is an ecolabel? In many respects this appears to be a relatively simple question; an ecolabel is a means by which to communicate the environmental impact of a product to other businesses and/or consumers to facilitate more informed choices. However, the methods and techniques that underpin any ecolabelling system are inherently complex and can vary significantly between ecolabelling schemes (IGD, 2023a). This has been known for some time. For example, Tzilivakis *et al*. (2011 & 2012) undertook a project for Defra to determine the potential for food ecolabels. A key finding from this work was that many schemes, and their associated standards, are practice rather than outcome-based; and this was especially the case for most mainstream assurance schemes. Ecolabels can range from simple green claims on packaging (with no verification); assurance labels (where production standards are monitored and verified, but without any assessment of environmental impact); through to those where the environmental impacts are quantified, e.g. using Life Cycle Assessment (LCA). The sources of information and data for any of these types of schemes is also key. As illustrated in Figure 1.1, data for assessing environmental impacts can range from secondary and/or modelled data on activities that cause environmental impacts, through to primary data of directly measured environmental outcomes. Primary data on activities is essential for foreground systems (i.e. the system being studied, e.g. a product), with environmental effect (mid-point) and outcome (end-point) metrics being the most desirable (as they provide the most reliable assessment). However, this data is not always easy or practical to obtain, and so many schemes also rely on secondary data with a consequential decrease in reliability. Secondary and/or modelled data is often considered acceptable for background systems (i.e. elements external to the foreground system, e.g. raw materials or energy used) but it can be of variable quality and relevance. Hence, it is important to understand what data is used; how it is used; and whether it is satisfactory to provide a robust, reliable and credible ecolabel.

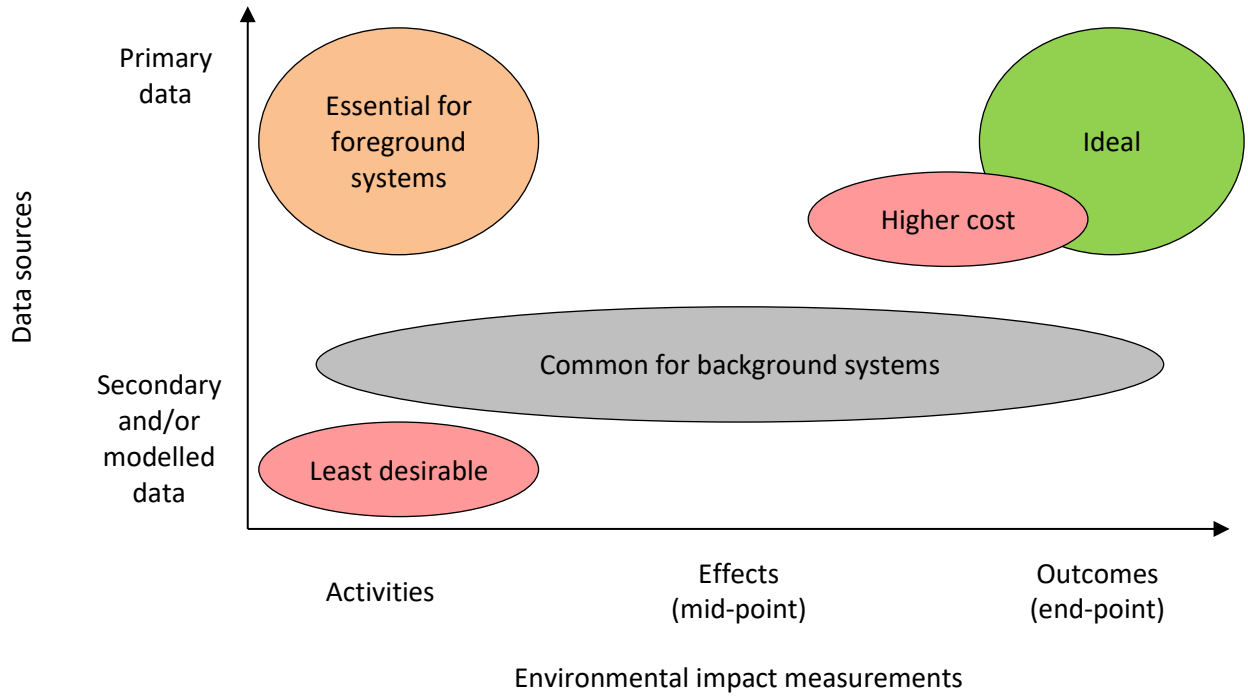


Figure 1.1: Spectrum of environmental impact measurements and data sources

The momentum for food ecolabels has been building over the last 10 years (Arayess & de Boer, 2022; Burrows, 2021; Schickler *et al*., 2023), from those which are producing labels with carbon footprint scores, to those trying to capture a much broader range of impacts. However, quantifying environmental impacts and attributing them to single food products is complicated. For example, the European Commission (EC) have tried to account for a range of impacts through the Product Environmental Footprint (PEF), where 16 indicators have been used (Sala *et al.*, 2018). However, these are seen by some as not far-reaching enough (Bambridge-Sutton, 2023; Burrows, 2022; Futtrup *et al*., 2021; Schulze *et al*., 2024) and/or they are a challenge to apply to food and beverage products which, to date, have not been included within the EU ecolabelling scheme (EU, 2024). Other food ecolabelling schemes have been developed in both Europe and the UK, but a common methodology is yet to emerge, there are differences in scope and approach, and there is a need for further research and development to improve methods and encourage harmonisation (Defra, 2024; IGD, 2023a).

Given the recent interest in ecolabelling for food products there is a need to understand the approaches that are being developed to understand their relative strengths and weaknesses, and thus what role they could play in helping address environmental challenges. The Consortium for Labelling for the Environment, Animal welfare, and Regenerative farming (CLEAR) commissioned a semi-systematic review to understand the extent to which current food ecolabels provide a true and fair view of the environmental impact of food production at the product level, and the implications for the transition to agroecology; food sovereignty; and meeting national environmental targets. This review forms the first step of a broader initiative by CLEAR on food labelling and socio-ecological footprint methods in agriculture and food.

1.2 Project scope, aims and objectives

The review aimed to examine ecolabelling schemes that are either already in operation in the UK; are operating in other countries and are under consideration for being applied in the UK; or are being developed for potential application in the UK. The purpose of the review was to use publicly available information to identify and explore the different methodological approaches across different schemes and determine to what extent do they provide a true and fair view of environmental impacts and the implications for a

transition to agroecology; food sovereignty; and meeting national environmental targets. In so doing, this will help identify any potential synergies and conflicts between different approaches to ecolabelling and other initiatives that encourage agroecological practices and systems that aim to facilitate the transition to sustainable food production. It is essential that there is coherence amongst different initiatives (to ensure we are all pulling in the same direction) to achieve this goal.

It is important to acknowledge that this review does not aim to explore the effectiveness of ecolabels as tools for changing the purchasing behaviour of different consumers or businesses. Understanding the perception and psychology of ecolabelling as a tool to change purchasing behaviour has been the focus of many other previous research studies (e.g. Chen *et al*., 2018; D'Souza *et al*., 2022; Gröfke *et al*., 2021). It is acknowledged that effectiveness of ecolabelling as a tool to change consumer behaviour can be variable; consumers are not homogenous and responses can vary between different groups (Defra, 2008). However, it is beyond the scope of this review to examine these aspects of ecolabelling. This review has been undertaken from the perspective that if ecolabels have the potential to have any impact in this respect, then to what extent do they provide a true and fair view of environmental impacts and the implications for a transition to agroecology; food sovereignty; and meeting national environmental targets.

With the scope above in mind, the aims and objectives of the project were developed in consultation with CLEAR. For a range of food ecolabels that could be applied in the UK, the project aimed to review and examine:

- Data sources, data methodologies, impact categories, models and metrics, and rating methodologies.
- Primary producer engagement.
- Sustainable vision and values.

The objectives were:

1. To identify and characterise ecolabels and schemes relevant to the UK (with respect to the aims above).
2. To identify the strengths and weaknesses of different ecolabels and schemes and evaluate the extent to which they provide a true and fair view of the environmental impact of the food at the product level.
3. To illuminate barriers to the integration of farm level data and identify pathways for the greater use of farm-gate data in the future.
4. To present the findings of the review within the context of supporting the transition of the UK food system to agroecology (incl. opportunities and challenges for primary producers); food sovereignty; and meeting national environmental targets.

Objectives 1 and 2 involved evidence collation, analysis and evaluation. This evidence also formed the foundation to derive findings and conclusions for Objectives 3 and 4.

2 Methods

2.1 Overview of the approach

The review consisted of the following phases:

1. Scoping: scheme selection
2. Characterisation: scheme description
3. Evaluation: scheme assessment
4. Synthesis: utilisation of the evidence gathered to address the aims and objectives of the review

Given the limited time and resources available for the review, it was necessary to focus efforts on those schemes that were of most interest in relation to the aims and objectives of the review. Thus, the scoping phase served to set the boundaries of the review with respect to selecting schemes to be reviewed. This resulted in three groups of schemes, which in summary were (1) product-based schemes; (2) assurance-based schemes; and (3) other schemes of general interest[1]. Those in Groups 1 and 2 were explored further in Phases 2 and 3, with those in Group 3 utilised to support discussions and wider perspectives in Phase 4.

Phase 2 of the review characterised each scheme in Groups 1 and 2. This involved collating publicly available information and data for a range of characterisation criteria, thus providing a consistent and systematic description of each scheme. The evidence collated was then used to support Phases 3 and 4.

Phase 3 of the review evaluated each scheme in Groups 1 and 2 with respect to:

- Environmental impact coverage: Establishing what environmental impacts and outcomes are covered by the schemes and the metrics used.
- Data sources, data quality and verification: What data (primary and/or secondary) is used to calculate environmental impacts, and what data quality and verification processes is it subject to.
- Environmental impact communication, normalisation and aggregation (Group 1 schemes only): The techniques used to normalise and/or aggregate environmental impacts (where applicable).
- Transparency: The level of transparency within each scheme with respect to the assessment of environmental impacts, verification processes and general clarity about the scheme.

Phase 4 of the review aimed to synthesise the information collated to specifically address the aims and objectives of the review. This includes:

- Comparison of the schemes
- Objectives of the schemes
    - General characteristics
    - Environmental impact coverage
    - Data sources, data quality and verification
    - Impact communication: interpretation, normalisation and aggregation
    - Transparency
- Transition to agroecology
- Wider perspectives

[1] It should be noted that the Group 1 and 2 schemes are not mutually exclusive. Produce from a farm can be subject to both a Group 2 assurance scheme and a Group 1 product ecolabel. The purpose of the grouping is to differentiate significant differences in approach and perspective.

2.2 Scoping phase (scheme selection)

The aim of the review is to examine a range of UK food ecolabels[2] with respect to the data sources, data methodologies, impact categories, models and metrics, and rating methodologies; primary producer engagement; and sustainable vision and values. The number of schemes that could be included within the review needed to be limited, whilst also providing a holistic and comprehensive perspective of the schemes that are available. Thus, a grouped approach was adopted where ecolabel schemes were scoped into the following groups:

- Group 1: Product-based schemes. Schemes in this group are those that aim (or claim) to provide a measure of environmental impacts or outcomes associated with the food product (or production system) typically using an LCA approach.
- Group 2: Assurance-based schemes: Schemes in this group are those that aim (or claim) to improve environmental performance, but do not necessarily measure environmental impacts or outcomes.
- Group 3: Schemes in this group include those that have the potential to provide interesting concepts and ideas but are either not related to food production; are located outside of the UK/EU; are very niche; or are conceptual and/or at an early stage of development/implementation. Schemes in this group have not been characterised or evaluated, but details have been drawn upon where relevant to support discussions or wider perspectives.

With these groups in mind, work began on the project by gathering information about as many environmental labelling schemes as possible, particularly trying to understand where they operate, what product categories they cover and what their approach is. This provided an initial list of schemes which were to be relevant to the project, having discarded those which were not applicable to the UK and did not cover food and beverage products. An initial characterisation was then carried out on these schemes, to further understand how they operate and help classify these into one of the three groups.

2.3 Characterisation and Evaluation Framework (CEF)

2.3.1 Overview of the CEF

As stated in Objective 2, a key element within this project is the concept of providing a 'true and fair' view. This concept has its origins in financial accounting and reporting and is increasingly being applied to non-financial reporting including sustainability accounting (Garvey *et al*., 2021; Gawęda, 2021, Monciardini *et al*., 2020; Parte *et al*., 2023). There is no established definition or framework for providing a true and fair view, however there are some fundamental principles that should be considered including:

- Bias: ensuring that bias and/or conflicts of interest are avoided.
- Consistency: ensuring that a consistent and systematic approach is taken.
- Pragmatism: ensuring that assessment procedures are pragmatic, i.e. seeking appropriate evidence relating to the 'substance' of the label rather than what is said in words.
- Subjectivity: ensuring that subjective elements are fully recognised; understanding the positive value and limitations of subjective professional judgements; and ensuring these are explicitly communicated.
- Substance over form: ensuring the substance of what the label represents (i.e. environmental impacts of food production) is adequately and faithfully represented, rather than, for example, simply meeting any economic, legal or institutional formalities for an ecolabel.

[2] The focus of the review is on ecolabels for food produced from terrestrial sources in the UK; thus it does not encompass ecolabels associated with fisheries (e.g. Marine Stewardship Council), textiles, timber, pharmaceuticals, non-food oils or energy. Schemes that focus on social and/or economic aspects of sustainability only (e.g. Fairtrade) have also been excluded; albeit schemes that take a broad perspective covering environmental, social and economic pillars have been included where appropriate.

- Transparency (and clarity): ensuring that assessment procedures are clear, accessible and transparent. This should include reflecting upon any limitations of the assessment and ensuring any assumptions are clearly documented and communicated.

With these in mind, a framework for characterising and evaluating the ecolabelling schemes has been developed that encompasses these principles, thus contributing to providing a 'true and fair' view. The Characterisation and Evaluation Framework (CEF) establishes the information to be collated for each label and scheme to characterise and evaluate it (within the context of the aims and objectives of this study). The framework builds upon the work undertaken in Defra project IF0131 (Tzilivakis *et al.*, 2009, Lewis *et al.*, 2010) and aims to provide a holistic, systematic and consistent description of each scheme. There are two elements to the CEF:

- **Characterisation:** a framework that lays out a set of criteria to provide a common and consistent description of each labelling scheme and provides data and information to undertake the evaluation.
- **Evaluation:** a framework for assessing each scheme to answer the aims and objectives of the project, i.e. an evaluation of the strengths and weaknesses of different ecolabels and schemes and the extent to which they provide a true and fair view of the environmental impact of the food at the product level.

Figure 2.1 shows how the CEF underpins the project. The general characterisation stage aims to systematically collate data and information for each labelling scheme to provide the evidence base for evaluation. This evidence base will then be used to formulate judgements on the relative strengths and weaknesses of different ecolabels and schemes and evaluate the extent to which they provide a true and fair view of the environmental impact of the food at the product level.

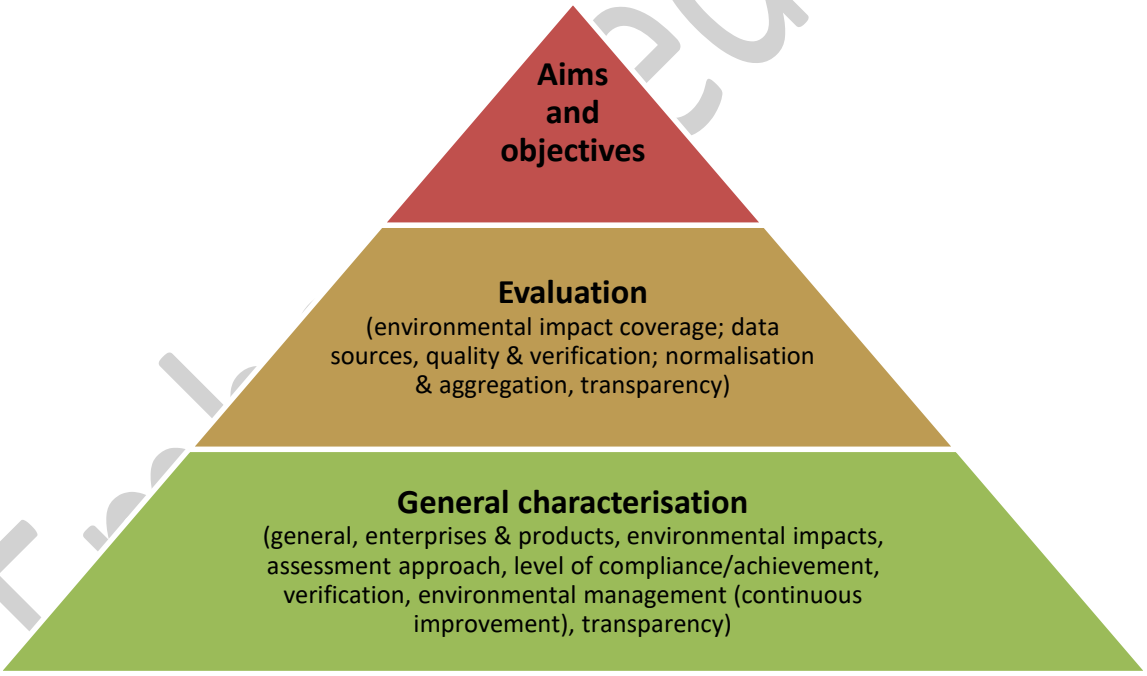


Figure 2.1: Overview of the CEF

Section 2.3.2 provides more details on each of the general characterisation criteria and Sections 2.3.2 to 2.3.6 provide details on the approach to the evaluation.

2.3.2 General characterisation

2.3.2.1 General

The first criterion aimed to gather all the general information about the scheme including its stated aims and objectives; ownership and governance (including whether primary producers are involved). It also collated

information, where available, on the origins of the scheme (i.e. a supply chain / product perspective (top-down) or a primary producer perspective (bottom-up)); when it was created; and numbers of members / products (if available) and/or verifiable market penetration.

Key questions:

1. What are the stated aims and objectives of the scheme; mission; sustainable vision and values?
2. Who owns the scheme and how is it governed? Are primary producers involved?
3. Does the scheme originate from a supply chain / product perspective (top-down) or a primary producer perspective (bottom-up)?
4. Is there any (verifiable) data on market penetration? NB. This information has been collected from the ecolabel organisations themselves, but not independently verified.

2.3.2.2 Enterprises and products

It is important to clarify what the ecolabel covers with respect to boundaries of the system it represents. This can include:

- A single product
- A group of products
- A single farm enterprise
- The whole farm (one site or multiple sites)
- Specific areas of a farm

In theory there could be overlaps between these categories and this may depend on what environmental impact categories are covered by the scheme (see below). Another element to this perspective was to determine:

- Whether the label is to be used within a retail environment (e.g. supermarket) or another type of outlet (e.g. restaurant or café).
- Whether the purpose of the label is to inform consumers and/or for other businesses.
- Where the label is displayed (e.g. product packaging, websites, menus) and what information does it carry.

Key questions:

1. Is the scheme whole-farm, relating to a single enterprise, a single product, specific areas of the farm?
2. Is the label for retailers or other outlets?
3. Is the label for communicating with consumers or other businesses?
4. Where is the ecolabel displayed? (e.g. product packaging, websites, menus)
5. What information is displayed on the label? What does it look like?

2.3.2.3 Environmental impacts

Food production can have a wide range of environmental impacts and influence the delivery of multiple ecosystem services (Mouchet *et al.*, 2017; van Oudenhoven *et al.*, 2012; van Zanten *et al.*, 2014). Environmental impacts can be broadly categorised into those that cause damage to ecosystem and/or human health, while ecosystem services are usually categorised into:

- Provisioning services: e.g. food, fibre and fuel.
- Regulation services: e.g. air quality regulation; mass stabilisation and control of erosion rates; flood protection; chemical condition of freshwaters; climate regulation (via emission and sequestration of greenhouse gases); pollination; pest and disease control.
- Cultural services: e.g. aesthetic, heritage, scientific, educational and recreational services.

Some of these will occur on the farm where production takes place (e.g. impacts on wildlife species) while others will be manifested off-farm (e.g. global impacts such as climate change).

Each scheme has been reviewed to establish what impacts it covers and the reasons for the selection of those impact categories. This has been compared to a comprehensive list of impacts (see Section 2.3.3) to determine the degree of coverage and thus any impacts that have been omitted.

Key questions:

1. What environmental impact categories are included?
2. Why have they been selected?
3. Are any significant impacts omitted?

2.3.2.4 Assessment approach

A key part of understanding any scheme is to establish what data is used to determine environmental impacts and performance. For example, does the scheme use primary data from environmental impacts measured on farms or are secondary data sources used (e.g. generic data for different types of agricultural products)? Each scheme has been reviewed to identify what metrics and data are used for each environmental impact category that is included in the scheme (see Section 2.3.3). This has also involved identifying what needs to be achieved (in terms of environmental performance / impacts) for any product or farm to qualify for the label (where applicable), i.e. what are the qualification benchmarks. Any involvement of primary producers in setting of benchmarks have also been noted.

Key questions:

1. What is measured to assess environmental performance?
2. How do they relate to environmental outcomes?
3. Where does the data come from?
4. What are the qualification benchmarks?
5. Who is involved in setting any benchmarks?

2.3.2.5 Level of compliance and achievement

Following on from Section 2.3.2.4, this criterion established what needs to be achieved in terms of compliance to qualify for the label (e.g. does a standard have to be achieved or is it simply a case of applying and being awarded a grade?). This could include, for example, whether all elements are compulsory or whether there is flexibility or room for discretion (which may depend on what is measured to judge performance). This also helped identify any potential weaknesses with respect to what is achieved and thus the benefits of the scheme. This included identifying if there are different levels of achievement / certification (e.g. A-E) within the scheme.

Key questions:

1. Does a standard have to be achieved to be accepted into the scheme?
2. Are there different levels of achievement / certification (e.g. A-E)?
3. Are all standards/requirements compulsory?
4. Is there any room for discretion in the standards? If so, does this enhance or reduce the benefits offered by the scheme?

2.3.2.6 Verification

An important element of any scheme are the various checks and procedures that exist to ensure and verify the data used and/or that scheme requirements are being met; and that the desirable outcomes and objectives of the scheme are being achieved/delivered. Thus, each scheme was reviewed to establish what verification processes exist, including how data or data sources are verified; and whether any inspections and/or audits are undertaken where relevant. Related to this are the protocols that exist when scheme standards or benchmarks are not achieved.

Key questions:

1. How is the data for a product or enterprise verified?

2. Are environmental impacts (positive and negative) independently verified? If so, how?
3. If the scheme requires inspections, are inspections regular? (At what interval?) Does the inspector audit only paperwork or visit the farm site?
4. Where certification applies, are all certified farms inspected?
5. Where meeting standards is required, are all standards enforced - is there any leeway? Does a single breach mean expulsion from scheme/can problems be corrected? If so, is this with or without penalty and/or re-inspection?

2.3.2.7 Environmental management (continuous improvement)

At the heart of all environmental management systems is the concept of continuous improvement. The idea is one of regularly reviewing performance to identify areas for improvement and/or ensuring adaptive capacity to address issues that can arise in a dynamic world. Each scheme was reviewed to identify (i) whether the scheme standards/benchmarks evolve/improve over time; and (ii) whether farms / products are encouraged to improve their performance over time; whether risks are assessed and appropriate mitigation identified; or whether action plans are drafted, implemented and monitored.

Key questions:

1. Does the scheme require its members to assess risks associated with their farm and mitigate those risks appropriately?
2. Does the scheme require the creation and implementation of action plans? (and is implementation checked, validated or reviewed?)
3. Do the scheme standards/requirements evolve (improve) over time?

2.3.2.8 Transparency

In the process of identifying and collating the information above for each scheme, information on the relative transparency of the scheme and its documentation has been noted. This included whether all the information is publicly/easily available; its clarity / ease of interpretation; whether the scheme mechanisms are clear; and whether any limitations of the scheme are honestly and openly admitted and communicated.

Key questions:

1. Are the procedures, standards, and requirements publicly available?
2. Are the procedures, standards, and requirements clearly presented? (and are they likely to be clear to all groups ranging from consumers to scientists/experts?)
3. Is it clear how any standards/requirements are enforced?
4. Are any limitations of the scheme openly communicated?

2.3.2.9 Characterisation key questions checklist

Table 2.1 summarises the key questions for each of the CEF criteria. This serves as a checklist to ensure that the data for each scheme is gathered in a systematic manner.

Table 2.1: CEF criteria key questions checklist

Criterion	Sub-criterion	Description
General	Aims & objectives	What are the stated aims and objectives of the scheme; mission; sustainable vision and values?
	Ownership	Who owns the scheme and how is it governed? Are primary producers involved?
	Perspective	Does the scheme originate from a supply chain / product perspective (top-down) or a primary producer perspective (bottom-up)?
	Market penetration	Is there any data on market penetration? NB. This information has been collected from the ecolabel

Criterion	Sub-criterion	Description
		organisations themselves, but not independently verified.
Enterprises and products	Scope	Is the scheme whole-farm, relating to a single enterprise, a single product, specific areas of the farm?
	Retail	Is the label for retailers or other outlets?
	Audience	Is the label for communicating with consumers or other businesses?
	Label location	Where is the ecolabel displayed? (e.g. product packaging, websites, menus)
	Label Type	What information is displayed on the label? What does it look like?
Environmental impacts	Impact categories	What environmental impact categories are included?
	Reason	Why have they been selected?
	Omissions	Are any significant impacts omitted?
Assessment approach	Metrics	What is measured and/or modelled to assess environmental performance?
	Outcomes	How do they relate to environmental outcomes?
	Data source	Where does the data come from?
	Benchmarks	What are the qualification benchmarks?
	Governance	Who is involved in setting any benchmarks?
Level of compliance	Qualification	Does a standard have to be achieved to be accepted into the scheme?
	Levels	Are there different levels of achievement / certification (e.g. A-E)?
	Requirements	Are all standards/requirements compulsory?
	Discretion	Is there any room for discretion in the standards? If so, does this enhance or reduce the benefits offered by the scheme?
Verification	Data verification	How is the data for a product or enterprise verified?
	Independent verification	Are environmental impacts (positive and negative) independently verified? If so, how?
	Inspections	If the scheme requires inspections, are inspections regular? (At what interval?) Does the inspector audit only paperwork or visit the farm site?
	Certification	Where certification applies, are all certified farms inspected?
	Implementation	Where meeting standards is required, are all standards enforced - is there any leeway? Does a single breach mean expulsion from the scheme/can problems be corrected? If so, is this with or without penalty and/or re-inspection?
Environmental management (continuous improvement)	Risks	Does the scheme require its members to assess risks associated with their farm and mitigate those risks appropriately?
	Actions plans	Does the scheme require the creation and implementation of action plans? (and is implementation checked, validated or reviewed?)

Criterion	Sub-criterion	Description
	Evolution	Do the scheme standards/requirements evolve (improve) over time?
Transparency	Public availability	Are the procedures, standards, and requirements publicly available?
	Clarity	Are the procedures, standards, and requirements clearly presented? (and are they likely to be clear to all groups ranging from consumers to scientists/experts?)
	Enforcement	Is it clear how any standards/requirements are enforced?
	Limitations	Are any limitations of the scheme openly communicated?

2.3.3 Environmental impact coverage

A fundamental aspect to explore for all the schemes was to determine which environmental effects, impacts and outcomes are covered; how these are measured and assessed; the data sources used; any verification processes employed; and the approaches utilised for performance assessment and benchmarking. To ensure that all relevant environmental impacts are covered, a bespoke environmental impact category framework has been developed. This framework encompasses LCA impact categories (e.g. Hauschild *et al.*, 2011), the planetary boundaries concept (e.g. Rockström *et al.*, 2009a&b; Steffen *et al.*, 2015) and ecosystem service frameworks (e.g. Haines-Young & Potschin, 2018) to provide a bespoke and holistic set of impact categories and associated metrics that cover the atmosphere, biosphere, geosphere and hydrosphere. A full description of the environmental impact category framework and how it was derived is provided in Appendix A. Table 2.2 lists the broad impact categories with a brief description of what they cover.

Table 2.2: Broad environmental impact categories

	Impact category	Description
Atmosphere	Climate regulation	Emissions of GHGs and sequestration of carbon (C) from the atmosphere. Key GHGs are carbon dioxide (CO_2); methane (CH_4) and nitrous oxide (N_2O).
	Air quality regulation	Emissions of pollutants to the atmosphere which can have negative impacts on humans and wildlife. Includes ammonia (NH_3); nitrogen oxides (NOx); Volatile Organic Compounds (VOCs); particulates; bioaerosols; and dust.
	UV-B radiation regulation	Emissions of pollutants that deplete the ozone layer increasing the amount of UV-B radiation reaching the surface of the Earth.
	Gaseous flows regulation	The management of landscapes can have an impact on gaseous flows (e.g. such as wind).
Biosphere	Animals provision	Wild animals can be a source of fuel, food and materials (e.g. fibres) for humans as well as food and materials for wildlife species.
	Biomass provision	Wild plants can be a source of fuel, food and materials (e.g. fibres) for humans and food as well as materials for wildlife species.
	Habitat provision	The management of landscapes can have a significant impact on habitats for different wildlife species, which in combination with the provision of different resources and the quality of resources, will impact upon the health, mortality and populations of different wildlife species. The configuration of different landscape features and the complementation of different resources at various times of the year can be crucial to many species.

	Impact category	Description
	Pollination regulation	The management of landscapes can have a significant impact on populations of pollinators and thus pollination of both crop and wild plant species.
	Seed dispersal regulation	The management of landscapes can have a significant impact on populations of species that disperse plant seeds and thus populations of wild plant species.
	Pest control regulation	The management of landscapes can have a significant impact on populations of species that are beneficial for the control of crop pests.
	Disease control regulation	The management of landscapes can have an impact on the risk and thus incidence of crop diseases. This includes the cropped environment and practices such as crop rotations which can help prevent the build-up of crop pathogens.
Geosphere	Fossil fuel provision	The consumption of fossil fuels is an issue of depleting a non-renewable resource.
	Nutrient provision	The consumption of nutrients Nitrogen (N), Phosphorus (P) and Potassium (K) within fertilisers for crops is an issue of both depleting non-renewable resources and over-exploiting renewable resources.
	Soil provision	Soil can be regarded as both an abiotic and biotic resource. However, for the purposes of this classification, it is regarded as an abiotic / physical resource that can be subject to erosion.
	Soil quality regulation	The abiotic and biotic condition of the soil with respect to performing different functions and/or meeting the needs of humans and wildlife species.
	Mass flows regulation	The management of landscapes can have a significant impact on soil erosion. This impacts on the soil itself (as a resource) and sediment lost from fields can be a physical pollutant.
Hydrosphere	Water provision	The management of landscapes can have a significant impact on hydrology influencing both the flows and provision of water within a catchment, for both human and wildlife populations.
	Water conditions regulation	Emissions of pollutants to surface and groundwater which can have negative impacts on humans and wildlife. This includes nutrients such as nitrate (NO_3^-), phosphorous/phosphate (PO_4^{3-}), emissions and deposition of ammonia (NH_3) and NOx; emissions of substances with a high Biochemical Oxygen Demand (BOD) (e.g. silage effluent, livestock slurry); emissions of pathogens (e.g. *Escherichia coli* and *Cryptosporidium parvum*); emissions of compounds with ecotoxic effects (e.g. pesticides, veterinary medicines and associated metabolites; oil; and plastics).
	Water flows regulation	The management of landscapes can have a significant impact on hydrology and the flows of water within a catchment. Land management practices will influence water retention and/or how quickly water enters watercourses, which can consequently contribute to flooding events downstream.

The purpose of the impact category framework is to facilitate an evaluation of UK food ecolabels with respect to the environmental impacts they cover.

This first step simply identifies whether a particular scheme explicitly covers each of the impact categories. Where the impact is covered, then the subsequent steps are undertaken. The second step is to determine the coverage of elements within an impact category. Some impact categories have more than one element to them (sub-impacts). For example, climate regulation includes emissions of three GHGs, sequestration of carbon in the soil and sequestration of carbon in biomass (with the latter two being associated with land use change); and air quality and water quality regulation include emissions of multiple different polluting

substances. Schemes do not necessarily cover all the sub-impacts within each impact category, for example, for climate regulation some may only focus on GHG emissions and not carbon sequestration.

To account for this, the review of each scheme identifies the proportion of the sub-impacts covered and are summarised as shown in Table 2.3.

Table 2.3: Coverage of sub-impacts

Coverage of sub-impacts	Icon
Uncertain*	
25%	
25-50%	
50-75%	
75-100%	

* In some instances, the documentation for scheme indicates that an environmental impact category is covered, but it is not clear what sub-impacts are included (e.g. climate change is covered, but it is not clear whether this covers GHG emissions, carbon sequestration and/or land use change). In these instances, the coverage is marked as uncertain.

2.3.4 Data sources, data quality and verification

As shown within the impact category framework (Appendix A), the metrics used for each category can range from those which cover activities and practices (e.g. consumption of fossil fuels) associated with the impact; effects and impacts of those activities (e.g. emissions to air and water; Global Warming Potential (GWP)); and environmental outcomes (e.g. data on species populations, health or mortality). The sources of data for each metric can also vary with some based on primary data (e.g. farm data) and others utilising secondary data (e.g. from databases of typical values). In many instances, this may also involve a combination of data sources (e.g. using primary data on activities, which are then multiplied by emission factors (from secondary sources) to derive effect and impact values). To capture this information, the key shown in Table 2.4 has been used.

Table 2.4: Data sources key

Data source	Activity data	Effect data	Outcome data
Unknown			
All Secondary			
Primary & secondary			
All Primary			
Not covered			

Following the keys in Table 2.3 and Table 2.4, a scheme that covers all sub-impacts and has primary data for activities, effects and outcomes would be all solid green, whereas a scheme that has low coverage of sub-impacts, uses secondary data for activities, effects and outcomes (or has no data) would be largely red and/or hollow, thus facilitating a rapid graphical overview and comparison of the schemes. Table 2.5 provides an example analysis overview (for climate regulation).

Table 2.5: Example analysis overview

Category	Scheme A	Scheme B	Scheme C	Scheme D	Scheme E
Climate regulation					

The final part of this section of the evaluation is to explore the processes employed by each scheme with respect to data quality and verification. This is largely an extension of the characterisation but aims to establish what processes are in place to determine the quality of data used and/or ensure that the highest

quality of data is used. With respect to the Group 1 schemes, this is likely to include the use of LCA data quality tools such as a pedigree matrix. With respect to Group 2 schemes, this focused on the procedures for verifying achievement of scheme standards, such as audits and inspections. Where appropriate, any potential strengths and weaknesses in the approaches adopted have been highlighted.

2.3.5 Normalisation and aggregation

This is applicable to Group 1 schemes only as these processes only apply to quantified environmental impact metrics. With respect to normalisation, there are two elements to explore here. Firstly, whether any normalisation is applied to the impacts that are determined for a product; and secondly, related to this, how a product is differentiated with respect to its environmental performance. For example, some schemes use planetary boundaries to derive a normalised score for a product (e.g. impact expressed as a percentage of the daily per capita target); whereas other schemes adopt an approach where a product's impacts are scored relative to other similar products.

There are several complex aspects to unpack on this topic, which are not easy to summarise, so are limited to being explored within a more detailed analysis (rather than inclusion in a summary table). This includes:

- Normalisation approach: e.g. Whether planetary boundaries or current impact levels are used.
- If planetary boundaries are used, which ones: There is a lot of debate on how to downscale planetary boundaries to more local or product levels (e.g. Ryberg *et al*., 2020). As shown with some example metrics in Appendix A, some are more robust and applicable than others (and some do not exist for some impacts), thus their systematic utilisation for all the impacts within an ecolabel could be problematic.
- If planetary boundaries are used, what targets are set: This is another area that is subject to debate, especially with respect to regional and equitable distribution of any burdens imposed by a target.
- Where products are scored relative to other similar products: This has the potential to be meaningless as it depends on the population of products used, e.g. if a product is scored relative to the best performing product, if that product has an extremely high or low environmental performance, this can skew the interpretation for any products compared to it.

Where impacts are normalised, the approach used by each scheme has been characterised and evaluated where appropriate.

With respect to aggregation, given the number of impact categories, there is often a desire to aggregate them into fewer categories or even a single value to facilitate simpler communication and interpretation of the ecolabel. However, this inherently results in several significant transparency issues including:

- There is a lack of consensus on appropriate aggregation techniques. For example, damage characterisation factors in LCA (which can be used to aggregate impacts) are an optional step under the ISO 14040 standards (ISO, 2006) partly because these factors are not fully established.
- Aggregation hides important detail. For example, negative impacts can appear to be cancelled out (hidden) by positive impacts.
- Related to the above, there is scope for burden shift. For example, a product could improve environmental performance in one area, but at the expense of another.
- Hidden impacts can damage the credibility of an ecolabel.

Where impacts are aggregated, the approach used by each scheme has been characterised and evaluated where appropriate.

2.3.6 Transparency

The data collated for each scheme has been used to judge the relative transparency of each scheme (with the acknowledgement that this is subjective). This ranges from those where all the information is easily and

freely available and easy to understand, through to those schemes where details are lacking, not available and difficult to comprehend. Table 2.6 shows the criteria that have been used for this judgement.

Table 2.6: Transparency criteria

Criterion	Sub-criterion	Description
General	Public availability	Are scheme documentation and details (e.g. procedures, standards, and requirements) publicly available?
	Clarity	Are scheme documentation and details (e.g. procedures, standards, and requirements) clearly presented to all groups (i.e. consumers to scientists/experts)?
	Ownership	Is scheme ownership and governance clear?
	Aims & objectives	Are the stated aims and objectives of the scheme; mission; sustainable vision and values clear?
	Limitations	Are any limitations of the scheme openly communicated?
Environmental impacts	Impact categories	Is it clear what environmental impact categories are included?
	Omissions	If applicable, is it clear what environmental impact categories are not included?
	Metrics	Is it clear what metrics are used?
	Outcomes	Is it clear where environmental outcomes are assessed?
	Data source	Are the sources of data (primary and secondary) used clear?
	Normalisation	If applicable, are normalisation techniques and processes clear?
	Aggregation	If applicable, are aggregation techniques and processes clear?
	Benchmarks	If applicable, are performance benchmarks clear? (i.e. impact-based benchmarks for Group 1 schemes, practice-based benchmarks for Group 2 schemes)
Verification	Data	Are data verification processes clear?
	Impacts	If applicable, are environmental impact verification processes clear?

3 Results

3.1 Ecolabelling scheme selection

Five schemes were selected for Group 1 (Table 3.1) and five for Group 2 (Table 3.2). A further 19 schemes were also identified as being of potential interest so were categorised in Group 3 (Appendix B). Schemes in Groups 1 and 2 were chosen as it was felt that they best represented how the UK food ecolabel movement was developing, and are aiming at environmental impacts, whether that is measuring impacts or outcomes, or improving performance.

Schemes in Group 1 are those that aim (or claim) to provide a measure of environmental impacts or outcomes associated with the food product (or production system) to varying extents. These schemes do not involve primary producers and are working from a top-down perspective. Therefore, these were initiated higher up the supply chain with the aims of encouraging consumers to choose more positive impacting/reduced negative impacting products, and businesses to improve their environmental impact scores. The schemes work at the single product level (either a single item or a combined ingredients product) and tend to be based on data from LCA.

Table 3.1: Group 1 ecolabelling schemes

Name	Description	Website
Eco-Score (ES)	Developed in France, label scores A-E, largely based on LCA data and PEF methods.	https://docs.score-environnemental.com/v/en/
Foodsteps (FS)	UK based, label rates carbon footprint A-E, based on LCA data.	https://www.foodsteps.earth/
Foundation Earth (FE)	EU scheme, label scores A+ to G, based on LCA and PEF method.	https://www.foundation-earth.org/
Institute of Grocery Distribution (IGD)	UK initiative to create an ecolabel, using LCA and PEF data, 4 focus impacts (climate change, land use, water use, water quality), trialling label with consumers but results not yet released (may be lacking available information).	https://www.igd.com/
Planet-Score (PS)	Developed in France, label scores A-E highlighting 3 factors (pesticides, biodiversity, climate) pulled from PEF categories, based on LCA data but wants to expand on this.	https://www.planet-score.org/en/

Ecolabelling schemes in Group 2 are those that aim (or claim) to improve environmental performance, but do not measure environmental impacts or outcomes. This includes some of those that would be considered 'assurance' or certification schemes where a certain level of best practice needs to be achieved to attain scheme membership (note: it was determined that only one organic scheme needed to be included within the review, hence the Soil Association was selected for this purpose). The schemes involve primary producers and are working from a bottom-up perspective. This means they are aimed at the farm level, where it is hoped that changes there will translate through the supply chain and inspire change in food businesses, retailers and consumer buying habits. The scheme is typically a certification or assurance scheme and involves compliance across the whole farm or at least across a single enterprise, rather than at the single product level.

Table 3.2: Group 2 ecolabelling schemes

Name	Description	Website
A Greener World (AGW)	Specifically regenerative agriculture labelling scheme which sits alongside 3 other labels (animal welfare, grassfed and non-GMO). Operations are currently in USA, UK, Australia and South Africa, with regenerative agriculture certified producers and products only in USA and Australia so far.	https://agreenerworld.org.uk/certifications/certified-regenerative/
Fair to Nature (FtN)	Originally called "Conservation Grade" (developed by Jordans Cereals) and formed a partnership with RSPB in 2016. A biodiversity conservation standard for farmers to purposefully encourage biodiversity on farm. Potentially quite niche but does attempt to measure biodiversity/habitats on farms.	https://fairtonature.org/
LEAF Marque (LEAF)	Global assurance scheme (UK based) with standards to enable sustainable practices on farms based on principles of IFM. Label given when farms are adhering to the standards.	https://leaf.eco/leafmarque/
Pasture for Life (PfL)	A certification label for farms, businesses and retailers to ensure that animals are fed exclusively on pasture which brings "positive impacts for biodiversity and carbon, human health and wellbeing, and animal health and welfare".	https://www.pastureforlife.org/
Soil Association (SA) Organic label	Scheme to enable farmers to be recognised as organic producers as set out by EU legislation by adherence to standards. They also encourage a higher standard of organic production than the EU requirements.	https://www.soilassociation.org/certification/

3.2 Group 1 schemes

3.2.1 Eco-Score

Eco-Score has been developed in France and the brand is owned by ADEME (the French Agency for Ecological Transition). The system assigns food products and ready meals a score out of 100, with colour-coding and letters for consumer ease of understanding. The score considers various factors, such as the environmental policy of the producing country, the transport mode, or the seasonality of the product. Based on these factors, it presents an aggregate score, aiming at making every shopping decision quick and easy.

Sources: Eco-Score website (ES, 2024).

3.2.1.1 General characterisation

Eco-Score aims "to be a decision-making tool to guide our food choices towards a more sustainable mode of consumption" and encourage sustainable farming practices through using their decision-making tool. It is organised by 11 French companies in a consortium, and it has been approached from a top-down perspective. Primary producers are not involved but the scheme wants to impact the supply chain such that change is encouraged through to farm level. The ecolabel is for single products (both single and multiple ingredient) and is displayed in a variety of places depending on who is using it. For example, Lidl (Germany) trialled it on

some of their products, the app 'Yuka' would display it when a food product is scanned that has been rated by Eco-Score, and Marmiton, the recipe website displays the Eco-Score rating for its recipes. The label displays the score using an A-E rating and using Red, Amber, and Green (RAG) colours. Eco-Score uses the 16 PEF indicators, but has added additional ones to aid with product differentiation and to cover a wider range of environmental impacts. Despite this, it still omits biodiversity and does not account for animal welfare. It is LCA-based and uses data from the AGRIBALYSE® database, so does not utilise any direct measurements, and cannot account for environmental outcomes directly. The data is not externally/independently verified for the scores. Eco-Score have made their information on how they operate and calculate the scores available on their website. Unfortunately, the English site only has the basics, so the French website needs to be used and translated. It gives a good understanding but could contain more detail to give the user more confidence in the approach. There are no additional downloads for information aside from regulations on how to use the logo correctly, and a datasheet to demonstrate how scores can be generated. The full characterisation for Eco-Score can be found in Appendix C.1.

3.2.1.2 Environmental impact coverage

Table 3.3 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.3: Impact coverage and data source: Eco-Score

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◍	▲	■	◇
	Air quality regulation	◑	▲	■	◆
	UV-B radiation regulation	●	▲	■	◇
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision				
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision	●	▲	□	◆
	Nutrient provision	◍	▲	□	◆
	Soil provision				
	Soil quality regulation	◔	▲	□	◆
	Mass flows regulation				
Hydrospher	Water provision	◍	▲	■	◇
	Water conditions regulation	◔	▲	■	◆
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Eco-Score uses the standard 16 PEF (weighted score for importance by PEF) indicators. These are reflected in Table 3.3 as follows:

- Climate regulation: The PEF category of 'Climate Change' is used. It is not clear what this covers with respect to GHG emissions, land use change and/or carbon sequestration. Like all other schemes, the outcomes of climate change (e.g. damage to ecosystems, wildlife populations and human health) are not measured, and impact metrics are based on GWP (a midpoint/effect metric) probably derived from

activity data rather than direct measurements of GHG emissions. It is not clear whether this is derived from primary or secondary data.

- Air quality regulation: The PEF categories of 'Human Toxicity – cancer', 'Human Toxicity - non-cancer', 'Particulate Matter' and 'Photochemical Ozone Formation - human health' are used. These metrics are effect and outcome oriented (with the latter related to human health) based on secondary data (emission factors) in combination with activity data, but it is not clear whether this is from primary or secondary sources.
- UV-B radiation regulation: The PEF category of 'Ozone Depletion' is used, which is an effect (midpoint) metric based on secondary data (emission factors) in combination with activity data. It is not clear whether this is derived from primary or secondary data.
- Fossil fuel provision: The PEF category of 'Resource Use – fossils' is used. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data, but it is not clear if this is from primary or secondary sources.
- Nutrient provision: The PEF category of 'Resource Use - minerals and metals' is used. It is not clear if this explicitly includes nutrients. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data, but it is not clear if this is from primary or secondary sources.
- Soil quality regulation: The PEF category of 'Eutrophication – terrestrial' is used, which can be considered an outcome metric. However, no other aspects or metrics related to soil quality regulation are used. It is not clear whether this is derived from primary or secondary data.
- Water provision: The PEF category of 'Water Use' is used, which is a measure of deprivation potential, which is an effect (midpoint) metric rather than an outcome. No other aspects or metrics related to water provision are used. It is not clear whether this is derived from primary or secondary data.
- Water conditions regulation: The PEF categories of 'Eutrophication – freshwater' and 'Eutrophication – marine' are used, which can be considered outcome metrics. However, no other aspects or metrics related to water conditions regulation are used. It is not clear whether these are derived from primary or secondary data.

In addition to the metrics above, the score derived for a product is adjusted to account for the production system (environmental benefits associated with other food labels, e.g. Organic), local supply (method of transport and distance travelled), environmental policy (Environmental Performance Index of the producing country), packaging (production and disposal based on materials packaging is made from) and threatened species (e.g. endangered fish stocks and species impacted by the cultivation of palm oil). These aspects do not measure environmental impacts, they only aim to account for other aspects that can impact on the environment that are not covered by the metrics above.

3.2.1.3 Data sources, data quality and verification

Eco-Score uses LCA data from AGRIBALYSE® exclusively for its ecolabel, and then adds on the additional categories to complete the overall score. The LCAs are carried out by AGRIBALYSE®, which has its own internal data quality system. Eco-Score does not appear to have any data quality checking of their own, and no system for verification of the LCA data coming through external to themselves. See Appendix D.1 for further details on processes used by AGRIBALYSE®.

3.2.1.4 Normalisation and aggregation

There does not appear to be any normalisation in relation to a recognised benchmark (e.g. planetary boundaries or impact per head of population). The description of the aggregation / calculation process is lacking clarity (possibly due to translation from French). However, it appears that the outputs for the 16 PEF are aggregated, possibly using the PEF weightings (albeit this is not clear). An aggregated score is derived from AGRIBALYSE® based on the type of product. A logarithmic curve is then used to convert this score to a 0 to 100 scale. This score is then adapted using additional indicators about the production system (5 to 20 points), local sourcing (0 to 15 points), environmental policy (-5 to +5 points), packaging (0 to -15 points) and endangered species (-10 points). Bonuses are cumulative, up to a maximum of 25 points, with each indicator rounded to the nearest integer.

The final score for a product is graded in classes of food products from A (low) to E (high) according to their impact on the environment. The 0 to 100 score derived above is classified A to E using the following bands: 0-20 = E; 20-40 = D; 40-60 = C; 60-80 = B; 80-100 = A; with the following additional rules implemented where appropriate:

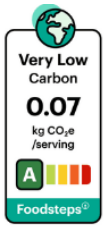
- Only products packaged in recyclable (or biodegradable) packaging are eligible for Eco-score A, regardless of other criteria.
- If the product contains a non-sustainable species (of fish), the product obtains the Eco-score (E), regardless of other criteria.

Overall, the lack of transparency on the approach means that there is scope for impacts to be hidden and/or burden shift, i.e. one impact increased at the expense of another.

3.2.1.5 Transparency

Eco-Score was developed in France, so the primary source of information for the scheme is on the French version of the website. An English version has been created but contains much less information about the scheme and how it operates. Therefore, it is better to translate the French website to English to get a fuller understanding. They provide all their information on a series of pages on the website, with only two downloadable additional documents, one stipulating the use of the logo and the second with worked examples for scoring for 3 products. It was decided that there is not enough information to be able to walk a product through the methodology to get a score, and assumed that this was due to the difference in work that was being done for product score calculations between AGRIBALYSE®, as the LCA data provider, and Eco-Score themselves. Eco-Score make it clear what the impact categories they use are and say a little about the omissions made. It does not look like they use normalisation as part of the calculation, so this is not applicable, but it is less clear how impacts are aggregated. The data is likely to be only verified internally, but there is little information available to justify this.

3.2.2 Foodsteps



Foodsteps was founded in 2019 and is a UK-based company which offers data and communication solutions for food businesses looking to measure, reduce and communicate their food's environmental impact. At the time of writing this review, Foodsteps only focused on climate change, thus the carbon footprint of products is the only metric used for this label. This is based on a database of LCA studies.

Sources: Foodsteps documentation (FS, 2023a&b), website (FS, 2023c), personal communication (Stephen, 2024).

3.2.2.1 General characterisation

Foodsteps is an ecolabel focusing on the GHG emissions of food, with ambitions to extend the impacts covered to include land use, water use, eutrophication and acidification (Stephen, 2024). Their stated mission is "to help the food system measure, reduce and communicate its environmental impact". It has been taken up so far by a small number of UK and global chain restaurants, recipe boxes and big businesses. The ecolabel is for single products and is displayed on menus and recipes, showing an A-E, RAG coloured score as well as the CO_2e value. Foodsteps source their LCA data primarily from Poore and Nemecek (2018) but are also data partners with OmniAction, HESTIA, Waste and Resources Action Programme (WRAP) and Global Farm Metric, and utilise additional data sources and expertise. Foodsteps claim to internally verify the data and use their own calculations to reach the final score output. Most of the information about the ecolabel is on the website, with an additional downloadable file which gives the scores for 100 food products and further information on the calculation methodology, but it could have more detail around this, and the data sources used. Foodsteps do acknowledge that LCA data is incomplete so approximations can be used in place of

missing data, and they have a data quality rating to account for the accuracy of the data used. The full characterisation for Foodsteps can be found in Appendix C.2.

3.2.2.2 Environmental impact coverage

Table 3.4 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.4: Impact coverage and data source: Foodsteps

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	●	▲	■	◇
	Air quality regulation				
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision				
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision				
	Nutrient provision				
	Soil provision				
	Soil quality regulation				
	Mass flows regulation				
Hydrosphere	Water provision				
	Water conditions regulation				
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

As Foodsteps is a carbon label it only covers one impact category, i.e. Climate regulation. It appears to cover all aspects of this, i.e. GHG emissions, land use change and/or carbon sequestration. Like many other schemes, the outcomes of climate change are not measured, and impact metrics are based on GWP (a midpoint/effect metric) derived from activity data rather than direct measurements of GHG emissions. It appears to be derived from secondary data only. As mentioned in Section 3.2.2.1, Foodsteps has ambitions to extend the impacts covered to land use, water use, eutrophication and acidification but these are yet to be implemented at the time of drafting this report (Stephen, 2024).

3.2.2.3 Data sources, data quality and verification

The LCAs in Foodsteps database are performed according to the GHG Protocol Product Life Cycle Accounting and Reporting Standards and align with the ISO 14040 Standard. They have constructed their own database using all these resources.

Foodsteps have a system to calculate the quality of the data they are generating called the Data Quality Score. It spans 6 dimensions, each scored 0-10, and summarises the quality and relevance of the data used for the impact estimates. The 6 dimensions are:

- Methodological: Foodsteps calculates impact estimates for different food items using various methods, depending on the food type and available data. If they can directly match a food item to their database, it gets a higher score than if they need to match it to a proxy item.
- Geographic: Assesses how well the sourcing profile matches the data tied to production and consumption regions.
- Recency: Assesses how recent the data supporting an estimate is.
- Source Reliability: Assesses the rigour of sources and studies used to generate impact estimates directly.
- Impact Estimate Dispersion: How much agreement and variation there is within the data points supporting a calculation.
- Completeness: Whether there is a lack of specificity or coverage within the underlying data supporting the impact estimates.

These are weighted according to their importance and the final score is calculated out of 10, with the higher the score, the better the food product's true emissions are estimated. The weightings information is not provided by Foodsteps. By generating these scores, Foodsteps know where they need to focus their efforts to source more data of better quality, accuracy, and relevance to improve their impact estimates and overall output (FS, 2023b).

Foodsteps do have the ability to verify their assessments and data, but it is unknown how regularly this occurs as they state: "We can organise for the assessment to be reviewed and verified by an independent third party".

3.2.2.4 Normalisation and aggregation

As Foodsteps only covers one impact category, aggregation is limited to combining metrics (i.e. emissions of different GHGs and carbon sequestration, expressed using GWP). The label displays the total GWP (as CO_2e) for a product per serving, plus a rating from A to E (best to worst) that reflects the carbon intensity of the product (carbon footprint per kilogram). This is potentially confusing as Foodsteps highlight that these pieces of information can conflict (FS, 2023c):

> *"Can the A-E rating system and the impact per kilogram conflict?*
>
> *Yes, the two pieces of information can occasionally conflict when comparing items with very different portion sizes. For example, small portions of high carbon intensity items may have a lower carbon footprint per serving than less carbon-intensive items served in large quantities. We think providing both pieces of information is key to comparing the carbon footprint of different food items fairly."*

Table 3.5 shows the carbon intensity (CO_2e per kg) threshold values for the A to E ratings.

Table 3.5: Foodsteps carbon intensity rating

Rating	Boundary	What this means
A	Below 1.81 kg CO_2e/kg	A-rated recipes are also referred to as 'Very Low' carbon impact and have the lowest impact on the planet. These recipes align to the planetary boundaries required to feed the planet sustainably by 2050.
B	From 1.81 to 2.90 kg CO_2e/kg	B-rated recipes are also referred to as 'Low' carbon impact. Although these recipes are on the pathway to staying within the planetary boundaries, diets with B-rated recipes will ultimately surpass them.
C	From 2.90 to 4.63 kg CO_2e/	C-rated recipes are also referred to as 'Medium' and although they are below the average carbon intensity in our diets today, continuing to eat diets with our current average carbon intensity will mean we surpass the planetary boundaries required.

Rating	Boundary	What this means
D	From 4.63 to 7.50 kg CO_2e/kg	D-rated recipes are also referred to as 'High' and are above the average carbon intensity in our diets. A diet consisting of D-rated recipes will mean we surpass the planetary boundaries required.
E	From 7.50 kg CO_2e/kg	E-rated recipes are also referred to as 'Very High' and have the highest carbon impact and highest impact on the planet. They are substantially above the average carbon intensity in our diets and a diet consisting of E-rated recipes will mean we significantly surpass the planetary boundaries required.

Source: Stephen (2024)

As described in Table 3.5 the A rating has been derived from planetary boundaries based on the EAT Lancet report (Willet *et al*., 2019), with B and C based on 2050 and 2030 targets in relation to this, with D and E multiples of these targets (Stephen, 2024). Thus, the rating system is largely normalised following the planetary boundaries concept.

3.2.2.5 Transparency

Foodsteps have a good website with details about the scheme available, and an additional download showing the scoring for 100 products (FS, 2023b), with more methodology explanation. There is also the option to request a demo of their platform. The clarity of the information is reasonable but there are still a few questions around their calculations left unanswered, as highlighted above. Ownership and aims are very clear for Foodsteps, and there is a little on the limitations. Their approach is to only use GHG emissions/CO_2 equivalent as the impact category and so discarding all other environmental impacts. Due to this, they do not use normalisation or aggregation. There is some explanation as to where they source their data from and that they also have developed their own database. They appear to have a system of internally verifying data but there is not much detail around this.

3.2.3 Foundation Earth

Foundation Earth was established in 2019 and is a non-profit organisation based in Europe, with its headquarters being split between Spain and the United Kingdom. It is financed by members through yearly membership subscriptions, fees for processing products through their scoring system, as well as through European innovation grants.

Sources: Foundation Earth documentation (FE, 2023a-d).

3.2.3.1 General characterisation

Foundation Earth is a business set up to bring about change in the food industry, so it becomes more sustainable. It is targeting both consumers and food businesses to do this and have created a scientific committee and industry advisory panel to ensure they stay grounded in the science and relevant to industry. They are developing an on-pack score to inform consumers of the environmental impact of the product, based on LCA data but not involving primary producers. They state that they will use a wider grade range than most with A+ to G ratings possible, and RAG colouring (FE, 2023b). Foundation Earth has been developing their label over time and has had a couple of rounds of trials with UK retailers. From this work they have concluded that using the EU PEF environmental indicators and sourcing the data from multiple databases was the way forward. They are also encouraging the use of primary data where possible and rates the data quality as part of the score accordingly. Using the PEF alone, means they are not accounting for animal welfare, biodiversity, carbon sequestration or nutrition. The environmental outcomes are not measured directly, although by using the LCA approach and the PEF, there is potential to do so in the future. Foundation Earth work to verify the data for each product as its score is generated for the data but this does

not appear to be independently verified. The website for Foundation Earth is clear with information about the scheme and LCA methodologies readily available either on screen or as downloadable documents. They acknowledge that there are some limitations around what is classified as primary data and how that is collected. The full characterisation for Foundation Earth can be found in Appendix C.3.

3.2.3.2 Environmental impact coverage

Table 3.6 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.6: Impact coverage and data source: Foundation Earth

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◕	▲	■	◇
	Air quality regulation	◍	▲	■	◆
	UV-B radiation regulation	●	▲	■	◇
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision				
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision	●	▲	□	◆
	Nutrient provision	◍	▲	□	◆
	Soil provision				
	Soil quality regulation	◔	▲	□	◆
	Mass flows regulation				
Hydrosphere	Water provision	◍	▲	■	◇
	Water conditions regulation	◔	▲	■	◆
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Foundation Earth uses the standard 16 PEF indicators. These are reflected in Table 3.6 as follows:

- Climate regulation: The PEF category of 'Climate Change' is used. This includes GHG emissions and land use change, but does not include carbon sequestration. Like many other schemes, the outcomes of climate change are not measured, and impact metrics are based on GWP (a midpoint/effect metric) derived from activity data rather than direct measurements of GHG emissions. This is derived from a mix of primary or secondary data.
- Air quality regulation: The PEF categories of 'Human Toxicity – cancer', 'Human Toxicity – non-cancer', 'Particulate Matter' and 'Photochemical Ozone Formation – human health' are used. These metrics are effect and outcome oriented (with the latter related to human health) based on secondary data (emission factors) in combination with activity data from a mix of primary or secondary sources.
- UV-B radiation regulation: The PEF category of 'Ozone Depletion' is used, which is an effect (midpoint) metric based on secondary data (emission factors) in combination with activity data from a mix of primary or secondary sources.

- Fossil fuel provision: The PEF category of 'Resource Use – fossils' is used. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data from a mix of primary or secondary sources.
- Nutrient provision: The PEF category of 'Resource Use – minerals and metals' is used. It is not clear if this explicitly includes nutrients. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data from a mix of primary or secondary sources.
- Soil quality regulation: The PEF category of 'Eutrophication – terrestrial' is used, which can be considered an outcome metric. However, no other aspects or metrics related to soil quality regulation are used. It is based on activity data from a mix of primary or secondary sources.
- Water provision: The PEF category of 'Water Use' is used, which is a measure of deprivation potential, which is an effect (midpoint) metric rather than an outcome. No other aspects or metrics related to water provision are used. It is based on activity data from a mix of primary or secondary sources.
- Water conditions regulation: The PEF categories of 'Eutrophication – freshwater' and 'Eutrophication – marine' are used, which can be considered outcome metrics. However, no other aspects or metrics related to water conditions regulation are used. It is based on activity data from a mix of primary or secondary sources.

3.2.3.3 Data sources, data quality and verification

Foundation Earth states that it sources its data from five databases, Ecoinvent, WFLDB, Agri-Footprint, AGRIBALYSE® and GFLI. They also suggest that they want to utilise as much primary data as possible to increase the accuracy of their impact estimates. They therefore have included a mechanism which considers the type of data used in the assessment. This is part of the data quality assessment "Foundation Earth PEF friendly methodology". It is a more qualitative method for data quality but is based on the PEF Data Quality Rating. Foundation Earth have assessed the data for quality for both foreground and background data, and then weighted it for importance. Although it is all written out, it is not straightforward or fully justified. They hope to automate it as there are multiple metrics which make up the score (FE, 2023a). See Appendix D.2 for further details on Foundation Earth's data quality approach.

3.2.3.4 Normalisation and aggregation

Foundation Earth aggregates the outputs from the LCA PEF impact categories following the weightings defined by the PEF, resulting in a single score (FE, 2023a). The single score is then converted to a grade A+ to G (best to worst) to normalise the score for each product (i.e. benchmarking against other products). Foundation Earth have adopted an 'equal product numbers' approach for determining grade boundaries (FE, 2023b). This was selected as "it ensures that a full range of grades are awarded and that there is incentive for food manufacturers to make changes to production chains to improve grading". However, this can be meaningless from the perspective of conveying the environmental impact of a product as it is always relative to the population of products on which it is based. For example, Figure 3.1 shows that the impact score for 35 products ranges from 50 to 526 (fictional data). Using Option 1, a product would be banded based on the range of impact scores using a linear relationship. However, Option 2, as adopted by Foundation Earth, means that products are equally distributed across the 7 bands, i.e. 5 in each one. Thus, for example, if a product has an impact score of 345 it gets categorised as Band E under Option 1 and Band C under Option 2, which is potentially misleading with respect to actual impact.

Figure 3.1: Different approach to banding environmental impacts

FE (2023c) outlines that products were previously normalised by comparing the findings to a basket of food items in the UK, but this is now changing to a much larger group of products. Foundation Earth intend to use their whole database for normalisation to be more effective and remove the challenge of regional differences in buying habits, or potential bias in the selection of the basket.

Foundation Earth does not appear to normalise the impacts against any environmental benchmarks such as planetary boundaries.

3.2.3.5 Transparency

Foundation Earth have a good website which provides a helpful overview of their work, and multiple downloads containing detailed information on their aims, approach, methodology and calculations. It is all well written and clear, covering their chosen impact categories and outlining limitations, as well as covering some of the omissions made. The metrics they use are stated but there is nothing on environmental outcomes. They use a primitive normalisation approach which is explained but their aggregation techniques are clearly explained. Overall, Foundation Earth have made a good effort to be transparent.

3.2.4 Institute of Grocery Distribution (IGD)

The Institute of Grocery Distribution (IGD) was established in 1909 to provide formal education for young people in the retail grocery trade. Today the IGD is a research and training charity covering the whole of the supply chain. Their work includes championing food waste reduction to address climate change; making healthy and sustainable diets easy for everyone; and providing strategic analysis of the economic, social and political challenges the industry is facing, to help support planning and decision-making. This has included work on ecolabelling of food. At the time this review was undertaken (Nov 2023- March 2024), IGD was developing a concept for an ecolabel for food in the UK, so the analysis below is based on that. The remit of IGD may have changed since then, but the analysis of their ecolabelling concept remains valid.

Sources: IGD documentation (IGD, 2023a&b).

3.2.4.1 General characterisation

IGD are a prominent voice for the food industry with a membership who were tasked with developing "a harmonised solution to environmental labelling". This included the stated objectives of increasing the transparency of the environmental impact of food production, including the supply chain, so consumers and businesses are better informed and can make better decisions about sustainability of purchases. It is still being developed but looks like it will be top down focused, with the labels going out to retailers on food products and carrying an A-E, RAG coloured score. IGD undertook extensive research including a wide range of stakeholders, enabling them to develop the most appropriate way forward to achieve their aims. Their most recent report explains their progress to date. This includes show the four environmental indicators to be used which have come from the PEF 16 to create a score which reflects the most pressing issues facing the earth and will rate them against planetary boundaries. The most significant omission in their indicators, from what is communicated, is that of biodiversity as there currently is not an adequate metric for this (land use is used by IGD as a surrogate, but this is a poor metric for representing impacts on biodiversity). The ecolabel will be LCA-based so impacts will not be directly measured on farms, although IGD would like to use supply chain specific data to improve the quality of the outputs. As part of their trials and research to explore developing a robust label, IGD have investigated what the governance of an ecolabel should look like and the role it is to have. They also state their desire to create a UK specific database with partners Anthesis rather than utilising the currently existing databases which do not well represent the UK food system. The public availability of information relating to the IGD ecolabel development is not as full as it could be. There is very little on their website directly, with a need to sign up to a free association with IGD to have access to some of the reporting documents. Updates are not regularly released, with the most recent one released in December 2023. There are potentially additional documents that are only available with a paid membership to IGD. The full characterisation for IGD can be found in Appendix C.4.

3.2.4.2 Environmental impact coverage

Table 3.7 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.7: Impact coverage and data source: Institute of Grocery Distribution (IGD)

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	●	▲	■	◇
	Air quality regulation				
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision				
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision				
	Nutrient provision				
	Soil provision				
	Soil quality regulation				
	Mass flows regulation				
Hydrosphere	Water provision	◍	▲	■	◇
	Water conditions regulation	◔	▲	■	◆

	Impact category	Coverage	Activity	Effect	Outcome
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

IGD uses 4 of the standard 16 PEF indicators. These are reflected in

Table 3.7 as follows:

- Climate regulation: The PEF category of 'Climate Change' is used. This includes GHG emissions, land use change and carbon sequestration. Like many other schemes, the outcomes of climate change are not measured and impact metrics are based on GWP (a midpoint/effect metric) derived from activity data rather than direct measurements of GHG emissions. This is derived from a mix of primary or secondary data.
- Water provision: The PEF category of 'Water Use' is used, which is a measure of deprivation potential, which is an effect (midpoint) metric rather than an outcome. No other aspects or metrics related to water provision are used. It is based on activity data from a mix of primary or secondary sources.
- Water conditions regulation: The PEF categories of 'Ecotoxicity – freshwater' and 'Eutrophication – marine' are used, which can be considered outcome metrics. However, no other aspects or metrics related to water conditions regulation are used. It is based on activity data from a mix of primary or secondary sources.

3.2.4.3 Data sources, data quality and verification

IGD have not been clear about where they source their data and have been planning to create their own databases specifically for the UK market and to the ingredient level, however this may have been recently retracted. They have been working with a wide range of stakeholders, which includes other ecolabels such as Foundation Earth and Foodsteps, and data partners ADEME, Mondra, OPRL and Oracle, so it could be that some of these are providing the data for LCA work.

Data quality is understood as important by IGD and needs to be handled correctly. They use WRAP's framework on Scope 3 for GHG reporting (WRAP, 2022) to handle data quality of their background data but not foreground data. IGD have a recommendation for it: "standardised data quality threshold for foreground and background data" based on evidence and stakeholder input. It also comes under their governance guidance as well where "rules or incentives to improve data quality over time e.g., incentivising businesses to move from representative impacts to supply chain specific data" and "specific and consistent methodologies and rules on minimum data quality standards for environmental reporting" are recommended (IGD, 2023a).

The approach to verification for IGD is not yet available as it is still under development but is likely to come under their governance section relating to consistency for assurance and compliance.

3.2.4.4 Normalisation and aggregation

IGD utilise the concept of planetary boundaries (see Section 2.3.5 and Appendix A) to normalise the outputs from their impact metrics, which involves expressing the impact category relative to a reference value that is considered to be within planetary boundaries. Planetary boundaries are expressed per capita per annum, which can then be converted to a daily per capita value, which aligns with food consumption. This has the potential to be meaningful with respect to placing the value within context on a food label. However, planetary boundaries do not exist for all impacts and associated metrics, thus their application to date has been limited.

IGD recommends that the normalised impact values are combined into a single score, adopting the weightings in the PEF as the means to aggregate them. However, IGD recognises that this is subjective and once the scores have been aggregated, the connection to planetary boundaries is lost. The aggregated score

is converted to a grade A to E (best to worst). How this is done has yet to be determined, with IGD stating that further research is needed.

3.2.4.5 Transparency

IGD are still in the process of developing their approach and so not everything is available. They also require signing up to their website to access most of the content they have released, and there is also a paid-for (IGD membership) section which increases website access. The clarity is reasonable for the content which can be accessed, with the ownership and aims being most clearly presented. The work they are doing is very thorough and explains well the chosen impact categories, the metrics used and methodology around normalisation and aggregation. However, there is less information about omissions and where the data will be sourced from, and very little about verification of the data.

3.2.5 Planet-Score

Planet-Score was developed in 2021 in France by Organic Food and Farming Institute (ITAB), research organisation Sayari, and consumer focused-research Very Good Future. Its aim is to differentiate environmental impacts between different categories of products (for example a meat product vs an apple), as well as within categories (for example between different varieties of apples) according to their differing production methods.

Sources: Planet-Score website (Planet-Score, 2024) and documentation (Planet-Score, 2021 & 2022).

3.2.5.1 General characterisation

Planet-Score is a dual-purpose organisation which evolved from l'Institut de l'agriculture et de l'alimentation biologiques (ITAB) to both enable an ecolabel to be produced and continue research to improve it. They state that they want to increase the transparency of the environmental impact of agricultural production and reduce greenwashing so that consumers and businesses can make more informed purchasing decisions that would encourage agricultural practice change. They appear have taken a top-down approach and have not included primary producers. Currently the label is not in the UK, with the main markets being in France and Germany, on single products across retailers. Planet-Score's methodology shows they use the PEF indicators, removing 4 of the 16 from their calculations and collapsing the others into 4 broader categories. It also shows they have included 3 sub-indicators bringing bonus/malus points to the overall score (human health, biodiversity & climate) which they also display separately on the label, and animal welfare, which is on the label but not included in the score. There are no direct measurements made, and data is sourced from AGRIBALYSE®. The data verification into product scores appears to be done by Planet-Score themselves using their calculation methodology. As Planet-Score is French, the important documentation is in French and needs to be translated, although their website has a full English equivalent. However, the score methodology is not explained fully. They themselves point out that a limitation of the AGRIBALYSE® database they use is that it does not go far enough to provide all the data they would like to utilise which is why they have added additional categories to their score and are continuing research to aid filling these gaps. The full characterisation for Planet-Score can be found in Appendix C.5.

3.2.5.2 Environmental impact coverage

Table 3.8 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.8: Impact coverage and data source: Planet-Score

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◍	▲	■	◇
	Air quality regulation	◑	▲	■	◆
	UV-B radiation regulation	●	▲	■	◇
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision				
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision	●	▲	□	◆
	Nutrient provision	◔	▲	□	◆
	Soil provision				
	Soil quality regulation	◑	▲	□	◆
	Mass flows regulation				
Hydrosphere	Water provision				
	Water conditions regulation	◑	▲	□	◆
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Planet-Score uses 12 out of the standard 16 PEF indicators (albeit the documentation is unclear in the explanation of what metrics are used). These are reflected in Table 3.8 as follows:

- Climate regulation: The PEF category of 'Climate Change' is used. It is not clear what this covers with respect to GHG emissions, land use change and/or carbon sequestration. Like many other schemes, the outcomes of climate change are not measured, and impact metrics are based on GWP (a midpoint/effect metric) probably derived from activity data rather than direct measurements of GHG emissions. The data seems to come from the AGRIBALYSE® database, implying it is fully from secondary sources.
- Air quality regulation: The PEF categories of 'Human Toxicity – cancer', 'Human Toxicity – non-cancer', 'Particulate Matter' and 'Photochemical Ozone Formation – human health' are used. These metrics are effect and outcome oriented (with the latter related to human health) based on secondary data (emission factors) in combination with activity data, which appears to be fully from secondary sources.
- UV-B radiation regulation: The PEF category of 'Ozone Depletion' is used, which is an effect (midpoint) metric based on secondary data (emission factors) in combination with activity data, which appears to be fully from secondary sources.
- Fossil fuel provision: The PEF category of 'Resource Use – fossils' is used. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data fully from secondary sources.
- Nutrient provision: The PEF category of 'Resource Use – minerals and metals' is used. It is not clear if this explicitly includes nutrients. This is an outcome-oriented metric (there is no effect/midpoint metric) that is based on activity data fully from secondary sources.
- Soil quality regulation: The PEF categories of 'Acidification' and 'Eutrophication – terrestrial' are used, which can be considered outcome metrics. However, no other aspects or metrics related to soil quality regulation are used. The data seems to come from the AGRIBALYSE® database, implying it is fully from secondary sources.
- Water conditions regulation: The PEF categories of 'Ecotoxicity freshwater', 'Eutrophication – freshwater' and 'Eutrophication – marine' are used, which can be considered outcome metrics. However, no other

aspects or metrics related to water conditions regulation are used. The data seems to come from the AGRIBALYSE® database, implying it is fully from secondary sources.

Planet-Score seems to have developed its own metrics to assess the impact of pesticides on biodiversity and human health (having withdrawn the use of the PEF categories for Human toxicity and ecotoxicity). However, the details of the metric are not clear (e.g. it is not clear by which pathways the impact of pesticides is being assessed). These aspects do not measure environmental impacts, they only aim to account for other aspects that can impact on the environment that are not covered by the metrics above (Planet-Score, 2021).

3.2.5.3 Data sources, data quality and verification

Planet-Score state that they source their LCA data from AGRIBALYSE®. There is no information on their website or online downloadable documents regarding data quality. If they are sourcing their LCA data from AGRIBALYSE®, then it will have the data quality scoring done by AGRIBALYSE® before the data is received (see Appendix D.1). Any data verification which is carried out is done internally by Planet-Score according to their methodology and not by a third party/independent auditor.

3.2.5.4 Normalisation and aggregation

The PEF metrics within Planet-Score appear to be converted to 0-100 scale using a logarithmic transformation of the outputs from each metric. There is reference to planetary boundaries within the Planet-Score documentation, but it is not clear how this has been employed (if at all) within the metrics to normalise them. Planet-Score have adopted an aggregation "similar" to the PEF to combine the LCA metrics into a single value. The aggregated score is converted to a grade A to E (best to worst). The conversion of the aggregated score to A to E (best to worst) appear to be simple linear distribution of the 0-100 scale, i.e. 80-100 = A; 60-80 = B; 40-60 = C; 20-40 = D; 0-20 = E. The metrics associated with pesticides, biodiversity and climate are also presented separately on the label using the 0 to 100 scale (the label also includes an assessment for animal welfare).

3.2.5.5 Transparency

Planet-Score was developed in France, so have a French and English version of their website, which is virtually the same. However, most of their more detailed information (available to download via a request system), is in French so needs translating before use. Most of this documentation is in the form of presentation material so is not as clear as it could be. There is some information about scheme ownership and limitations, but the aims and objectives are clear. They outline their impact categories as well as some of the omissions and metrics, but there is nothing on outcomes. There is some communication about where they source their data, and the aggregation methodology used, but nothing about normalisation, so it is unclear whether it is something they utilise or not. Their benchmarking approach is also well laid out and understandable.

3.2.6 Summary outputs for Group 1 schemes

Table 3.9 shows the outputs for the impact coverage assessments for all the Group 1 schemes.

Table 3.9: Impact coverage and data source: Group 1 schemes

	Impact category	ES	FS	FE	IGD	PS
Atmosphere	Climate regulation	◍▲■◇	●▲■◇	◕▲■◇	●▲■◇	◍▲■◇
	Air quality regulation	◑▲■◆		◍▲■◆		◑▲■◆
	UV-B radiation regulation	●▲■◇		●▲■◇		●▲■◇
	Gaseous flows regulation					
Biosphere	Animals provision					
	Biomass provision					
	Habitat provision					
	Pollination regulation					
	Seed dispersal regulation					

	Impact category	ES	FS	FE	IGD	PS
	Pest control regulation					
	Disease control regulation					
Geosphere	Fossil fuel provision	●▲☐◆		●▲☐◆		●▲☐◆
Geosphere	Nutrient provision	◍▲☐◆		◍▲☐◆		◔▲☐◆
Geosphere	Soil provision					
Geosphere	Soil quality regulation	◔▲☐◆		◔▲☐◆		◑▲☐◆
Geosphere	Mass flows regulation					
Hydrosphere	Water provision	◍▲■◇		◍▲■◇	◍▲■◇	
Hydrosphere	Water conditions regulation	◔▲■◆		◔▲■◆	◔▲■◆	◑▲☐◆
Hydrosphere	Water flows regulation					

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △☐◇ = Not covered

3.3 Group 2 schemes

3.3.1 A Greener World – Certified Regenerative

A Greener World was established in the USA in 2014 and transitioned to an autonomous not-for-profit organisation in 2016. Initially operating in the USA and Canada, they now have operations around the world including the UK. They operate several labels including Animal Welfare Approved, Certified Grassfed, Certified Non-GMO and Certified Regenerative, the latter being of most relevance and explored within this review.

Sources: A Greener World website (AGW, 2024) and Certified Regenerative Standards version 1.1 (AGW, 2023).

3.3.1.1 General characterisation

A Greener World Certified Regenerative label aims to "function as a management tool that helps producers meet their own regenerative goals through an audited, regenerative plan—and offers early access to regenerative markets without being certified organic". It is therefore targeting primary producers and operating from a bottom-up perspective. AGW is operating in the UK, but there are no products available for retail bearing the Certified Regenerative label yet, and no information about how many producers are working towards it (only 1 farm found so far on their UK website). The scheme appears to cover the whole farm and products coming from the farm can bear the label if certification is given. The impact categories are those associated with regenerative agriculture practice and centre around soil, water, air quality and biodiversity, with a few additional categories to be positively managed. The scheme does require that some measurements be taken, covering fossil fuel usage, water and water quality, soil health, air and biodiversity. However, these are largely indirectly related to environmental outcomes. To be accepted into the Certified Regenerative scheme, the farm must meet the requirements of the Animal Welfare Approved certification first. A Greener World operate by setting the scheme standards but work closely with the farm to develop an action plan including risk management. The standards are not all compulsory as some are recommendations only. It appears that they have their own trained independent auditors who verify the data and visit farms once a year for inspections. They ensure standards are being met and adhered to but work with farmers to find solutions where breaches occur. The information on A Greener World's website and in their standards documentation is clear and publicly available. The full characterisation for A Greener World Certified Regenerative can be found in Appendix C.6.

3.3.1.2 Environmental impact coverage

Table 3.10 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.10: Impact coverage and data source: A Greener World – Certified Regenerative

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◕	▲	□	◇
	Air quality regulation	◑	▲	□	◇
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision	●	▲	■	◆
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision	●	▲	□	◇
	Nutrient provision				
	Soil provision	●	▲	□	◇
	Soil quality regulation	◑	▲	■	◆
	Mass flows regulation	●	▲	□	◇
Hydrosphere	Water provision	◑	▲	□	◇
	Water conditions regulation	◑	▲	□	◇
	Water flows regulation	◑	▲	□	◇

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

A Greener World has several standards relating to specific environmental impacts. These are reflected in Table 3.10 as follows:

- Climate regulation: Principle 5 of the standards states that "Agricultural carbon sequestration and other management practices can mitigate global warming. A regenerative system should capture, store and cap carbon in the soil. Regenerative stewards must also avoid polluting the air as part of the atmosphere"; there is also mention of monitoring fossil fuel usage. No reference to land use change is evident.
- Air quality regulation: Section 5 of the standards contain specific requirements for air including the certified holding must minimise risk of air pollution. There is specific reference to dust, particulates and ammonia emissions.
- Habitat provision: Section 8 of the standards contain specific requirements for biodiversity including, "The list and actions to measure habitats and species on the holding will be used as a benchmark in order to demonstrate the improvement in habitat and species over the time of the Regenerative Plan".
- Fossil fuel provision: Section 2 requires fossil fuel usage to be monitored.
- Soil provision: Section 3 of the standards contains requirements to minimise and prevent soil erosion.
- Soil quality regulation: Principle 5 of the standards states that "Certified Regenerative agriculture works to maintain, restore, and build soil health to the best extent possible for that location". Every holding must track two measures of soil health. Section 3 of the standards are devoted to best practices for soil.

- Mass flows regulation: Section 4 of the standards has requirements to have buffer zones alongside watercourses to prevent sediment lost via erosion entering the water.
- Water provision: Section 4 of the standards cover water consumption including monitoring the quantities used per year.
- Water conditions regulation: Section 4 of the standards cover preventing water pollution.
- Water flows regulation: Section 4 of the standards cover some issues relating to flows of water.

3.3.1.3 Data sources, data quality and verification

A Greener World have "independent trained auditors" which carry out the annual inspections for Certified Regenerative farms. The process to becoming Certified Regenerative starts with the farm/holding writing a Regenerative Plan alongside a Qualified Expert. This is reviewed by AGW's Review Panel who then decide whether to agree it. A physical audit to the farm is then undertaken once a year by "Certified Regenerative staff or agents" where records, measurements and the Regenerative Plan are used as evidence of compliance to the standards. Included in the Regenerative Plan are assessments with expected results over time to monitor change. This is for soil, water, air, fuel use for machinery (for emissions record), biodiversity, species log and habitat improvement plan standards.

3.3.1.4 Transparency

A Greener World has a comprehensive website where the information is clearly laid out and all available, so their multiple schemes can be understood. Their Certified Regenerative standards are available on their website and as a download and are straightforward. They also provide the forms and templates in which to document farm information and measurements needed for the regenerative plan. The aims of the scheme are well presented but there is no mention of scheme limitations. The standards document is the main one to use for the impact category information, and the metrics to be used are reasonably clear. There is some suggestion that there are environmental outcomes. The data sources and benchmarks are well explained but due to being an assurance scheme, there is no use of normalisation and aggregation. The data is verified through inspection by their approved auditors, but only a hint at verification of impacts.

3.3.2 Fair to Nature

Fair to Nature is operated by the Royal Society for the Protection of Birds (RPSB) and is a biodiversity farming standard that requires farms to create and/or actively manage a specified range of high-quality wildlife habitats, and manage their soils, crops and livestock to support nature. Farmers are required to manage at least 10% of their farmed land in a range of habitats and farming practices that benefit wildlife. The history of this scheme can be traced back to 1989, when Bill Jordan (Jordan's Cereals) helped create "Conservation Grade" farming. In 2016, The RSPB formed a partnership with Conservation Grade and it was rebranded as Fair to Nature (RSPB, 2016).

Sources: Fair to Nature website (FtN, 2024), Fair to Nature standard, Version 3.1a (FtN, 2023).

3.3.2.1 General characterisation

Fair to Nature aims to "help to protect and restore nature on farmland while making it easier for people to recognise sustainable products and support businesses that are committed to making a genuine difference". It is a bottom-up scheme with primary producers involved, but appears quite niche in the UK with only a few products including animal feed and birdseed shown on the website. These products are also only able to be sold by approved licensees. The scheme states that it covers the whole farm and requires a minimum of 10% of the farm to be developed for high quality habitat for wildlife. Biodiversity is the impact category which the scheme covers, meaning many other important impact categories are not covered. However, they require a carbon footprint assessment to be done on joining the scheme and every 4 years after, a soil management

plan needs to be devised every year with improvements made, and an Integrated Pest Management (IPM) plan every 2 years with the focus being around reducing pesticide use, so integral to the scheme are positive practices for other impact categories. The measurements which seem important for the scheme are those around the amount of land which is being managed for high quality habitat and there is a minimum needed to qualify for acceptance onto the scheme, although there is support available to help farmers reach this. Farmers can choose to go beyond this and other standards of the scheme, but these do not appear to bring additional benefit to the farmer to do so, but should increase the environmental benefits of managing their land in this way. Fair to Nature say that they have their own auditors/advisors who visit every farm in the scheme every 2 years to verify the adherence to the scheme standards, environmental impacts made, and review action plans. They also have procedures to deal with scheme non-conformance which can result in membership suspension. Fair to Nature state that they have put in place an advisory panel and steering committee to aid the governance of the scheme and these groups also regularly revise the standards, so the scheme continuously evolves over time. The information and documentation for the scheme are publicly available on the website and in downloads, and are clearly presented. The full characterisation for Fair to Nature can be found in Appendix C.7.

3.3.2.2 Environmental impact coverage

Table 3.11 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.11: Impact coverage and data source: Fair to Nature

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◍	▲	■	◇
	Air quality regulation				
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision				
	Habitat provision	●	▲	■	◆
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation	●	▲	■	◇
	Disease control regulation				
Geosphere	Fossil fuel provision				
	Nutrient provision	●	▲	□	◇
	Soil provision				
	Soil quality regulation	◕	▲	■	◇
	Mass flows regulation				
Hydrosphere	Water provision	◑	▲	□	◇
	Water conditions regulation	◑	▲	□	◇
	Water flows regulation	◑	▲	□	◇

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Fair to Nature has several standards relating specific environmental impacts. These are reflected in Table 3.11 as follows:

- Climate regulation: Section 4 of the standards specifically covers carbon management which includes undertaking a full farm carbon foot-printing assessment every four years. It is not clear what the footprint

should include and there is no reference to measuring emissions (thus it is assumed that these would be calculated using activity data and emission factors).

- Habitat provision: This is the primary focus of the scheme and Section 2 of the standards contains significant details of what is required. A Fair to Nature Habitat Assessment is undertaken every two years and members are requested to survey the wildlife on the farm annually using farm staff or volunteers.
- Pest control regulation: Section 6 of the standards requires that an IPM plan is maintained, and this should include maximising the potential for natural pest control.
- Nutrient provision: Section 7 of the standards requires records of nutrient applications to be made.
- Soil quality regulation: Section 3 of the standards covers soil management including that records are kept from soil monitoring ("at least one of Soil Organic Matter (SOM) testing, Visual Evaluation of Soil Structure (VESS) or earthworm counts").
- Water provision: Section 8 of the standards covers water use including water efficiency and minimising use.
- Water conditions regulation: Section 8 of the standards covers water pollution with a general requirement to "identify specific risks to water quality".
- Water flows regulation: Section 8.4 of the standards specifically covers requirements on water flows within the context of flood management.

3.3.2.3 Data sources, data quality and verification

For Fair to Nature, it appears that inspections are carried out by their own staff rather than an independent third party or certification body. The documentation states that inspections/audits are conducted every 2 years, and are particularly important where farms have a supply contract. A farm plan is put together by the farmer and checked in the inspection that progress is being made. This particularly covers carbon footprint, IPM, water management and fertiliser use. Compliance to the control points in the standards is achieved by production of relevant documentation and evidence at audit. All the control points have a verification description which shows what needs to be met to prove compliance. Measurement proof is needed for soil management control points, that SOM has improved and test results for P and K show improvement. In addition to checking compliance, Fair to Nature say they will carry out a Habitat Assessment to track the development of nature friendly habitats. This is also done every 2 years by an approved advisor.

3.3.2.4 Transparency

Fair to Nature have made available publicly their information, approach and standards and have clearly presented these. Their website is comprehensive with the standards available as a click-through to a download. The scheme is identified as owned by RSPB and the aims of the scheme laid out. There are no limitations included in the information. The impact categories and metrics are transparent, but nothing has been written on omissions, despite the scheme being relatively narrow on impact scope. The data source and benchmarks are well explained, and some information is available about environmental outcomes. The scheme data is verified by inspection, with some suggestion that the impacts are verified as well.

3.3.3 LEAF Marque

Linked Environment And Farming (LEAF) was established in 1991 to promote Integrated Farm Management (IFM) and developing more environmentally friendly farming systems. This included the development of the LEAF Audit and a network of demonstration farms. LEAF Marque was established in 2001 with the aim of rewarding farmers for their commitment to the environment and to give consumers a choice of buying food that was produced to high environmental standards.

Sources: LEAF Marque website (LEAF, 2024) and LEAF Marque Standard. Version 16.1 (LEAF, 2023).

3.3.3.1 General characterisation

The LEAF Marque scheme aims to "inspire and enable more circular approaches to farming through integrated, regenerative, and vibrant nature- based solutions, that deliver productivity and prosperity among farmers, enriches the environment, and positively engages young people and wider society". It is now a global scheme, and in the UK has been taken up by some of the major retailers such as Tesco. The label is displayed on food products when certification has been attained. The scheme impact categories are stated as soil health, crop health, pollution control, animal husbandry, water, landscape/nature conservation, stemming from the IFM principles. To become a LEAF Marque farm, products must already carry a baseline scheme certification, such as Red Tractor, and a LEAF Sustainable Farming Review completed. LEAF say that they utilise Certification Bodies to independently verify data and award certifications. The Landscape and Nature Conservation Audit is assessed by a specialist advisor and inspections are done every year, but it is unclear whether these functions are performed by LEAF, the Certification Body or another party. It is also unclear whether every farm in the scheme is inspected every year. The scheme standards have shown to evolve over time and there are procedures to enforce standards and deal with non-compliances. Information on the LEAF Marque is available to the public on their website and in downloadable standards and other documents. The information is relatively clear but spread across several documents, so it is not always straightforward to find the desired information. The full characterisation for LEAF Marque can be found in Appendix C.8.

3.3.3.2 Environmental impact coverage

Table 3.12 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.12: Impact coverage and data source: LEAF Marque

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	●	▲	■	◇
	Air quality regulation	◑	▲	□	◇
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision				
	Biomass provision	●	▲	□	◇
	Habitat provision	◕	▲	■	◆
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation	●	▲	■	◇
	Disease control regulation	●	▲	■	◇
Geosphere	Fossil fuel provision	●	▲	■	◇
	Nutrient provision	●	▲	■	◇
	Soil provision	●	▲	■	◇
	Soil quality regulation	◑	▲	■	◇
	Mass flows regulation	●	▲	□	◇
Hydrosphere	Water provision	●	▲	■	◇
	Water conditions regulation	●	▲	■	◆
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

LEAF Marque has several standards relating specific environmental impacts. These are reflected in Table 3.12 as follows:

- Climate regulation: The LEAF Marque system aims to deliver positive action for climate including "implementation of strategies to reduce GHG emissions and sequester carbon". This includes requirements in soil management plans to improve carbon capture, carbon sequestration and retain soil organic carbon; and carbon footprint calculations are made on an annual basis (incl. land use change) as a means of recording GHG emissions.
- Air quality regulation: The standards include several requirements to reduce air emissions as part of a generic pollution risk assessment.
- Biomass provision: Section 8 of the standards includes a requirement for strategies to provide nesting habitat and food for native fauna.
- Habitat provision: Section 8 of the standards covers landscape and nature conservation which includes a requirement for strategies to provide habitat for native fauna. There is also a requirement for at least one representative species or habitat to be monitored on the farm.
- Pest control regulation: Section 3 of the standards requires that there be a system in place for monitoring and recording pests (including vertebrate), disease, weed levels and beneficial predatory species.
- Disease control regulation: Section 3 of the standards requires there is a system in place for monitoring and recording disease levels.
- Fossil fuel provision: Section 6 of the standards cover energy efficiency including monitoring consumption.
- Nutrient provision: Section 2 of the standards includes the development of an integrated nutrient management plan which also considers the sustainability of nutrient inputs, and strategies to source from more sustainable alternatives or reducing use where possible; and all organic and inorganic fertiliser applications are recorded.
- Soil provision: Section 2 of the standards includes requirements to reduce the risk of soil degradation and includes "no significant visual evidence of soil damage such as compaction or soil erosion".
- Soil quality regulation: The LEAF Marque system aims for improved soil management to enhance soil quality and soil health; and the soil management plan should include "targets to improve and maintain biological, physical, and chemical attributes of soil health" and "measures to conserve and build up soil organic matter". Section 2.14 requires that soil health is measured using one or more of the following: - Visual Soil Assessment; earthworm counts; or a measure justified by the business. Measurements are taken and recorded at least annually or at a frequency justified by the business, which identifies and implements an appropriate sampling strategy.
- Mass flows regulation: Section 2 of the standards includes requirements to reduce the risk of soil degradation and includes "no significant visual evidence of soil damage such as compaction or soil erosion"; and Section 5 includes requirements to reduce soil erosion and run-off from grassland.
- Water provision: Section 7 of the standards covers water management which covers water use and that water use efficiency is measured.
- Water conditions regulation: Section 4 of the standards covers water pollution control; Sections 2 and 3 cover nutrient and pesticide pollutants, Section 5 pollutants from livestock and animal feeds; and Section 7 includes a requirement to monitor water quality. This should include one or more of the following: biological health (e.g. freshwater invertebrates, microbiological testing); physical health (e.g. turbidity); chemical health (e.g. ammonia, nitrate, phosphorus, pH); visual monitoring of quality and condition of drainage ditches and/or watercourses.

3.3.3.3 Data sources, data quality and verification

LEAF state that LEAF Marque audits are carried out by approved Certification Bodies, so the certification is independently third party verified. These take place on a yearly basis on-farm. Verification of standards in the audit can be by interview, documentation or observation, and are outlined in the standards document (LEAF, 2023).

Management plans form an important part in demonstrating compliance. These cover different areas of compliance and may or may not overlap with one another. The latest iteration of the standards (16.1) now

includes more aspects related to soil health and carbon sequestration improvements. There is an IPM plan to record and reduce chemical applications. GHG emissions on farm are recorded and used to build strategies for improvement. They are now recommending the use of a carbon calculator and records are shown at inspection. New recommended standards are on water sources and water quality monitoring, both of which are tested on inspection via interview, observation and records. The inspection also covers conservation of nature and landscapes (LEAF, 2023).

3.3.3.4 Transparency

LEAF Marque has a good website where everything is available across several pages and click-throughs to the standards which can also be downloaded. However, the multiple pages occasionally makes it more challenging to find the needed information. The ownership and aims are clearly laid out but no limitations or impact omissions are discussed. The impact categories and metrics used in the scheme are transparent, as are the data sources and benchmarks, but there is less on outcomes. The explanation and information about data verification is comprehensive, but the verification of impacts is less clear.

3.3.4 Pasture for Life

Pasture for Life was established as an association in 2009 and transitioned to a Community Interest Company in 2011. It champions the restorative power of grazing animals on pasture, and the positive impacts this brings for biodiversity and carbon, human health and wellbeing, and animal health and welfare. They work to restore ecosystems, implement positive change in food and farming systems, and to demonstrate the benefits of 100% pasture-fed.

Sources: Pasture for Life website (Pasture for Life, 2024) and Pasture for Life standards Version 4.4 (Pasture for Life, 2022).

3.3.4.1 General characterisation

Pasture for Life is a UK scheme which appears relatively niche and products are being retailed by butchers and farm shops as well as directly by the farmers themselves. It covers single enterprises with specific products, so not necessarily the whole farm. The impact categories covered by the scheme are animal welfare and biodiversity with the seemingly obvious omissions being air, water and GHG emissions. However, the stated metrics are only for the welfare outcomes assessments, with recommended standards encouraging monitoring soil health in addition to this. If this recommended standard was followed, it might lead to an environmental outcome relating to improved soil health. Required standards must be achieved to be accepted onto the scheme, but several recommended standards that are not compulsory are also included. Pasture for Life state that they use auditors to verify data and arrange annual site visits where required paperwork needs to be submitted. However, they do try and tie the visits in with other schemes to be most efficient. Each certified enterprise is visited at least once a year. The documentation shows that action plans are to be created and are particularly relevant whilst the enterprise converts to a Pasture for Life certified one. Information and documentation for the scheme are publicly available and is clearly presented. The full characterisation for Pasture for Life can be found in Appendix C.9.

3.3.4.2 Environmental impact coverage

Table 3.13 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect, or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.13: Impact coverage and data source: Pasture for Life

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation				
	Air quality regulation				
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision	◔	△	□	◇
	Biomass provision	◔	▲	□	◇
	Habitat provision	◑	▲	□	◇
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation				
	Disease control regulation				
Geosphere	Fossil fuel provision				
	Nutrient provision	●	▲	□	◇
	Soil provision	●	▲	■	◇
	Soil quality regulation	◕	▲	■	◆
	Mass flows regulation	◑	▲	□	◇
Hydrosphere	Water provision				
	Water conditions regulation	◑	▲	□	◇
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Pasture for Life has several standards relating specific environmental impacts. These are reflected in Table 3.13 as follows:

- Animals provision: Section 7.2 of the standards refers to habitats (field margins and strips) that are required for voles which then provide food for barn owls. However, there is no explicit mention of ensuring food supply for wildlife more generally and/or monitoring this.
- Biomass provision: Section 7.4 of the standards contains requirements to provide nesting habitats.
- Habitat provision: Section 7 of the standards contains requirements for managing and ensuring the provision of a range of habitats.
- Nutrient provision: Section 6 of the standards requires nutrient management including application targets; and "artificial fertilisers must only be used when nutrient management planning indicates a need that cannot be met by composts, manures, or green manures".
- Soil provision: The standards emphasise the need to protect soil health and soil structure and that "farm level soil health monitoring should be carried out" (6.1.2).
- Soil quality regulation: The standards emphasise the need to protect soil health and soil structure and that “farm level soil health monitoring should be carried out" (6.1.2). Section 6 also includes requirements for "Actions to maintain and build soil nutrients, soil organic matter and soil microbiological activity; and that the soil health monitoring could include carrying out earthworm counts, slake testing, soil organic matter tests, digging soil pits and similar activities".
- Mass flows regulation: Section 6 of the standards includes requirements for "Actions to eliminate soil erosion". There are also some recommendations to have rough grass at the edges and corners of fields (7.2.5) which can "help slow down run-off from fields". There are also recommendations for waterside management to preserve the structure of any banks.
- Water conditions regulation: The requirement to avoid artificial fertilisers (6.1.6) may help reduce nitrate leaching. There are requirements to avoid pollution from stored silage (7.1.7).

3.3.4.3 Data sources, data quality and verification

Pasture for Life demonstrate that they use approved Certification Bodies to provide independent third-party verification that standards are being met. This is an on-site audit and inspection which follows a self-assessment application declaring compliance by the business or producer. When the requirements have been met, certification is achieved, and products can carry the mark. This is reviewed and renewed annually. Pasture for Life also have a programme for spot inspections which can occur at any time, not just at the annual renewal time. They have tried to reduce the audit burden on businesses by combining inspection visits with other schemes such as Red Tractor, and utilising plans and records made for additional schemes. The inspections are largely record-based to demonstrate adherence to the Pasture for Life standards. In addition to the records, farms need to create a pasture management plan which can include soil health monitoring/tests, and demonstrate they are working effectively to manage and maintain areas of wildlife habitat (Pasture for Life, 2022).

3.3.4.4 Transparency

Pasture for Life have made their information and standards publicly available through a good website and downloadable documents. These are clearly presented, as are their aims and objectives and scheme ownership. The information around the utilised impact categories is present, as well as the metrics used with them. The data sources and benchmarks are clear, but the outcomes are less so. The scheme communicates that the data is verified by inspection but does not discuss verification of impacts.

3.3.5 Soil Association Organic label

The Soil Association has a long history due to being established in 1946. Soil Association Certification Ltd certifies organic products in farming, food processing, restaurants and catering, fisheries, textiles and leather, and health and beauty products. It sets standards for packaging, animal welfare, wildlife conservation, residues and additives. In the context of this review, the Soil Association has been used to represent organic production standards as their organic label is the most widely recognised in the UK and it is the UK's largest and oldest organic certification body.

Sources: Soil Association Organic Standards. Version 1.3 and website (SA, 2023 & 2024).

3.3.5.1 General characterisation

The Soil Association is registered with Defra to certify organic production through the Soil Association Certification. They ensure adherence to the EU regulations for organic production (834/2007, 889/2008 and 1235/2008)[3], but also set higher standards to encourage better and more environmentally beneficial farming practices (SA, 2023). The scheme is targeted to primary producers and therefore a bottom-up approach, although they are consumer facing as well. The Soil Association certifies 70% of all UK organic food and drink products, including imports as well as UK produced (SA, 2024). Their impact categories are stated as animal welfare, protecting human and animal health, safeguarding the environment, and protecting interests of organic consumers. These are quite broad and do cover a range of environmental indicators as standards cover biodiversity conservation and enhancement, preventing environmental contamination, resource use, soil management, and restrictions on agrochemical use. Metrics appear to be largely record keeping rather than measurements, although for soil management, some testing is included. Standards do have to be achieved to be accepted onto the scheme and this usually includes a conversion period where the farm/enterprise changes over to organic production, which is a recognised limitation to the scheme. There is

[3] Organic production is the only agricultural system that is defined by government regulations. None of the other ecolabelling schemes or systems of production in this review have a legal definition.

some discretion written into the scheme whereby research projects can be commissioned if higher standards are reached in a different way to the standard requirements, and a decision made by the Soil Association following this as to whether an Organic label should be awarded. The Soil Association state they use Certification Bodies to verify compliance to their scheme and a physical visit is made once a year. The Certification must be renewed annually, and there are procedures to follow if non-compliances are found. An action plan is developed by the enterprise, and this is checked every year as part of the inspection. Soil Association do have information publicly available for the scheme on their website with downloadable standards, and it is clearly presented, but it can be difficult to navigate the website to find the information needed. The full characterisation for the Soil Association Organic label can be found in Appendix C.10.

3.3.5.2 Environmental impact coverage

Table 3.14 provides an overview of (i) the coverage of environmental impacts (following the impact categories outlined in the methodology – see Section 2.3.3); (ii) whether the impact categories are based on activity, effect or outcome-based metrics; and (iii) whether the data used for those metrics is derived from primary and/or secondary data sources.

Table 3.14: Impact coverage and data source: Soil Association Organic label

	Impact category	Coverage	Activity	Effect	Outcome
Atmosphere	Climate regulation	◍	△	□	◇
	Air quality regulation	◔	▲	□	◇
	UV-B radiation regulation				
	Gaseous flows regulation				
Biosphere	Animals provision	●	▲	■	◆
	Biomass provision	●	▲	■	◆
	Habitat provision	●	▲	■	◇
	Pollination regulation				
	Seed dispersal regulation				
	Pest control regulation	●	▲	□	◇
	Disease control regulation	●	▲	□	◇
Geosphere	Fossil fuel provision	●	▲	■	◆
	Nutrient provision	●	▲	■	◆
	Soil provision	●	▲	□	◇
	Soil quality regulation	●	▲	□	◇
	Mass flows regulation	◑	▲	■	◇
Hydrosphere	Water provision	◑	▲	■	◇
	Water conditions regulation	●	▲	□	◇
	Water flows regulation				

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

Soil Association Organic label has several standards relating specific environmental impacts. These are reflected in Table 3.14 as follows:

- Climate regulation: carbon is only mentioned briefly in relation to the use of peat; and carbon sequestration is reference to trees as a secondary benefit. There do not appear to be any other requirements.
- Air quality regulation: Ammonia is mentioned briefly in reference to providing suitable housing (3.8.2) and that "at inspection we may measure environmental parameters such as ammonia and dust levels", but in reference to assessing the suitability of housing (not emissions reduction). It is also mentioned briefly as an additional benefit of planting trees for shelter with respect to "capturing ammonia emissions" (3.12.16). Section 2.3.2 also covers avoiding the loss of nutrients to the air.

- Animals provision: Section 2.10 Standards for wild harvesting and includes requiring a management plan for assessment and regular monitoring of the target resources and habitats.
- Biomass provision: Section 2.10 Standards for wild harvesting and includes requiring a management plan for assessment and regular monitoring of the target resources and habitats.
- Habitat provision: Amongst the general principles of organic production (1.2.1) is "to foster biodiversity and protect sensitive habitats and landscape features". Section 2.1.7 also covers "Maintaining High Conservation Values". Section 2.3.1 covers Biodiversity conservation and enhancement. Habitats should be mapped. Their quality seems to be based on existing designations rather than a site-specific assessment. There does not appear to be any requirement to monitor species and/or populations.
- Pest control regulation: Section 2.3.1 mentions "using practices that attract or introduce beneficial insects, provide habitat for predatory birds and mammals and increase soil biodiversity fulfil vital ecological functions", albeit with no details or requirement for monitoring or measurement.
- Disease control regulation: Section 2.6 covers preventing diseases.
- Fossil fuel provision: Section 2.3.3 of the standards requires the responsible use of energy and minimisation of non-renewable resources. It includes recording use and encourages the adoption of energy efficient measures.
- Nutrient provision: Section 2.3.3 of the standards requires the responsible use of other natural resources and minimisation of non-renewable resources. Although there is no specific mention of nutrients in this context, maximising efficient use of nutrients and minimise the use of brought-in inputs is covered in Section 2.4.1, which also states that mineral nitrogen fertilisers cannot be used.
- Soil provision: Section 2.4 covers soil maintenance, but there does not appear to be requirements for measurement or monitoring.
- Soil quality regulation: Section 2.4 also covers managing soils to enhance stability, soil organic matter levels and soil structure and to prevent compaction, erosion and run-off. There does not appear to be a requirement for the measurement or monitoring of soil quality.
- Mass flows regulation: Section 2.4 covers managing soils to prevent compaction, erosion and run-off; and Section 2.3.3 includes identifying areas prone to run off and soil erosion, and adopt appropriate strategies to minimise these. There does not appear to be requirements for measurement or monitoring soil erosion or sediment loss; or requirements for capturing sediment.
- Water provision: Section 2.3.3 requires the responsible use of water, including monitoring water use.
- Water conditions regulation: Section 2.3.2 covers preventing environmental contamination including water. There does not appear to be any requirements to monitor effects and impacts.

3.3.5.3 Data sources, data quality and verification

The Soil Association organic scheme is verified and certified by Soil Association Certification. These will have been approved by Defra as an accredited organic certification body. Records are needed to be kept by farmers/businesses to prove organic status and show compliance to the set standards. Inspections by Soil Association Certification are carried out once a year on-site, although additional inspections might be made if there are any concerns around risk. They will be checking that the declaration of activities on farm matches reality, and that they are compliant with the organic standards. An inspection report is put together highlighting deficiencies and non-compliances which must be signed and corrected by the farm/business in question. The organic licence is renewed each year when it is shown that standards are continued to be met and the renewal fee paid.

3.3.5.4 Transparency

Soil Association Organic has a good website containing all the information required but can be challenging to navigate as it is across several pages, under different headings. There is additional information which is accessible only if the user is signed up as a client or organic producer. The standards are available to download if various links are followed and there are a range of standards options depending on what the user is working on and where they are operating. The standards are lacking clarity with respect to what impact categories are covered by the scheme and associated environmental metrics and/or outcomes. The data sources and

benchmarks are very clear. The scheme does not use normalisation and aggregation as it is not applicable. The data is verified through inspection, however, there is not any evidence that this covers impacts as well.

3.3.6 Summary outputs for Group 2 schemes

Table 3.15 shows the outputs for the impact coverage assessments for all the Group 2 schemes.

Table 3.15: Impact coverage and data source: Group 2 schemes

	Impact category	AGW	FtN	LEAF	PfL	SA
Atmosphere	Climate regulation	◕▲□◇	◍▲■◇	●▲■◇		◍△□◇
	Air quality regulation	◑▲□◇		◑▲□◇		◔▲□◇
	UV-B radiation regulation					
	Gaseous flows regulation					
Biosphere	Animals provision				◔△□◇	●▲■◆
	Biomass provision			●▲□◇	◔▲□◇	●▲■◆
	Habitat provision	●▲■◆	●▲■◆	◕▲■◆	◑▲□◇	●▲■◇
	Pollination regulation					
	Seed dispersal regulation					
	Pest control regulation			●▲■◇		●▲□◇
	Disease control regulation			●▲■◇		●▲□◇
Geosphere	Fossil fuel provision	●▲□◇		●▲■◇		●▲▲◆
	Nutrient provision		●▲□◇	●▲■◇	●▲□◇	●▲▲◆
	Soil provision	●▲□◇		●▲■◇	●▲■◇	●▲□◇
	Soil quality regulation	◑▲■◆	◕▲■◇	◑▲■◇	◕▲■◆	●▲□◇
	Mass flows regulation	●▲□◇		●▲□◇	◑▲□◇	◑▲■◇
Hydrosphere	Water provision	◑▲□◇	◑▲□◇	●▲■◇		◑▲■◇
	Water conditions regulation	◑▲□◇	◑▲□◇	●▲■◆	◑▲□◇	●▲□◇
	Water flows regulation	◑▲□◇	◑▲□◇			

4 Discussion

4.1 Comparison of schemes

4.1.1 Objectives of the schemes

Each of the schemes has a different set of aims and objectives as to why they are operating and what they hope to achieve. Each one was summarised into one sentence from reading information that the schemes produced themselves (see tables in Section 3). Doing this enabled the understanding of where their point of focus was and is presented in Table 4.1 and Table 4.2. The focus differed depending on whether the scheme was in Group 1 or Group 2, but within the groups were largely the same. Those in Group 1 are consumer-focused with the aim of helping them make more sustainable choices. Three of the schemes, Foodsteps, Foundation Earth and IGD are also focused on food businesses as part of their drive is to impact the wider food industry. It is possible that by communicating environmental impacts to consumers and food businesses that the knowledge will cause behaviour change which then translates down the supply chain, impacting the other actors and helping them to make positive changes as well. How effective this will be to change agricultural practices at the primary producer level is unknown, and is likely to need change and direction in policy to drive it (Garrett *et al.*, 2020).

Those in Group 2 are all farmer-focused except for the Soil Association who are also consumer-focused. The drive is largely that the schemes will enable and support changes in farming practice away from conventional and intensive methodologies to those which have more positive environmental impacts. The expectation is that consumers would want to buy food which has better environmental credentials and will know the products to choose due to the label, and therefore change the supply chain decisions to increase the uptake of such products. However, currently some of these products tend to have a premium price attached (e.g. organic produce) which can be off-putting to the consumer and outweigh the desirability of the improved production method (Williams *et al.,* 2023). Several of the Group 2 schemes are also quite niche. The exception to this is LEAF Marque, who have worked hard to gain entrance into the supermarkets, with the most recent uptake being Tesco, which makes them more accessible to the standard customer.

Table 4.1: Group 1 scheme aims and objectives summary

Scheme	What are the aims and objectives of the scheme?	Summary
Eco-Score	Helping consumers make more sustainable food choices and encouraging better agricultural practices to care for the environment.	Consumer-focused
Foodsteps	Helping the food system measure, reduce and communicate the environmental impact of food production, and improving the understanding of this for both consumers and businesses.	Food business & consumer-focused
Foundation Earth	Want to create a more sustainable food industry by helping businesses and consumers to make more environmentally sustainable choices through on-pack scores.	Food business & consumer-focused
IGD	Increasing the transparency of the environmental impact of products and supply chain in the food system, so consumers and businesses are more informed and better able to make sustainable decisions.	Food business & consumer-focused
Planet-Score	Providing clear information to enable better consumer purchasing decisions and to help producers and agri-food companies make progress in improving agricultural practices and reducing greenwashing.	Consumer-focused

Table 4.2: Group 2 scheme aims and objectives summary

Scheme	What are the aims and objectives of the scheme?	Summary
A Greener World	Supporting and rewarding producers moving to regenerative practices	Farmer-focused
Fair to Nature	Utilising a proven approach to restore nature on farms and helping consumers recognise sustainable products and support businesses who are caring for their land.	Farmer-focused
LEAF Marque	Enabling the improvement of farming practices to be more sustainable, regenerative and nature-based by adhering to Integrated Farm Management principles	Farmer-focused
Pasture for Life	To provide certification for 100% grass-fed/pasture-fed, grain-free ruminant meat and dairy production to benefit consumers, the environment and animal welfare.	Farmer-focused
Soil Association Organic label	To encourage higher organic standards than the UK requirements particularly in the areas of animal welfare, human and animal health, safeguarding the environment and consumer interests.	Farmer and consumer-focused

4.1.2 General characteristics

The majority of the schemes display the ecolabel on the food product, whether that is on the packaging or on a menu. In addition, some of the schemes also have the information on their website and/or an app, increasing the information available to customers. Mostly the schemes assessed are labels which communicate to consumers, with Eco-Score, Foodsteps and IGD also communicating to businesses, usually as an intermediate step before the information reaches the consumers. The labels are all designed to communicate to the consumer, but vary in what they are communicating. For the Group 2 ecolabels, it is about showing the consumer that a product has been produced in a particular way (e.g. organic farming) because it carries the ecolabel. For the Group 1 ecolabels, it is about effectively communicating with the consumer the calculated environmental impact score. All the labels attempting to do this have chosen to use both a letter scale (A-E or A*-G) and a RAG colour scheme, similar to that of the nutrition labelling traffic light system.

Eco-Score, Planet-Score and Foundation Earth are using the 16 PEF indicators. Of these, Foundation Earth is using them exclusively without changing the categories, and has kept the original PEF weightings, though they have ambitions to improve on it. Eco-Score has chosen to add additional indicators as bonus/malus points to extend the reach of the environmental impacts covered. Planet-Score have approached the PEF differently, by collapsing the 16 indicators into 4 broader categories (Environmental health and toxicity, biodiversity and ecosystems, climate (carbon), and resources) and including further indicators into each category. They have also chosen to include scores for Pesticides, Biodiversity and Climate onto the label in addition to the overall score, and a RAG scale animal welfare image, to better inform the consumer. IGD began their development process with the 16 PEF indicators but decided that they were not able to reflect well enough the environmental impact that they wanted to cover, so went for 4 broader categories (climate change, land use, water use, water quality) which encompassed some of the main PEF indicators which fulfilled criteria that they set out. They have also chosen to include calculating in the planetary boundaries into the final score. Foodsteps, focuses exclusively on carbon footprinting, which is equivalent to the PEF "Climate Change" indicator. The kg CO_2e value is also put onto the label so consumers can compare emissions between products. See Section 4.1.3 for a more detailed analysis of the coverage of environmental impacts.

The Group 2 ecolabels tend to be more well-known and have been in use for much longer. They all have a different focus and desired outcome so use a range of different indicators for this. Some of these overlap with the PEF and additional indicators present for the Group 1 labels and others provide new indicators. Fair

to Nature, is the simplest one of these, with its focus on biodiversity and improving this on farm, but encompassing soil health, carbon footprint and aspects of animal welfare as well. Pasture for Life extends a little further, with its emphasis on animal welfare in addition to biodiversity. A Greener World is focussed on regenerative agriculture which brings in some of the environmental indicators as part of the methodology. These include soil, water, air quality and biodiversity. They also encourage the "positive management" of cropping systems, livestock, wild harvested resources and human/societal factors which ties in with their emphasis on regenerative agriculture practice. The Soil Association Organic label has its focus on organic production with the standards adhering to those set by the EU. However, its stipulations go beyond the legislated requirements to further the positive environmental impacts/reduce the negative impacts and include the indicators of "animal welfare, protecting human and animal health, safeguarding the environment and protecting interests of organic consumers". LEAF Marque encourages sustainable farming practices, particularly around their nine Integrated Farm Management principles. These and the standards they set provide the indicator categories for the environmental impact. See Section 4.1.3 for a more detailed analysis of the coverage of environmental impacts.

4.1.3 Environmental impact coverage

Table 4.3 shows the coverage of environmental impacts, metrics used and data sources for both Group 1 (left) and 2 (right) schemes. With respect to coverage of environmental impact categories, Group 2 schemes tend to have a greater coverage of impacts, especially in the biosphere compared to Group 1 schemes, but also in respect to soil provision, mass flows regulation and water flows regulation. This is largely driven by the lack of LCA metrics for these impacts, with issues such as impacts on biodiversity being a recognised limitation of LCA and acknowledged by many of the Group 1 schemes.

Table 4.3: Environmental impact coverage and data source: Group 1 and 2 schemes

	Category	ES	FS	FE	IGD	PS	AGW	FtN	LEAF	PfL	SA
Atmosphere	Climate regulation	◍▲■◇	●▲■◇	◕▲■◇	●▲■◇	◍▲■◇	◕▲□◇	◍▲■◇	●▲■◇		◍△□◇
	Air quality regulation	◑▲■◆		◍▲■◆		◑▲■◆	◑▲□◇		◑▲□◇		◔▲□◇
	UV-B radiation regulation	●▲■◇		●▲■◇		●▲■◇					
	Gaseous flows regulation										
Biosphere	Animals provision									◔△□◇	●▲■◆
	Biomass provision								●▲□◇	◔▲□◇	●▲■◆
	Habitat provision						●▲■◆	●▲■◆	◕▲■◆	◑▲□◇	●▲■◇
	Pollination regulation										
	Seed dispersal regulation										
	Pest control regulation								●▲■◇		●▲□◇
	Disease control regulation								●▲■◇		●▲□◇
Geosphere	Fossil fuel provision	●▲□◆		●▲□◆		●▲□◆	●▲□◇		●▲■◇		●▲▲◆
	Nutrient provision	◍▲□◆		◍▲□◆		◔▲□◆		●▲□◇	●▲■◇	●▲□◇	●▲▲◆
	Soil provision						●▲□◇		●▲■◇	●▲■◇	●▲□◇
	Soil quality regulation	◔▲□◆		◔▲□◆		◑▲□◆	◑▲■◆	◕▲■◇	◑▲■◇	◕▲■◆	●▲□◇
	Mass flows regulation						●▲□◇		●▲□◇	◑▲□◇	◑▲■◇
Hydrosphere	Water provision	◍▲■◇		◍▲■◇	◍▲■◇		◑▲□◇	◑▲□◇	●▲■◇		◑▲■◇
	Water conditions regulation	◔▲■◆		◔▲■◆	◔▲■◆	◑▲□◆	◑▲□◇	◑▲□◇	●▲■◆	◑▲□◇	●▲□◇
	Water flows regulation						◑▲□◇	◑▲□◇			

Sub-impact coverage: ◍: uncertain; ◔: 25%; ◑: 50%; ◕: 75%; ●: 100%
Data source: ▲ Activities; ■ Effects; ◆ Outcomes. ▲■◆ = All secondary; ▲■◆ = Primary and secondary; ▲■◆ = All primary; ▲■◆ = Unknown/uncertain; △□◇ = Not covered

There is also some variability of coverage within each impact category. For climate regulation, some schemes do not cover all aspects, i.e. all GHG emissions, land use change and carbon sequestration. For air quality regulation and water conditions regulation, no scheme appears to explicitly cover all air and water pollutants and/or coverage is uncertain. Similarly, for soil quality regulation, most schemes do not cover all aspects of soil quality (albeit with the caveat that soil quality needs to be defined within the context of soil function).

Coverage of water provision issues within Group 1 schemes is uncertain and tends to be only partially covered in Group 2 schemes.

Table 4.3 also shows the type of metrics that are utilised by each scheme with respect to whether the metric is based on activities, effects or outcomes (see Appendix A for definitions and examples). The pattern here is somewhat expected in that Group 1 schemes tend to be based on effect and outcome-based metrics and Group 2 schemes more on activity-based metrics. Group 1 schemes do often rely on activity data (e.g. where activity data is combined with emission factors to model an impact value) which can come from a range of sources (see Section 4.1.4). Certification in Group 2 schemes is usually based on activity data alone, albeit there appears to be increasing requirements to monitor and/or model environmental effects (e.g. use of carbon calculators to derive a carbon footprint for the farm). There are also a few instances where monitoring of outcome metrics is also encouraged (e.g. monitoring of wildlife species). Finally, in the case of Fair to Nature, farmland habitats are independently assessed, which is probably the closest to an outcome-based metric that is verified.

4.1.4 Data sources, data quality and verification

Table 4.3 also indicates the source of the data that is used for the metrics, i.e. is primary, secondary of a combination of data used. The pattern here is again somewhat expected in that Group 2 schemes tend to be based on primary data from the farm, whereas Group 1 schemes are more reliant on secondary data. Some Group 1 schemes do express a desire to utilise more primary data (e.g. Foundation Earth), but the extent of its use is unclear and/or limited.

With respect to the Group 1 schemes, they tend to use a combination of databases from which they source their data (see Figure 4.3). The ADEME-developed database AGRIBALYSE® is the most used. Foundation Earth supplements their use of this with data from additional databases, Ecoinvent, Agri-Footprint, GFLI and WFLDB. Foodsteps have chosen not to use AGRIBALYSE® but have developed their own database based on the LCA data from Poore and Nemecek (2018). It is still not clear what data sources IGD will utilise as this is still under development but (at the time of writing this review) are aiming to produce a UK specific database (AGRIBALYSE® is France specific) at the ingredient level. All these ecolabels have worked with data providers to assist their development, with 4 out of 5 using ADEME. Eco-Score also worked with Quantis, Foundation Earth with Blonk Consultants, and IGD with Mondra and Oracle. Foodsteps did not work with ADEME, but instead worked with HESTIA, OmniAction, and Global Farm Metric (see Section 4.3.1 for an exploration of scheme and database relationships).

With respect to data quality, the Group 1 schemes all seem to adopt a similar approach, which is based around a pedigree matrix approach (Henriksen *et al.*, 2021; Weidema, *et al.*, 2004; Weidema & Wesnæs, 1996) where a range of criteria are used to score data sources used in the LCA. The pedigree matrix approach is a method that aims to provide a rapid overview of the robustness of the data used in an LCA. The criteria aim to provide an indication of representativeness and reliability of the data. The criteria can include, for example, geographical, temporal and technological relevance; completeness; and consistency. Each source of data used in the LCA is scored and this score can be aggregated and communicated to end users of the LCA so that they have some idea of how reliable the LCA is (e.g. has it been based on generic data that is not very representative of the product; or has it been based on specific data that is of most relevance to the product; where are the strengths and weaknesses in data through the LCA, etc.). How this approach is adopted across the schemes is variable both in terms of the criteria used and how the data quality scores are used. Some schemes rely on the data quality processes that are built into the databases they use (e.g. Eco-Score and Planet-Score), whereas others apply their own data quality processes (e.g. Foodsteps and Foundation Earth). It is not clear how the data quality scores once calculated are used across schemes. For example, does the data have to meet a minimum standard? How are data quality weaknesses communicated within the ecolabel? For example, although the title of FE (2023d) is "Ensuring minimum data quality thresholds when assessing the environmental impact of food products", the document does not outline what the minimum threshold is. Finally, with respect to the related issue of data verification, some of the Group 1

schemes do state that they have data verification processes (e.g. Foodsteps, Foundation Earth and Planet-Score), but these are internal processes (i.e. not done independently) and the description is vague.

With respect to the Group 2 schemes, the situation is almost the inverse of the Group 1 schemes. They are based on primary data collected on farms coupled with independent (for most schemes) inspection and verification procedures. Data quality is not explicitly assessed (as it is less applicable) with the verification processes being the key mechanisms to ensuring reliability with respect to ensuring that practices are being implemented on the farms as expected. Inspections are usually undertaken on an annual basis (biannual for Fair to Nature) with the points for verification clearly outlined in the scheme standards.

A key weakness of the Group 2 schemes (as highlighted in Table 4.3) is the measurement and verification of environmental impacts and outcomes. Improvements have been made by some schemes in recent years to encourage the measurement and monitoring of environmental effects and impacts. For example, measuring energy and water use (e.g. AGW, LEAF, SA); using calculators to determine GHG emissions and carbon sequestration (e.g. FtN, LEAF); soil sampling and analysis to determine soil health (e.g. AGW, FtN, LEAF, PfL); and monitoring of wildlife species and biodiversity (e.g. AGW, FtN, LEAF, SA). However, the measurements made do not form part of the certification process, i.e. there is no benchmark or environmental target for impacts and outcomes and no verification of the data. The only scheme that comes close to this is Fair to Nature where a habitat assessment is independently undertaken every two years to monitor improvements in habitats and help ensure the delivery of biodiversity benefits, but the outcomes do not form part of the certification requirements.

4.1.5 Impact communication: interpretation, normalisation and aggregation

All the schemes (Groups 1 and 2) have the potential to generate a lot of data which creates a challenge for communication within the context of an ecolabel. There are several aspects to consider including:

- What do the values of the metrics mean with respect to impacts on the environment and/or the environmental performance of the product? (i.e. positive or negative; small or large; best, worst or indifferent, etc.).
- Can metrics be legitimately aggregated without losing important detail and/or do they become meaningless?
- Do gaps in metrics (see Section 4.1.3) present an issue with respect to driving change? (i.e. missing issues are externalised)

As revealed in Section 3.2, some Group 1 schemes do attempt to normalise impacts by expressing them relative to a benchmark. The planetary boundaries approach is proposed by IGD and may be used within Eco-Score (it is mentioned but is not clear how they are used). The planetary boundaries concept is scientifically appealing as in theory it can present the performance of a product relative to a desirable benchmark (i.e. a level that is sustainable / within the boundaries of what the planet can support). This has the potential to be a powerful driver with a robust foundation (provided that the planetary boundary benchmarks have been robustly determined). However, planetary boundaries have not been determined for all the standard LCA impact categories, let alone the wider set of impact categories defined within this study (Appendix A). Thus, this does not provide a complete solution.

Other schemes attempt to express the performance of a product relative to others, i.e. a 'league table' approach. This can be a powerful driver within the context of improving business environmental performance, i.e. no business wants their products to be at the bottom. However, it does not reflect the degree of impact on the environment, it simply sets the position of a product relative to the best and worst performers; and this potentially raises questions on whether the differences between products are significant. This in turn has the potential to be misleading to consumers, i.e. if the difference in impact between the worst and best performing products is negligible in terms of, for example, planetary boundaries (i.e. they are all unsustainable), what would the consumer response be to this knowledge? Additionally, the systems used for judging relative importance can also be problematic. As shown in Section 3.2.3, Foundation

Earth have adopted an approach of equally distributing the performance of products across eight bands (A+ to G, best to worst), on the basis that this approach provides an "incentive for food manufacturers to make changes to production chains to improve grading". This means that the grading works on the population of products and not necessarily on significant changes in environmental impact. For example, if the system were flooded with new lower performing products, perversely the grade for an existing product could improve without any change in environmental impact.

With respect to the Group 2 schemes, the benchmarking process is one of relative practices rather than measured or modelled impacts. It is about providing assurance that the production system is operating to a defined standard that in theory results in reduced negative and increased positive impacts on the environment. Where this standard is achieved, the farm is 'rubber stamped' via certification. However, this only means that the standards of production have been achieved, any changes in environmental impact have not been measured and/or are not the basis of certification. For a few Group 2 schemes, e.g. Fair to Nature and LEAF Marque, some environmental monitoring is encouraged, and in the case of Fair to Nature, a habitat assessment is independently undertaken every two years, but the outcomes do not form part of the certification requirements (i.e. achievement of a certain habitat or population of species is not a requirement). Thus, although Group 2 schemes are encouraging and requiring positive actions, they are not measuring impacts and/or assessing the relative magnitude of any impacts against any benchmarks such as planetary boundaries.

With respect to aggregation, as the Group 2 schemes are not measuring impacts, there is no explicit aggregation. The achievement of a certain standard (i.e. farm assurance) across multiple environmental issues is providing an overall perspective, but it is not an aggregation of performance across the different environmental issues. With respect to the Group 1 schemes, they have numerous effect and outcome metrics (16, or more for some schemes), which presents a challenge for communication within the context of an ecolabel. Hence, there is a demand to aggregate metrics into a fewer or even a single measure. However, this is problematic for several reasons. Firstly, detail is lost in an aggregated metric as it is not clear which impacts are resulting in the final score (i.e. two products could have the same aggregated score but very different impacts). This also introduces scope for burden shift, where an improvement in one impact is made at the expense of another (e.g. reducing GHG emissions to air by increasing nitrate leaching to water), which could in theory either maintain the aggregated score or improve it (if more weighting is given to climate change in the aggregation process). Secondly, as highlighted by IGD (see Section 3.2.4), if impacts have been normalised (e.g. against planetary boundaries) if they are then aggregated this interpretation of the impact can become lost. One possible solution would be to utilise progress towards environmental or sustainability targets (such as planetary boundaries) as the metric, and if targets are met then the product qualifies for the ecolabel. However, establishing targets can be problematic and/or subjective, and if a holistic range of impacts are included, the likelihood of any product achieving them could be low.

Finally, as outlined above, some schemes have significant gaps in the environmental impact categories that they cover be it due to a lack of metrics or a deliberate decision to focus on one issue (e.g. Foodsteps focused on climate change only, albeit with plans to extend their impact categories into land use, water use, eutrophication and acidification). In so doing, this externalises the environmental issues that are excluded and has the potential to drive production systems to only address the issues included, possibly at the expense of those excluded, which is unlikely to be sustainable. Some Group 1 schemes recognise that some key issues are missing and attempt to include them (e.g. use of bonus/malus points in Eco-Score and Planet-Score), but it tends to result in a convoluted approach, more so when coupled with the issues associated with aggregation and normalisation above.

4.1.6 Transparency

Transparency of information provided by the schemes is an important aspect to consider through the evaluation process, as the availability and clarity affects what we can understand about the operation of the schemes, but also what a potential customer might understand and importantly be able to trust.

All 10 ecolabels had a website where the information was placed, and most had additional downloadable documents which contained further information, calculations/methodology and standards. The clarity of the documentation is variable, for example, information on the Soil Association Organic label is spread over multiple pages, multiple areas of standards and understanding impacts is difficult. Some schemes are open and transparent about their approach and any limitations, while others are less forthcoming with such details (see Appendix C).

Overall, the Group 2 schemes have a slightly better transparency than Group 1. This could be due to the difference in the information that the two groups are trying to communicate, with potentially a standards-based system easier to communicate than a calculation-based one. From Group 1, Foundation Earth was very transparent, which reflects the years of research undertaken to develop and test the scheme and the reports/papers available covering all the aspects of their operations and methodologies. There are still some questions around their normalisation and aggregation approach, but their impact categories scored highly. From Group 2, Fair to Nature and LEAF Marque are also very transparent across all the criteria. However, all the schemes have work to do to improve their transparency, and most ignore or fall short of any information around environmental outcomes.

A slightly alternative perspective on transparency that was not explicitly included within the characterisation and evaluation was how easy and clear it is to find out an ecolabel rating for a product. Some provide a worked example (e.g. IGD shows an example of the CO_2e and planetary boundaries for a lettuce; Foundation Earth provide an example of one product and how they label it, but no ingredients list), while others although they provide full details of the calculation method, do not provide any examples. Products with Eco-Score labels can be found on the Open Food Facts website (Open Food Facts, 2024), which is independent of Eco-Score, but there seems to be lots of missing data, resulting in scores being lower than they should be or absent (unless French-based). It is likely that this variability in approach relates to different business models of each scheme, for example, some selling labelling or quantification solutions to businesses, with others providing more general frameworks for supply chains or more actively promoting the approach to increase public awareness. Thus, in this respect, judging the transparency of this element is always likely to be not an equivalent comparison.

4.2 Transition to agroecology, food sovereignty and national environmental targets

4.2.1 Agroecology, food sovereignty and environmental targets

A key concept behind ecolabelling of food is to encourage the purchase of products that have a lower environmental footprint and thus drive the adoption of associated production practices. It is beyond the scope of this project to determine the relative role and effectiveness of food ecolabels for changing purchasing behaviour. There have been numerous other research projects that have explored this in detail, with a range of findings with some clearly showing the benefits of ecolabelling and others revealing a less significant role (Beyer *et al*., 2024; Delmas & Gergaud, 2021; Lami *et al*., 2022; Rezazga *et al*., 2024; Tiboni-Oschilewski *et al*., 2024; Williams *et al*., 2023). However, the key element here is identifying the drivers within the food production and consumption system and how these are likely to influence the transition to agroecology and associated food systems (food sovereignty). It is within this context that the findings of this review are explored, i.e. it is assumed that ecolabelling will have some role in driving change. As a first step agroecology and food sovereignty need to be defined.

The concept of agroecology is not new with the term being first used in the 1930s within the context of observing the biological interactions of ecosystems and agriculture (Silici, 2014). It is a scientific discipline, but has also become associated with specific agricultural practices and political and social movements (Wezel *et al*., 2009 & 2020). Indeed, the European Association for Agroecology describe it as a "transdisciplinary field that includes all the ecological, sociocultural, technological, economic and political dimensions of food

systems, from production to consumption" (Agroecology Europe, 2024). The term food sovereignty is connected to agroecology. It was introduced by La Via Campesina (LVC, 1996) at the World Food Summit in 1996 and includes 6 main principles: focuses on food for people; values food providers; localises food systems; puts control locally; builds knowledge and skills; and works with nature (Stella *et al.*, 2019). These overlap with the 13 principles for agroecology defined by Wezel *et al*. (2020) (Table 4.4), which are also related to the 10 elements outlined by the FAO (2018).

Table 4.4: Thirteen agroecological principles

Principle	Scale	FAO elements
1. Recycling. Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.	FI, FA	Recycling
2. Input reduction. Reduce or eliminate dependency on purchased inputs and increase self-sufficiency.	FA, FS	Efficiency
3. Soil health. Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.	FI	Reflected in diversity, synergies and resilience
4. Animal health. Ensure animal health and welfare.	FI, FA	Reflected in resilience
5. Biodiversity. Maintain and enhance diversity of species, functional diversity and genetic resources and thereby maintain overall agroecosystem biodiversity in time and space at field, farm and landscape scales.	FI, FA	Part of diversity
6. Synergy. Enhance positive ecological interaction, synergy, integration and complementarity amongst the elements of agroecosystems (animals, crops, trees, soil and water).	FI, FA	Synergies
7. Economic diversification. Diversify on-farm incomes by ensuring that small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.	FA, FS	Parts of diversity as well as circular and solidarity economy
8. Co-creation of knowledge. Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.	FA, FS	Co-creation and sharing of knowledge
9. Social values and diets. Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.	FA, FS	Human and social values Culture and food traditions
10. Fairness. Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.	FA, FS	Part of human and social values
11. Connectivity. Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.	FA	Part of circular and solidarity economy
12. Land and natural resource governance. Strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers as sustainable managers of natural and genetic resources.	FA, FS	Responsible governance
13. Participation. Encourage social organisation and greater participation in decision-making by food producers and consumers to support decentralised governance and local adaptive management of agricultural and food systems.	FS	Part of human and social values

FI = field; FA = farm agroecosystem; FS = food system

Agroecology is often discussed in association with sustainable food production and consumption systems (in some contexts the terms are used interchangeably). However, in the context of this review, it refers to the agroecological practices and systems that can help facilitate the transition to sustainable food production.

As shown in Table 4.4, the principles are very holistic and encompass many of the environmental impacts covered within this review (see Appendix A). There is little doubt that a more holistic perspective is needed, however, this introduces greater complexity to decision making, be that for farmers, consumers or policy makers. In the past, with a single bottom line, decisions were about finding the economic optimum, but with the emergence of the triple bottom line concept (i.e. accounting for social, economic and environmental aspects), there are multiple social, economic and environmental objectives to achieve. Win-win-win synergistic solutions are needed, but commonly there are trade-offs to consider, not just between environment and economy, but sometimes between different environmental objectives. For example, grass-fed beef production systems when viewed solely from the perspective of climate change will be assessed as having negative environmental impacts due to emissions of GHGs (Desjardins *et al*., 2012; Gerber *et al*., 2015; Lynch, 2019; Ritchie, 2020). However, grass-fed beef production systems can also have environmental benefits such as soil health, water quality, and biodiversity (Bragaglio *et al*., 2020; de Vries *et al*., 2015; Jackson, 2022; Mondière *et al*., 2024; von Greyerz *et al*., 2023). Thus, there is a trade-off to consider, i.e. are the negative environmental impacts an acceptable trade-off for the environmental benefits. The picture is further complicated when considering the demand for food (i.e. a defined amount is needed to feed a population). More extensive production systems tend to require more land area to meet the demand (which competes with other land uses and ecosystem services) and/or environmental impacts per tonne can be variable with some higher than intensive production systems (Boschiero *et al*., 2023; Coppola *et al*., 2020; Gamage *et al*. 2023; Muller *et al*., 2017; van der Werf, *et al*., 2020). Many of these complexities and challenges are echoed when seeking to develop an approach to ecolabelling that provides a true and fair view of the environmental impact of the food at the product level. How these potentially influence the drivers within the food production and consumption system are explored below.

Finally, with respect to national environmental targets there are several issues to consider. Firstly, the UK 25 Year Environment Plan (25-YEP) (HMG, 2018 & 2023) outlines 10 environmental goals (Table 4.5).

Table 4.5: Ten goals of the 25 Year Environment Plan

Goal	Description
1	Thriving plants and wildlife
2	Clean air
3	Clean and plentiful water
4	Managing exposure to chemicals and pesticides
5	Maximise our resources, minimise our waste
6	Using resources from nature sustainably
7	Mitigating and adapting to climate change
8	Reduced risk of harm from environmental hazards
9	Enhancing biosecurity
10	Enhanced beauty, heritage, and engagement with the natural environment

Many of these are reflected in the Food Data Transparency Partnership (FDTP) policy paper (Defra, 2024) especially with respect to delivering on targets for climate and nature (including the Net Zero Strategy (HMG, 2021) and improving nature metrics to support commitments under the Global Biodiversity Framework (GBF) for Convention of Biological Diversity (CBD) (UNEP, 2024a&b), respectively) and improving farm productivity and maintaining domestic food production.

4.2.2 Impact coverage

The environmental issues and impacts selected to judge performance (be that internally within a business or externally on an ecolabel) will influence direction of travel (Broom, 2021; Chiriacò *et al*., 2022; Cleveland *et al*., 2015; Lanzoni *et al*., 2023; Mottet *et al*., 2020; Movilla-Pateiro *et al*., 2021; van der Werf, *et al*., 2020). In the past, the use of a single (economic) bottom line resulted in the externalisation of environmental costs, leading to many of the environmental issues society faces today. In theory, the triple bottom line concept helps avoid the externalisation of environmental and social issues. However, even when all issues are considered, the choice of appropriate metrics and how these are interpreted are key for judging performance, diagnosing issues and developing solutions that aid the transition to agroecology.

As shown in Table 4.3 there is less coverage of environmental impact categories by the Group 1 schemes compared to the Group 2 schemes. This means that the performance of production systems focused on these labels are likely to be geared towards addressing LCA impact categories only, thus running the risk of externalising other impacts (albeit with the acknowledgement that some may be covered via compliance with compulsory government regulations).

Atmosphere

A key impact category for most of the Group 1 and 2 schemes is climate change, albeit with some variability with respect to what is covered in relation to carbon sequestration and/or land use change. Group 1 schemes quantify GHG emissions and carbon sequestration based on activity data, albeit several Group 2 schemes (e.g. LEAF Marque) now also encourage the use of carbon calculators to derive a carbon footprint for the farm. Thus, these align well with supporting Goal 7 of the 25-YEP (Table 4.5) and national targets for GHG emissions, such as Net Zero.

Emissions of other air pollutants (i.e. NH_3; NOx; VOCs; particulates; bioaerosols; and dust) is more variable across both Group 1 and 2 schemes. For the LCA based schemes, these tend to be embedded impact categories such as 'Human Toxicity – cancer', 'Human Toxicity – non-cancer', 'Particulate Matter' and 'Photochemical Ozone Formation – human health', rather than explicit emissions and impacts. The Group 2 schemes do not quantify these emissions, but do cover practices to reduce air pollutants generally and specifically for ammonia, dust and particulates. Out of all the other air pollutants, emissions of ammonia are probably the most significant for agriculture, thus the adoption of agroecological practices to reduce them either at source or mitigation after release are important. The Group 2 schemes do contain clear requirements in terms of practices to reduce emissions. However, with respect to Group 1 schemes it is not clear if this level of detail is accounted for when determining emissions of ammonia and associated values for relevant impact categories. The reliance on secondary data would suggest that details of practices on individual farms may not be accounted for, thus reducing this element as a driver for change (see Section 4.2.3) and lacking support for Goals 2 and 4 of 25-YEP (Table 4.5).

The emission of ozone depleting substances is covered by the Group 1 schemes, but not by Group 2 schemes. This may be due to these emissions being largely addressed by legislation, thus has become less of an issue in recent years.

Gaseous flows regulation is not covered by any of the schemes. This is a relatively minor ecosystem service related impact category. Given that this is a very minor issue, its omission from the schemes is not considered to be a concern in terms of how that might drive production systems.

Biosphere

A key gap for Group 1 schemes is coverage of biosphere impacts, especially those relating to wildlife species populations and biodiversity. Given the current biodiversity crisis (Burns *et al*., 2023; Dasgupta, 2021; IPBES, 2019), this is a significant concern as it could lead to externalisation of this issue and would not support national targets for this issue (incl. Goals 1 & 6 of the 25-YEP - Table 4.5). This weakness is recognised by some of the schemes (e.g. FE, IGD, PS), but an adequate solution is yet to be developed. Some of the LCA impact categories (and associated metrics) do relate to potential effects and impacts on biodiversity (e.g.

eutrophication and ecotoxicity categories) but these tend to be based on generic relationships. This highlights another weakness of LCA impact categories in that they are not good at accounting for very site-specific effects and impacts (Bare, 2010; Damiani *et al*., 2023; Ding *et al*., 2023; Nemecek *et al*., 2024; Reap *et al*., 2008). For example, losses of nutrients and pesticides are often derived by taking usage data and multiplying by emission factors for eutrophication and ecotoxicity. However, the fate and transport of these substances will depend on site-specific factors (including usage and mitigation practices; geospatial parameters such as soil type, geology and climate; etc., which may only be available via primary data from farms) and effects and impacts will vary with exposure to different species. Such complexity is often lacking in standard LCA impact metrics. The Group 2 schemes do account for site specific factors and practices, but they do not attempt to measure emissions and/or associated effects and impacts (albeit some do now attempt to model them, e.g. using carbon calculators). There are also many other biosphere impacts that are not associated with emissions of pollutants. For example, the provision of wildlife habitats including their configuration in the landscape (e.g. connectivity) and habitat complementation (i.e. provision of the different resources needed by different species and/or species lifecycle stages). The Group 2 schemes do cover some elements of these (to a limited extent), but the Group 1 schemes do not cover this aspect at all.

Geosphere

The consumption of resources is covered to some extent by both Group 1 and 2 schemes. Those that do not cover explicitly (e.g. FS and IGD) may cover it indirectly, e.g. carbon accounting with respect to fossil fuel use. Group 1 schemes do try to express the consumption of fossil fuels relative to the reserves remaining. It is assumed that the consumption of nutrients is covered in a similar fashion under the LCA category 'Resource use – minerals and metals', but this cannot be confirmed without a worked example. Group 2 schemes cover resource consumption indirectly by focusing on use efficiency rather than any assessment of the consumption rate and remaining reserves. Generally, resource use efficiency (and thus minimising the consumption of non-renewable resources and/or overexploitation of non-renewable resources) tends to be a key driver within any production system, if only for economic reasons. Thus, it is envisaged that its coverage by an ecolabelling scheme is likely to be a minimal driver in this respect.

With respect to soil, the related impact categories of soil provision and mass flows regulation are notable gaps in the Group 1 schemes. There is some coverage of soil quality regulation, but largely within the context of soil acidification and eutrophication rather than detailed indicators of soil health (albeit with the acknowledgement that this needs to be defined within the context of soil function). Given the importance of soil in agroecology (e.g. Principle 3 in Table 4.4) this is a significant weakness. The Group 2 schemes have greater coverage of soil-related impact categories, which is not unexpected given the practice-based nature of these schemes and the importance of soil in production systems. Many would argue (Davis *et al*., 2023; Tahat *et al*., 2020) that soil quality and health is fundamental to the sustainability of any production, thus it is essential that this be reflected in an ecolabel scheme as a driver for the transition to agroecology and for supporting Goal 6 of the 25-YEP (Table 4.5) (e.g. there are plans to publish a baseline map of soil health for England by 2028 and bring at least 40% of England's agricultural soil into sustainable management by 2028, HMG, 2023). The Group 2 schemes appear to do this, but the Group 1 schemes would be considered inadequate in this respect.

Hydrosphere

The consumption of water as a resource (water provision) is a little unclear amongst the Group 1 schemes, which is probably a reflection of the status of the metrics used for this impact within LCA. The three schemes that cover water provision (ES, FE and IGD) all use the PEF category of Water Use, which is a measure of deprivation potential based on the midpoint indicator AWARE (Boulay *et al*., 2018; WULCA, 2024). This represents the relative available water remaining per area in a watershed, after demand from humans and aquatic ecosystems has been met. However, it is not clear what is measured, in terms of water use, to determine this. Some examples focus on irrigation of crops, but clarity is needed on what other water consumption is included. Also, as the indicator is essentially a modelling approach, there is the likelihood that it does not account for very localised impacts of over exploitation of water resources. The Group 2 schemes

are more specific in terms of accounting for water use on farms and encouraging water efficiency. However, they do not require accounting for the impact on local water resources.

The emission of pollutants to water (water conditions regulation) is a similar picture to air quality regulation in that it is variable across both Group 1 and 2 schemes, thus a potential weakness with respect to supporting national targets for this issue (incl. Goals 1 & 6 of the 25-YEP - Table 4.5). The Group 1 schemes only partially cover this with the LCA impact categories of 'Eutrophication – freshwater' and 'Eutrophication – marine', with Planet-Score covering an additional impact category of 'Ecotoxicity – freshwater'. As with air quality regulation, the lack of details on site-specific risk reduction and mitigation practices and the use of secondary data (see Section 4.2.3) means that Group 1 schemes have the potential to reduce this element as a driver for change. The Group 2 schemes are also variable, ranging from basic requirements to assess the risk of water pollution, through to specific pollution reduction practices. Most of the Group 2 schemes do not account for environmental outcomes of water pollution. However, LEAF marque appears to take an extra step in requiring some form of water quality monitoring, albeit how this operates in practice is not clear.

With respect to water flows regulation, none of the Group 1 schemes cover this; and it is only partially covered by two Group 2 schemes (AGW & FtN). The role of land use in managing flow of water within a catchment can be critical (Kingsbury-Smith *et al*., 2023; Wheater & Evans, 2009), especially with respect to flooding events downstream, and this criticality is likely to increase within the context of extreme weather events associated with climate change. Thus, its omission from Group 1 schemes and lack of coverage by Group 2 schemes, could be significant with respect to drivers in the transition to agroecology and supporting Goal 7 of the 25-YEP (Table 4.5).

4.2.3 Data sources, data quality and verification

In addition to the range of issues and impacts covered, the data that is used is also important with respect to presenting the environmental 'picture' of production and consumption systems. Different data can paint a very different picture and thus drive the system in a different direction.

With respect to the Group 1 schemes, the reliance on secondary data is a significant issue. A key question is whether the secondary data is representative for the product to which it is applied, especially with respect to the agricultural production system and practices, and the site-specific circumstances of the farm (e.g. soil, climate, topography, etc.). In theory, the approach to assessing data quality (see Section 4.1.4) should identify when data are not representative, but as outlined in Section 4.1.4, the processes in this respect are vague. Clearly, there have been significant advances in LCA databases in recent years, so more data for more products are available, which has the potential to provide more reliable data. It is beyond the scope of this review to critique all the databases; however, it is likely that they do not have enough data to be sufficiently representative for all products, production systems, practices and circumstances; something that is recognised by many of the schemes and databases themselves (Deconinck & Toyama, 2022; Defra, 2024; IGD, 2023b; Scarborough *et al*., 2023). Thus, the danger is again that the use of labels that are not fully representative of the system of production has the potential to skew the picture towards those elements that are more robust (thus externalising those issues that are less robust). The granularity of the system is key, e.g. if an ecolabel does not respond to changes in farm practices (because the LCA database does not have that level of detail), then there is no pressure to change the production system.

With respect to the Group 2 schemes, these are based on the adoption of best practices. For a farm to be certified, certain practices must be implemented which are then independently verified. Thus, there is a clear driver for change. However, the delivery of environmental outcomes is not measured or part of the certification process. Thus, the approach is reliant on the assumption that the adoption of the practices will deliver the desired outcomes. In many instances, the science behind the assumptions will be sound, but in other instances less so and/or dependent on a complex combination of factors. In the context of diagnosis, where outcomes are not being delivered, the practices can be investigated to determine the issues and form solutions to address those issues. However, if outcomes are not measured, then this cannot be done. The integration of more outcome-based metrics in the concept of continuous improvement (which is at the heart

of environmental management systems, and approaches such as IFM) will help address this. However, the development of outcome-based metrics that can be practically applied within a commercial setting remains a challenge.

The utilisation of primary data is also relevant within the context of agroecology and food sovereignty. The Group 1 schemes are driven by a top-down product-oriented perspective, while the Group 2 schemes have a bottom-up farm-oriented perspective. The latter perspective has more resonance with the principles of food sovereignty, especially with respect to connecting producers and consumers. More broadly, there is also likely to be more governance and control over how data are utilised within any scheme or initiative when there is a clear requirement for primary data. Thus, utilising more primary data could be beneficial with respect to both painting a true and fair picture of the environmental impact of food and enhancing food sovereignty.

4.2.4 Impact communication: interpretation, normalisation and aggregation

Normalisation and benchmarks

In the context of the transition to agroecology and making progress towards national targets, the key element for interpretation is with respect to normalisation and benchmarking. As explored in Section 4.1.5, several different approaches are taken to interpreting the data collected in this respect, including expressing impacts relative to planetary boundaries and/or relative to other products for Group 1 schemes; and relative to a defined standard (best practices) for the Group 2 schemes. Thus, the question that needs to be posed is 'how do these approaches support the transition to agroecology and achieving national environmental targets?'

The planetary boundaries concept would seem to have the most resonance for agroecology (i.e. is the production system working within boundaries that have been determined to be sustainable?). However, as outlined in Section 4.1.5, planetary boundaries have not been determined for all impacts. Thus, their use for some impacts, and not all, runs the risk of skewing the interpretation to focus on those impacts that have planetary boundaries. The alternative is the Group 2 approach, where practices that could be considered agroecological are the benchmarks, thus achieving certification implies that an agroecological approach has been achieved. However, this does not provide a measure of the environmental outcomes achieved other than by association.

Finally, the transition to agroecology and national targets both imply a destination, i.e. determining when agroecology or targets have been achieved. It can be argued that agroecology is more about the journey than the destination. We live in a dynamic world in which challenges are evolving, thus is agroecology about achieving the capacity to adapt and respond to evolving challenges? Indeed, at the heart of all environmental management systems (and integrated farm management) is the concept of continuous improvement, in recognition that systems need to continually identify issues and implement actions to address them. This is also often termed adaptive capacity and/or resilience, which also aligns with Goal 7 of the 25-YEP (Table 4.5) in relation to adapting to climate change. Adaptive capacity and/or resilience are emergent properties of complex systems, thus are not directly measurable (it is often measured using novel or surrogate indices that account for multiple factors related to resilience). Given the importance of such properties, how they can be accounted for in any assessment of performance, such as ecolabelling, needs to be considered.

Aggregation

A key aspect of ecolabelling is communication of environmental impact to end users (be that other businesses and/or different consumer groups). It is beyond the scope of this study to explore the complexities of communication with different audiences and the psychology of behaviour change in response to that communication (Majer *et al*., 2022; Potter *et al*., 2021 & 2023; Tzilivakis *et al*. 2012). However, it is within the scope of this review to explore how and what information is communicated within the context of providing a true and fair view of the environmental impact of the food and how this potentially impacts on drivers in the transition to agroecology.

When communicating the outputs of any environmental impact assessment there is an inherent desire for simplicity and thus a drive towards a single value or conclusion, i.e. is it bad, indifferent or good; high, moderate or low; red, amber or green. Such information makes decision making easier within any context. Thus, as highlighted in Section 4.1.5, most of the Group 1 schemes aggregate environmental impacts to provide a single value or grade for a product. As described in Section 4.1.5, aggregation is problematic as it hides detail, introduces scope for burden shift, and nullifies any assessment of planetary boundaries to provide a benchmark of sustainability. These are also problematic attributes within the context of the transition to agroecology, for example burden shift (i.e. reducing one impact at the expense of another) would not be regarded as a step towards an agroecological future.

Reality dictates that the world is always more complicated. In some instances and contexts, presenting outputs as an environmental profile can be more helpful. For example, an analogous context is one of providing environmental information to policy makers (who also often demand simplified or aggregated results as it makes decision making easier). Work was recently undertaken by Rainford *et al*. (2023) to develop a Pesticide Load Indicator (PLI) for the UK. The approach was based on a similar approach developed in Denmark (Kudsk *et al*., 2018), the output of which was a pesticide load index that aggregated multiple pesticide fate and ecotoxicity metrics. In the process of developing the UK indicator it was determined that an aggregated indicator was not useful for policy development as it could potentially hide issues such as burden shift. Thus, the PLI evolved from a single aggregated metrics to one of presenting a profile of 20 metrics (4 fate and 16 ecotoxicity). This is neatly illustrated in Rainford *et al*. (2023) with the example of the withdrawal of neonicotinoid seed treatments on oilseed rape in 2018 due to concerns about their impact on bees. The PLI showed that this withdrawal had the desired effect of reducing the ecotoxic load on bees. It also showed that there were synergistic benefits with a decrease in load on other taxa including birds, mammals and fish. However, PLI also showed that there was an increase in load on parasitic wasps, which was due to an increase in use of acetamiprid in response to the withdrawal of neonicotinoids. This sort of information is valuable for policy formulation and would have been hidden in an aggregated metric, hence the environmental profile approach is more useful in this respect. This perspective can be transposed into the context of ecolabelling. For example, in nutritional labelling, consumers are presented within a nutritional profile. They can then select a product based on preference or health needs. Adopting a similar multi-component (environmental profile) approach for ecolabelling would also facilitate consumer preference. However the decision making could be more challenging (e.g. having to decide between biodiversity and climate change should products differ in this respect) and as outlined above it is beyond the scope of this review to examine psychology of purchasing behaviour.

4.3 Wider perspectives

4.3.1 The 'Ecosystem' of schemes and organisations

Investigating the Group 1 ecolabels in this review has revealed a complicated web or 'ecosystem' of the interactions between the different components. This includes not only the ecolabels themselves, but the databases, data partners, charities, businesses (particularly retailers), associations and government departments all of which have a stake. The description and diagrams below are just a snapshot based on publicly available information (websites, downloadable documents, scientific literature), so should not be regarded as comprehensive and are liable to change. The main purpose is to illustrate the complexity and highlight where the same data could be used by different schemes and/or be recycled. However, it is interesting to consider whether the independence or inter-dependence of the eco-label schemes with respect to the data sources and data providers influences the accuracy and reliability of the outputs and therefore trustworthiness to different consumer groups, but this goes beyond the remit of this review.

LCA databases have been developing over the last 20 years, with the first being Ecoinvent in 2003 (Ecoinvent, 2024). This had a couple of upgrades with the v3 (Weidema *et al.*, 2013) coming out in 2013, around the same time as several new databases were being created in the 2010s. They have subsequently released

further iterations, but to reduce the complexity of Figure 4.1, data flows are demonstrated to v3 only. Several of the LCA databases were built using external databases such as FAOSTAT (FAO, 2024) and CIQUAL (ANSES, 2024). The Intergovernmental Panel on Climate Change (IPCC) is a key resource for most of the databases, providing data and methodologies/calculations for GHG emissions. Poore and Nemecek (2018) authored a key review bringing together 570 studies from around 2010 to build a global LCA database covering five important impact indicators. It also drew on existing databases and has become itself a key source of data for subsequent studies, database development and ecolabels. The authors themselves have also been involved with the development of other databases and platforms. It is likely that the databases developed later in time have utilised data from those created before them, but this information is not always easy to find.

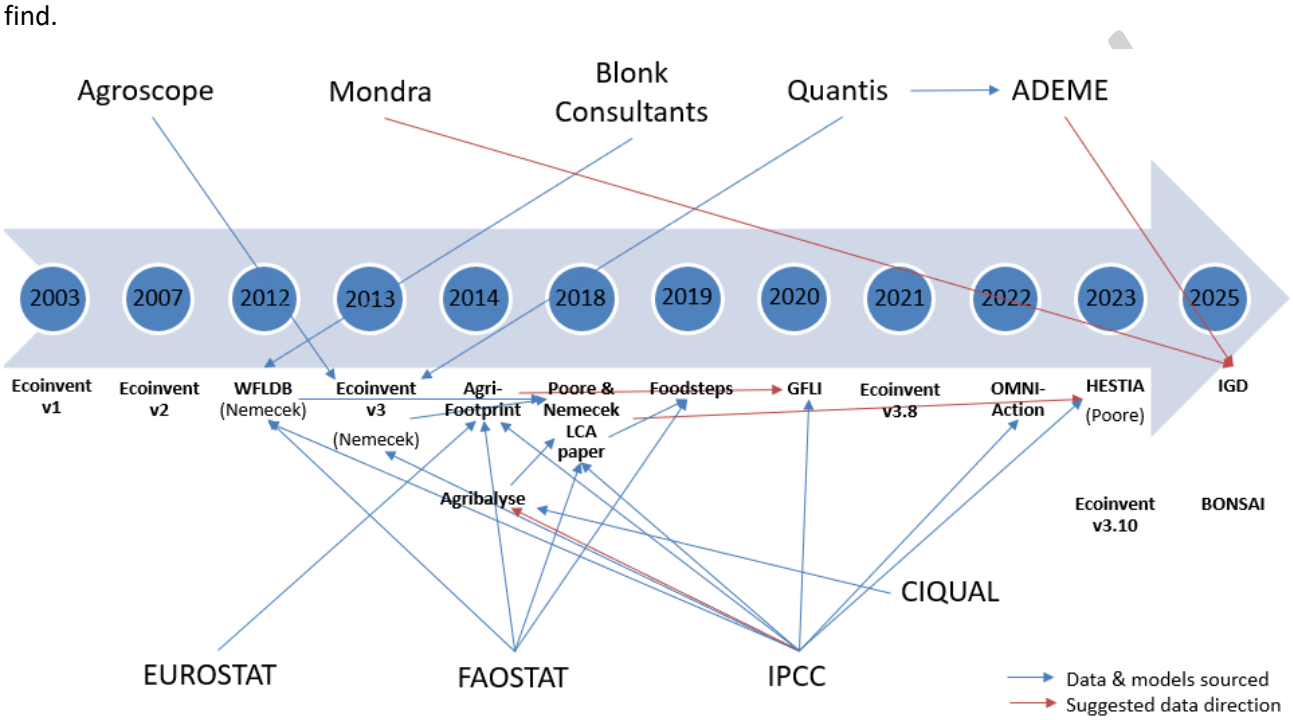


Figure 4.1: Flow of data between data partners, external databases and LCA databases
(Last updated: April 2024)

There are several data partners/supporting organisations who are operating in this space. The main ones of these are Agroscope, Mondra, Blonk Consultants, Quantis and ADEME. They have often helped develop a database and/or supplied data to them. Some have been involved in more than one database, and in the case of ADEME, have also funded the creation of the World Food LCA Database (WFLDB) (Quantis, 2024) (Figure 4.2).

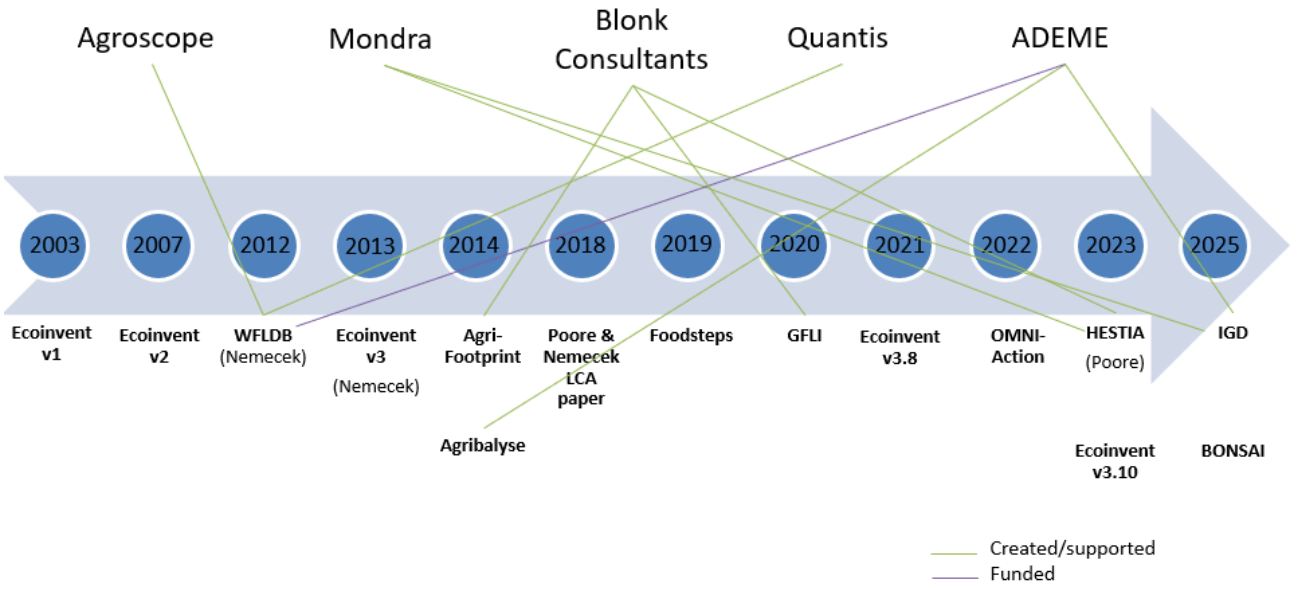


Figure 4.2: Interactions between data partners and LCA databases
(Last updated: April 2024)

LCA data is the most pertinent for the schemes that have been classified as Group 1. Investigating these has revealed that there are several common databases, partners and supporters between them (Figure 4.3). There is also a degree of interaction between the schemes themselves. The databases are used differently by the ecolabels, with Foundation Earth choosing to utilise five out of the six of them, and AGRIBALYSE® being used by 3 of the schemes. As observed with the database ecosystem, there are several data partners/supporting organisations involved with the ecolabels and overlapping with those supporting database development. ADEME is involved in some form with all the ecolabels apart from Foodsteps, and most ecolabels have an association with two or more of these organisations, with Planet-Score as the exception as they are only working with ADEME. Some of these organisations are also working with one another.

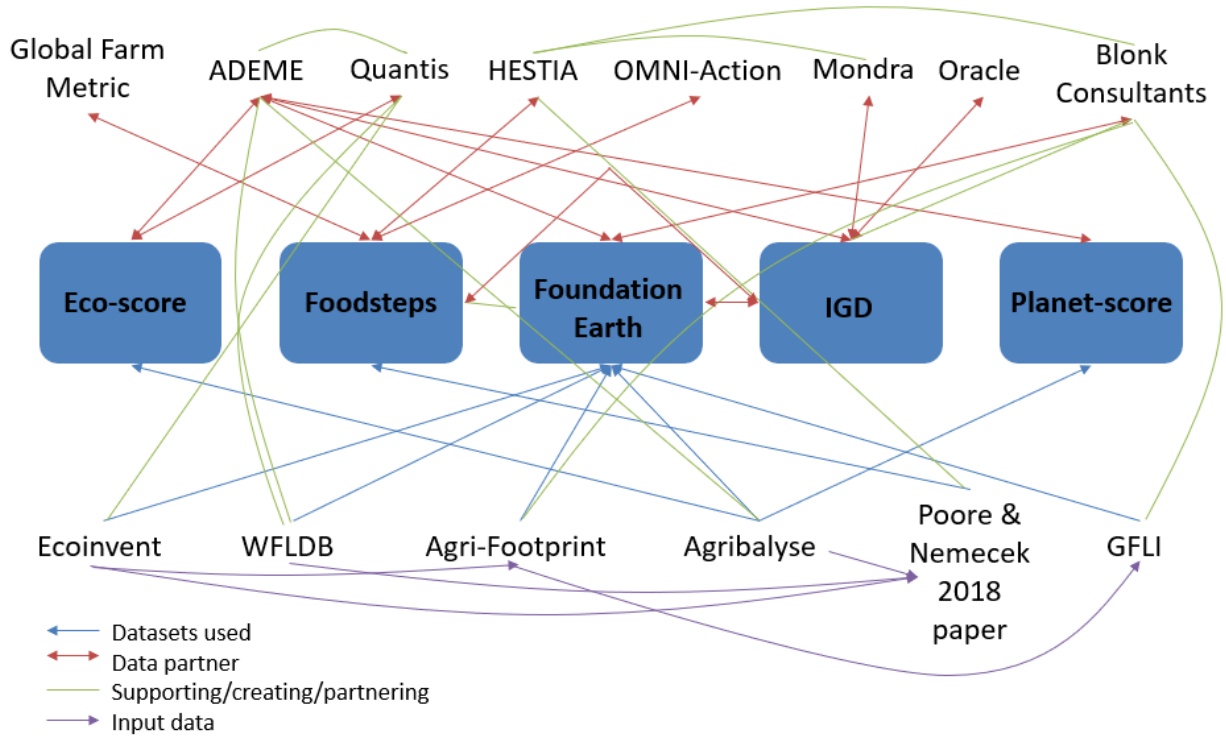


Figure 4.3: Complexity & interactions between ecolabels, LCA databases & data partners
(Last updated: April 2024)

To try and understand how the ecosystem complexity interacts with food businesses and retailers, work was done to record details of who was working with whom across the supply chain, where information was available. This helped to build a picture of the interactions at play, and which were some of the most active businesses and what the global reach might be for some of the partners and ecolabels discussed above. Figure 4.4 illustrates how two of the big businesses with multiple interactions are fitting into the ecosystem. It is interesting that there are some shared partnerships/agreements between them, with two of the ecolabels (Foundation Earth and IGD) and the Courtauld Commitment (WRAP, 2024), but also that they have made different decisions about which additional labels they have chosen to work with (Foodsteps vs Planet-Score and HowGood), which might reflect the more global reach of Nestlé compared to Tesco. They have also formed different data provider partners (Mondra and Anthesis vs Quantis), and other collaborations made with databases (Nestlé & WFLDB) and initiatives to pull the sector together (Tesco & WWF and Global Farm Metric Coalition). It is also worth noting that Tesco is the only one to be working with a Group 2 scheme. Generally the information used to build Figure 4.5 was gathered not from Tesco and Nestlé directly, but from the organisations they work with.

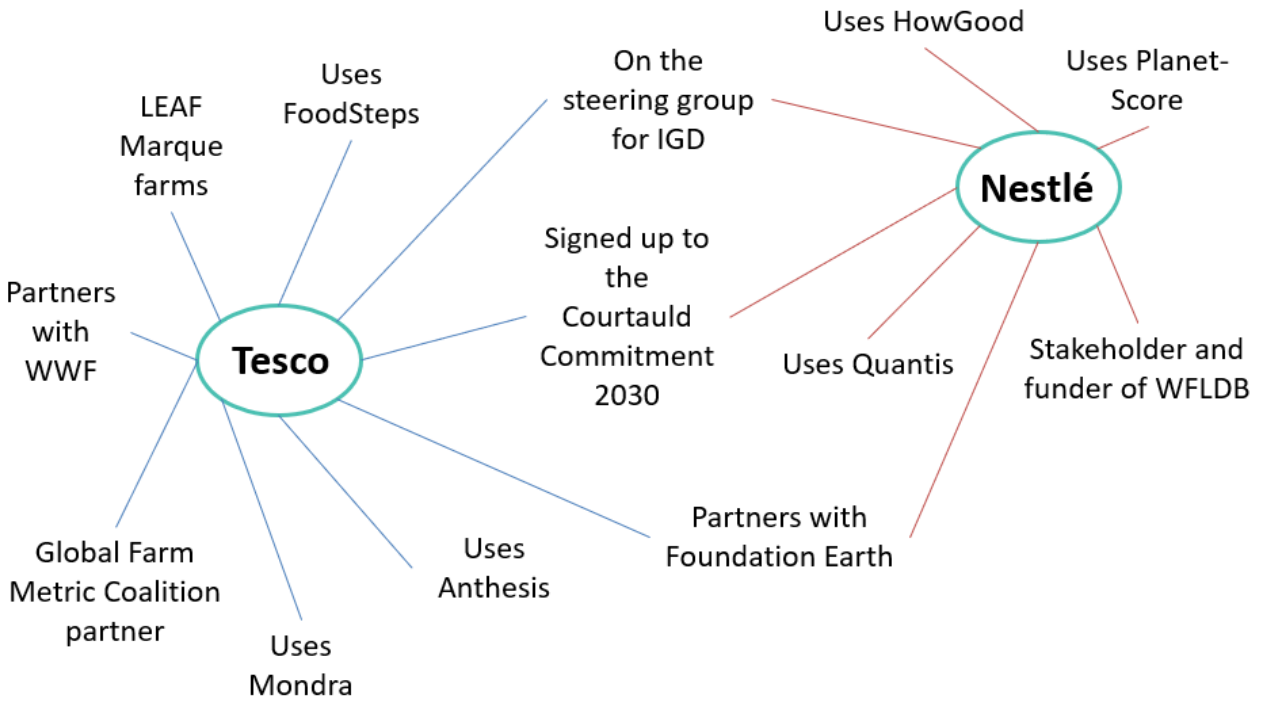


Figure 4.4: Two big businesses in the ecosystem
(Last updated: April 2024)

The Group 2 schemes also sit within an ecosystem (Figure 4.5) which is not quite as complex as the Group 1 schemes (Figure 4.3). The main players in the ecosystem are the certification bodies and the retailers. The certification bodies which are linked to each scheme to verify/audit that standards are adhered to and award certification if they have been met, allowing the produce to bear the mark. LEAF Marque utilise three certification bodies in the UK to verify their farms which are independent from themselves. Soil Association Organic use a Soil Association spin-out certification body called Soil Association Certification, which has been approved by Defra to verify EU organic standards. Pasture for Life have also outsourced their certification to like-minded groups to provide the third-party verification: Soil Association Certification, OF&G and the Biodynamic Association. Often, inspections will be done together, reducing burdens on farmers. Both A Greener World and Fair to Nature appear not to outsource certification but to audit internally with trained advisers.

The retailers investigated here are the eight main UK ones. Of these, six are operating farms that have LEAF Marque certification, with the exception currently being Sainsbury's and Morrisons. By checking their websites, five carry their own brand produce which is Soil Association Organic certified. It appears that Marks and Spencer operate their own organic scheme which is unclear who certifies it, and it was difficult to search for organic produce on Lidl and Aldi websites, so either they do not retail organic produce at all, or have website search functions that are unable to differentiate these goods. Fair to Nature have a limited product range but do work with Marks and Spencer and G's Growers, as well as licensing particular parties for retailing their products. A Greener World Certified Regenerative and Pasture for Life, are also both niche schemes with low numbers of products and tend to retail through farm shops, butchers, the scheme website or direct from farmers.

Fair to Nature, LEAF and Soil Association are all partners of the Global Farm Metric Coalition, pushing for "a common framework for defining and measuring impacts at farm-level". LEAF and Soil Association have also signed up to the Courtauld Commitment 2030 which aims to collectively reduce food waste, GHG emissions and manage water resources better across the food system in the UK. Control Union has a role to play with the inspections for the Soil Association Organic label.

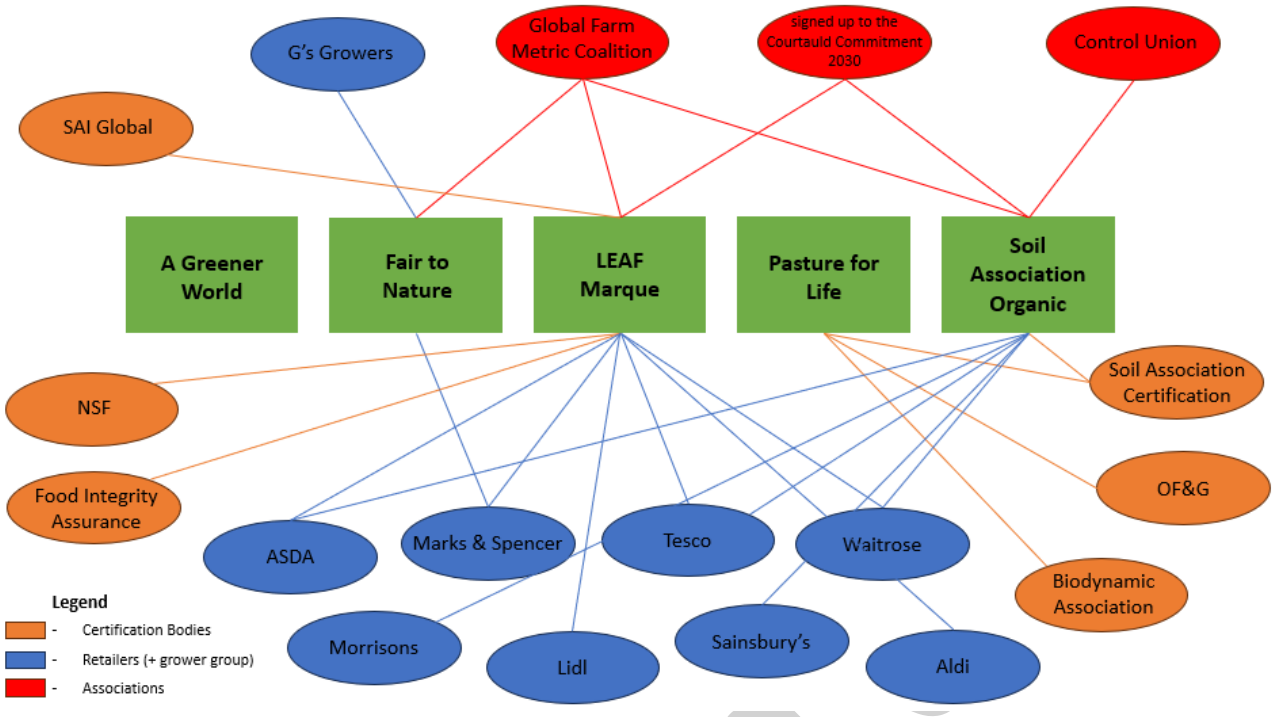


Figure 4.5: Connections between Group 2 schemes, certification bodies, retailers and associations
(Last updated: April 2024)

This review has revealed a complex ecosystem with lots of overlaps, interactions and shared resources. This potentially has positive and negative consequences for the validity and quality of the ecolabel outputs from Group 1, particularly in the level of understanding and collaboration amongst those involved, or the likelihood of propagating errors. This is largely down to the quantity and quality of data involved in LCA and the need to harmonise calculation techniques, methodologies and modelling within it. This is not a new discovery as similar findings came out of a study over a decade ago (Tzilivakis *et al*., 2011 & 2012), but with this more recent drive towards consumer facing ecolabels for environmental impacts, there are now calls from across the ecosystem for a more unified approach. This includes some of the ecolabels investigated in this report, UK Government, industry and campaigners (see Figure 4.6). With the recent release of the FDTP policy paper (Defra, 2024), this desire to create a more harmonised system, and particularly standardised LCA methods, has been voiced again and it is hoped that with their diverse scientific committee and government backing this may come to fruition, which would be very welcome.

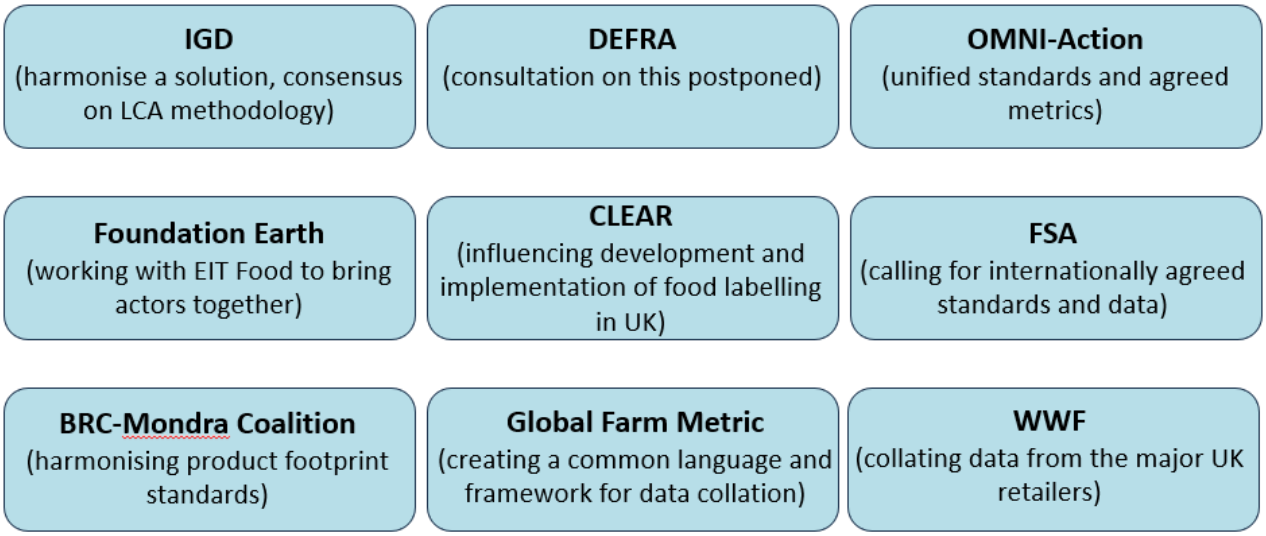


Figure 4.6: Organisations pushing for a unified approach to ecolabels

For the Group 2 schemes, the retailers appear to have a much bigger role in the promotion of good agricultural practice through working directly with several schemes and selling the produce from them, compared to Group 1. Several rely on Certification Bodies for their verification of data, adherence to standards and certification of those participating. A true system of data verification/third party or independent review is currently lacking in the Group 1 schemes, so there are likely lessons which could be learned between them. The calculation of data which potentially could come from farms as primary data into ecolabel schemes through LCAs, could enable a truer representation of the on-farm environmental impacts. However, much of this data either is not being captured on-farm, is not possible to capture as the technology is not yet suitable for collection, or is being captured but is held somewhere along the supply chain and not yet being utilised. If these issues could be rectified and the appropriate systems put in place to allow the data capture, governance, control and transfer, LCA studies could be undertaken that result in more meaningful and trustworthy ecolabel outputs.

4.3.2 New technologies and scientific understanding

Technologies are evolving at a rapid pace via a combination of improved scientific understanding; the development and improvements in remote sensing, on-farm and in-field sensors, the internet of things, and cloud-based data storage and processing; machine learning; and artificial intelligence (AI). These all have the potential to increase the amount of data that can be practically collected on farms including data related to environmental effects, impacts and outcomes, e.g. direct measurement and/or real-time monitoring of emissions. It is beyond the scope of this review to explore all these technologies in detail, but a few have been outlined below to provide a few examples.

Remote sensing can be used to derive data, often utilising satellite monitoring systems and interpreting the data suitable for agriculture. Recent examples of these are the ClearSky programme (Agrimetrics, 2022) and the start-up Agtelligence, with products like FarmScore® (Agtelligence, 2024); and remote sensing for measuring soil carbon (FCT, 2023). Drone technology is also developing, allowing both remote sensing and in-field monitoring with companies such as Drone Ag and Outfield operating in this space (Drone Ag, 2024; Outfield, 2024). In-field sensors for real-time monitoring are also important. A recent innovation from Sencrop is a probe measuring soil moisture and temperature trying to capture information to help farmers monitor soil conditions more effectively (Hort News, 2024). Sensor technology is not limited to fields and crops, with sensors to directly measure emissions from livestock now becoming available, e.g. emissions of NH_3 and CH_4 (Bielecki *et al.*, 2020; Choudhari *et al.*, 2023; Singh *et al.*, 2019). Sensors have also been developed for monitoring wildlife species populations and biodiversity, including novel bioacoustics

approaches (Kadish & Stoy, 2022; Kohlberg *et al*., 2024; Lahoz-Monfort & Magrath, 2021; Sharma *et al*., 2022). The challenge with many of these technologies is the quantity of data produced and the interpretation needed to make the information useful, which is where machine learning and AI can come into play, but more progress is needed to make these truly informative particularly on an impact and outcomes basis.

4.3.3 Sustainability

A common phenomena in the ecolabelling literature is the use of the term sustainability either within the context of an ecolabel or even interchangeably. For example, a tagline on the website for Foundation Earth states: "Building a more sustainable food industry through ecolabelling". The environmental issues covered in this review are one of the three pillars of sustainability, the others being social and economic. For any system to be sustainable, all three must be addressed and operating within limits determined to be sustainable. There are many debates over what those limits are (some covered in this study, e.g. planetary boundaries), however the important and primary point to emphasise here is that an ecolabel is not equivalent to sustainability, thus any use in this way should be avoided.

To assess and communicate sustainability would involve the integration of socio-economic impacts and metrics alongside environmental ones. To date, these have tended to be covered by separate schemes, for example RSPCA assured (RSPCA, 2024) and Fairtrade (Fairtrade, 2024) for animal, and worker health and welfare, respectively. However, there are initiatives exploring the possibility of a single or omni label to cover a more holistic range of metrics. For example, One Blue Dot (BDA, 2024) which combines nutritional advice with environmental sustainability metrics to help consumers make better choices for their diets for both their health and the health of the planet; or the OmniAction project (OmniAction, 2024) which is aiming to provide a unified global framework for inform on social and sustainability goals for business, finance and policy covering topics such as environment, land, labour, safety and nutrition. There have also been efforts to develop social metrics for LCA and/or a social LCA (S-LCA) framework (Life Cycle Initiative, 2022; Sala *et al*., 2015; Tokede & Traverso, 2020). However, these approaches are still relatively novel and lacking established methods. Questions remain over what metrics to use, what would be considered sustainable within those metrics, and the issues associated with aggregation within the context of a food label (outlined in this review). Additional criteria needed for sustainability would result in more metrics to communicate which could also become hidden in an aggregated score and/or would demand a multidimensional label as a solution (Brown *et al*., 2020; Pedersen *et al*., 2024; Stein & Lima, 2022).

4.3.4 Other uses of environmental data in the food supply chain

As outlined in the introduction (see Section 1.1), data on the environmental impacts associated with food, farming and land management has several potential uses in addition to ecolabelling. This includes demonstrating the delivery of public goods with public money within the Government's ELMs schemes; PES schemes where farmers are paid for the delivery of ecosystem services, such as cleaner water; trading schemes for carbon, nutrients and biodiversity; and corporate and/or supply chain reporting. All these demand data and thus associated environmental impact and outcome metrics. This presents several challenges including (1) ensuring that the burden to collect the data does not increase in multiples with the demands of each initiative; and (2) ensuring that the environmental picture presented for one scheme is not different, or even contradictory, to that presented in other schemes and initiatives.

With respect to the first point this is not a new phenomenon. The avoidance of collecting and/or entering the same data more than once is a common issue for many businesses including farmers. In theory, it can be resolved with efficient data management systems and/or ensure data interoperability. This is recognised in the FDTP policy paper with plans to support data infrastructure for interoperability and data sharing.

With respect to the second point, this is potentially a major issue due to many of the issues identified in this review. As outlined in Section 4.1.3, the ecolabelling schemes have some significant differences in terms of the environmental impact covered and the metrics used, which has the potential to present different views

of the environmental impact. For example, the Group 1 schemes lack coverage of biosphere impacts including wildlife species populations. Thus, in theory, there could be a scenario where a Group 1 ecolabel is applied to a product that is participating in a biodiversity trading scheme. The metrics used to convey the biodiversity benefits on the farm would not get captured within the Group 1 label, thus there could be a situation where the product from the farm has a poor ecolabel grade (based on LCA impact categories and metrics) whilst at the same time is selling positive biodiversity benefits. The consequent story that could arise is that scenario could ultimately lead to a loss in confidence of both schemes. This is of course hypothetical, but it demonstrates the type of problem that could arise when metrics, data and assessment methods are not harmonised (efforts to improve harmonisation and/or a more unified approach could help in this respect – see Section 4.3.1).

4.4 Limitations of the study

The aim of this review was relatively ambitious within the limited time and resources available. Thus, inevitably there are some limitations that need to be reflected upon to place the work in context. These largely relate to:

1. The boundaries of the study
2. The depth of analysis
3. Engagement with schemes

4.4.1 Study boundaries

The focus of this review has been ecolabelling, which has been interpreted as anything relating to the environmental impacts of food production and consumption. This has meant more socio-economic aspects were not included. From a sustainability perspective (see Section 4.3.3), products should be aiming to address both socio-economic and environmental issues, but this only further increases the challenges for ecolabelling outlined in this report. Thus, having different labels for these issues is likely to be the most viable solution for the near future.

Within the topic of the environmental impacts of food production and consumption, this study has presented a novel holistic impact category framework (see Appendix A) as a basis for comparing the different schemes reviewed. As this is novel there are a few issues that need to be reflected upon with respect to the categories included and omitted.

Firstly, there are four impact categories that have been identified as largely relevant to human receptors only, thus could be questioned with respect to being included within an ecolabel. These are: Biosphere: Pest control regulation; Biosphere: Disease control regulation; Geosphere: Fossil fuel provision; and Geosphere: Nutrient provision. For pest control regulation, the benefits of increasing populations of beneficial organisms are human within the context of reduced pest populations and thus improved yield and gross margins. However, it can also be argued that the habitat management for beneficial organisms could benefit other wildlife species (and the beneficial organisms themselves could be prey for other species); and there could be reductions in the use of pesticides which can have benefits in terms of reduced ecotoxic effects and reduced resource consumption. Similarly, for disease control regulation, the main benefits are for humans, but there could also be co-benefits for some wildlife species and reduced resource consumption. Thus, on balance it seemed reasonable to retain these impact categories for this study. For fossil fuel and nutrient provision, the benefits are largely human (i.e. ensuring any diminishing non-renewable resources are used efficiently, and any renewable resources consumed at a sustainable rate to ensure they are available to future generations), thus there is no direct benefit for wildlife. The consequent use of these resources does have impacts on wildlife, but these are covered under other impact categories (i.e. Climate regulation, Air quality regulation, Soil quality regulation, Water conditions/quality regulation). It could be argued that the extraction of these resources also has impacts on wildlife species, albeit this would be considered indirect in the context of food production. Given the significance of consumption of fossil fuels and nutrients and the connection

with other impacts, it is likely that its exclusion from an ecolabel would be perceived as a bit odd, hence why they were retained for this study.

Secondly, with respect to potential omissions, cultural ecosystem services have been omitted from this study. Most ecosystem service classifications consist of provisioning, regulating and cultural ecosystem services. The latter typically consists of aesthetic, educational, scientific, heritage and spiritual / symbolic services provided by ecosystems. The management of landscapes for aesthetic, recreational and educational value would be a key example of cultural services. By their very nature, cultural services are highly subjective and often relate to the intrinsic value of the landscape (e.g. the aesthetic value placed on a landscape can be very different between individuals). However, such values are often prevalent in many governance systems, schemes and initiatives (e.g. Areas of Outstanding Natural Beauty (AONBs) are legally defined and managed). Thus, the question that needs to be addressed is whether the explicit exclusion of cultural services is a significant omission? Many of the other impact categories included within the framework will also impact on cultural ecosystem services. For example, actions that aim to enhance wildlife species habitats and populations (e.g. greater diversity of habitats, more connected, etc.) could also enhance the aesthetic, recreational, scientific, and educational value of the landscape. However, there could be specific activities that have an impact on cultural ecosystem services that are not accounted for within these other categories, for example, activities to avoid damage or destruction of important ancient monuments and areas of archaeological or historical interest (a requirement under the LEAF Marque scheme – LEAF, 2023). However, the question then arises of whether these are pertinent within the context of an ecolabel (as strictly speaking these are not ecological)? There are also issues with how cultural ecosystem services are measured; often relying on environmental valuation techniques for which consensus is often lacking. On balance, it was decided to exclude cultural ecosystem services due to their inherent subjectivity and difficulties associated with measurement.

Thirdly, a more nuanced topic is one of resource use efficiency. The consumption of both renewable and non-renewable resources is covered within the framework from the perspective of unsustainable exploitation and use of diminishing resources respectively (e.g. see Animals for energy, food and materials provision; Biomass for energy, food and materials provision; Fossil fuel provision; Nutrient provision; Soil provision; and Water provision). However, resource use efficiency (i.e. consumption of inputs per unit of output) is not explicitly covered. Use efficiency is a critical aspect with respect to sustainable production as it is an indicator of wastage in production systems. Where non-renewable resources are consumed it is vital that remaining reserves are used efficiently to generate outputs; and where renewable resources are consumed, efficient use reduces the pressure on supply and thus lowers the risk of over-exploitation. In the context of food products, Group 1 labelling schemes have the potential to account for efficiency of use within the functional unit, i.e. where impacts are expressed per kg of product, those with lower resource consumption impacts per kg are more efficient. For Group 2 schemes, where effects and impacts are not quantified, then this is not possible, and the use of practices to increase efficiency are the key metric. Therefore, for Group 1 schemes, it is considered that use efficiency is captured within the functional unit and it is not necessary to have an explicit and separate use efficiency metric.

4.4.2 Depth of analysis

Given the breadth of the review, there was an inevitable trade-off with the depth, i.e. the level of detail to which different aspects could be reviewed and explored. On balance, the depth provided was sufficient to address the aims and objectives of the review, but there will always be scope to explore some aspects in more detail. Some examples are outlined below:

1. Environmental impact coverage: A key finding of this review is the lack of coverage of all environmental impact categories (see Section 4.1.3). To explore this further, some detailed worked examples of how this lack of coverage could be manifested would be valuable. However, this would involve both collating LCA data for a product plus data for the omitted impacts to provide some insights into how the omissions

might distort the picture of the environmental impact of the product. This was beyond the time and resources available for this project.

2. LCA databases: These are heavily used by the Group 1 schemes. Ideally, the content of these databases needs to be reviewed to determine how representative they are with respect to different production systems and practices. Many do incorporate assessments of data quality, but there is still a lack of transparency in this respect, especially clarity on how data quality is used and communicated within the context of an ecolabel.
3. Impact metrics: Appendix A details the impact category framework developed for this review and includes some example metrics for each impact. Each of the metrics have strengths and weaknesses with respect to their underlying methodologies and data. The latter is partially accounted for within this review (e.g. whether the metrics is activity, effect or outcome-based and whether primary or secondary data is used), but the methodological details have not been explored within this review. For example, the impact characterisation factors used for LCA impact categories vary in their approach and reliability for different contexts and scales (Nemecek *et al*., 2022; Pennington *et al*., 2004; Reap *et al*., 2008; Yan *et al*., 2011).
4. In relation to Points 2 and 3 above, there is scope for refinements to characterising and evaluating the data used for the impact metrics and data stored in LCA databases. This includes identifying where primary data is either directly or indirectly measured; whether surrogate metrics are utilised; whether data is derived from real-time measurement/monitoring; is only measured once (i.e. a snapshot) or over a defined period. However, it was not possible to achieve this level of detail within the time and resources available.

4.4.3 Engagement with schemes

The analysis of the schemes has largely been based on what is publicly available (which also contributed towards assessing their transparency – see Sections 2.3.6 & 4.1.6), with the exception of Foodsteps where a demonstration request facility on their website was utilised and facilitated further investigation. Generally, this was sufficient for the purposes of this review, however if more time and resources had been available, then more direct contact with the schemes and relevant staff may have enhanced the analysis within this study. For example, the documentation for Planet-Score refers to planetary boundaries but without any clear indication of if, or how, this has been used in the ecolabel. More direct contact with the schemes may have clarified some of these points, although it is not considered a major issue for the work that has been presented.

4.5 Further research and development

The environmental impacts of food production, within the wider context of sustainable production and consumption, has been a complex and challenging topic for research and development for decades. The development of environmental impact metrics, models and assessment frameworks (such as LCA) have been a key part of this, be that from the perspective of fundamentally understanding impacts and/or using the data to formulate policies and actions to bring about positive change. The role of ecolabelling as a tool to stimulate purchasing behaviour has been explored in many different product sectors, with food being one of the more challenging ones. There is little doubt that there is a need for further research and development on this topic.

Table 4.6 summarises the key issues identified within this review and outlines some initial ideas for further research and development. The recently published FDTP policy paper (Defra, 2024) covers some aspects and challenges addressed with this review, but largely from a product-based perspective. Some of the suggestions in Table 4.6 align with the research and development outlined in FDTP's policy paper, while others go beyond these.

Table 4.6: Areas for further research and development

Issue	Research and development
Environmental impact coverage	
The environmental impacts associated with food production are not adequately covered. The Group 1 schemes have some significant gaps in impact coverage and the metrics used for some of the impact categories do not adequately account for site-specific effects and impacts. The Group 2 schemes lack outcome-based metrics.	• Identify novel metrics that could plug gaps in coverage of key environmental impact categories, especially those that need to account for site-specific impacts. • Seek practical options for measuring environmental outcomes on farms. • Explore new technologies to generate data.
Data sources, data quality and verification	
The Group 1 schemes tend to rely on secondary data in databases for pre-farmgate emissions and impacts, thus there is a question mark over how representative and reliable this is, and thus, whether the granularity of the data sufficiently reflects the benefits associated with the adoption of agroecological practices.	• Use of data collected (and verified) within assurance / certification schemes to improve data in other supply chain initiatives (this potentially aligns with the FDTP's plans: "Integrating primary data into secondary datasets"; and "data infrastructure for interoperability and data sharing"). • Enhanced systems for data governance and control to improve food sovereignty. • Development of hybrid approaches that combine both Group 1 and 2 approaches.
Impact communication, interpretation, normalisation and aggregation	
Normalisation of impacts (i.e. placing them in context relative to a defined benchmark) is a key issue both with respect to communicating the impact of a product to businesses and consumers and as a driver for the transition to agroecology. Some approaches (e.g. planetary boundaries) exist for some impacts, but not all.	• Explore and identify benchmarks or targets for all metrics within the context of what needs to be achieved for the transition to agroecology.
Aggregation of impact values into fewer or a single impact value or rating for a product is problematic, as it hides detail, introduces scope for burden shift, and nullifies any assessment of planetary boundaries to provide a benchmark; thus has the potential to be counterproductive with respect to the transition to agroecology.	• Explore alternative approaches to aggregation that do not hide important detail and/or avoid the issue of burden shift. • Explore the viability of multi-component (environmental profile) labels, in recognition of the fact that aggregated eco-scores/labels are potentially meaningless or misleading.

Further research and development should be undertaken by ecolabel developers and practitioners, be that industry, government, regulators, academic institutions, or third sector organisations, in a collaborative fashion to ensure a harmonised solution emerges. If everyone attempts to develop their own solutions there is a continued risk of having different pictures of the environmental impact of food production and consumption across the supply chain which could be counterproductive with respect to achieving sustainable food systems.

5 Conclusions

Tzilivakis *et al*. (2011 & 2012) undertook a study for Defra exploring effective approaches to environmental labelling of food products. The conclusion of that study was that the science and methods available were not sufficiently robust to develop an outcome-based environmentally broad ecolabel. The work highlighted the complexity and challenges of ecolabelling in terms of the mechanisms and drivers within the industry, the practicalities of implementation and communication, and the objectives and purpose of the scheme. It has been over a decade since this work was undertaken and there have been some significant advances in science, technology and data during that time, but many of the challenges remain.

A fundamental issue to consider is 'fitness for purpose', i.e. are the ecolabelling schemes and their associated methods and processes suitable to meet the desired aims and objectives? To make such a judgement requires a definition of purpose. In the context of this review, this has been defined as firstly providing a true and fair view of the environmental impact of food at the product level, and secondly supporting the transition of the UK food system to agroecology, food sovereignty and meeting national environmental targets. It is from this perspective that the conclusions below have been made.

Two types of schemes have been reviewed within this study. Those which are focused on product level ecolabelling (product-oriented) (Group 1); and those which are focused on farm level ecolabelling (farm assurance-oriented) (Group 2) (often viewed as top-down and bottom-up approaches respectively). The approaches underpinning both types of schemes potentially have a positive role to play in terms of understanding environmental benefits and burdens of food production, aiding decision making and facilitating the development of improvements. However, their application within the context of communicating environmental impacts within an ecolabel as a mechanism for driving the industry to transition to agroecology, food sovereignty and meeting national environmental targets raises several issues.

Firstly, the two approaches are potentially giving rise to a 'perspective disparity' that is being driven by different data demands and purposes, which are conflicting with respect to understanding what is fit for purpose for food ecolabelling and with respect to enhancing food sovereignty. This is clearly manifested when considering system boundaries (what is the foreground and background system) and thus where primary and secondary data are utilised. In a product-oriented perspective, pre-farmgate emissions and impacts (which are usually the largest for food products) are categorised as Scope 3, i.e. they are outside the direct control of the assessed entity and are thus considered part of the background system in LCA, for which secondary data is often assessed to be adequate. However, from a farm-oriented perspective, pre-farmgate emissions and impacts are considered part of the foreground system, Scope 1, for which primary data should be sought and used. In the context of the transition to agroecology, changes in practices on farms are required that deliver the environmental outcomes society demands. Indeed, the FDTP policy paper recognises that "farmers are central to delivering our targets for climate and nature, alongside their core role as food producers, through emissions reductions and sequestration, and in realising the huge co-benefits of nature-based solutions, such as improving biodiversity and water quality" (Defra, 2024). If ecolabelling is to be used as a tool to drive this transition, then it must be responsive to changes at the farm level and farmers should have the tools available to govern and control this data to enhance food sovereignty. Thus, a product-oriented approach is potentially flawed with respect to providing an ecolabelling scheme fit for this purpose.

With respect to Group 1 schemes, firstly, the use of standard LCA impact categories (such as the 16 PEF categories) and their associated models and metrics results in the omission of several significant impacts. This notably includes the exclusion of biosphere-related impacts, such as wildlife species populations and biodiversity; and a lack of accounting of very site-specific impacts, not just in terms of wildlife and biodiversity, but effects and impacts on air, soil and water quality, soil provision and water flow regulation, all of which are critical with respect to agroecology and could become more so due to climate change. Some schemes acknowledge these omissions, while others only focus on the impacts they do cover. Secondly, there is heavy reliance on the use of secondary data rather than primary data from farmers and food producers. Advances are being made in developing databases, but a question mark remains over how detailed and

representative they are with respect to reliably reflecting variability within different production systems and practices. There are also questions over whether a product-oriented perspective creates issues for data governance and control within the context of food sovereignty.

The standardised approach provided by LCA is appealing in a business (or corporate) context. When there is a need to assess thousands of products, some of which are multi-ingredient, the use of a standardised approach across multiple products is an attractive option, more so when coupled with databases that make calculations easier and cheaper to undertake. However, the standardised approach conflicts with the holistic perspective needed to provide a thorough assessment and a true and fair picture of the environmental impacts of food production. It could also be argued that the adoption of standardised approaches can stifle innovation. The transition to agroecology and meeting national environmental targets need to be driven by scientific understanding and not just the methods available, otherwise this runs the risk of externalising some environmental issues. A few decades ago, LCA was an advance in terms of providing a framework for consistent environmental assessments. However, in many respects it has not kept pace with the evolving world and the demands of society; hence the weaknesses identified within the context of ecolabelling.

With respect to Group 2 schemes, these potentially cover a wider range of environmental impact categories, especially those relating to the biosphere compared to the Group 1 schemes. They are also based on primary farm data and account for local conditions and circumstances that can greatly influence environmental effects and impacts. However, certification is based on practices adopted and not achieved/measured environmental impacts and outcomes. Thus, the delivery of environmental benefits is unverified and thus their contribution to national environmental targets is uncertain.

The use of primary data for food production activities and environmental effects and impacts is clearly desirable with respect to providing a true, fair and reliable picture. However, when taking a product-based perspective, an LCA approach often demands data for thousands of activities and processes, each of which would need to be environmentally characterised and quantified (Wernet *et al*., 2016). As outlined above, this leads to many activities and processes in the food system being considered part of the background system, for which databases of secondary data are considered adequate. For example, Weidema *et al*. (2013) explain that the Ecoinvent Life Cycle Inventory (LCI) datasets are intended as background data for LCA studies where problem- and case-specific foreground data are supplied by the LCA practitioner. Thus, the use of secondary and/or modelled data for key life cycle stages in food production, such as pre-farmgate, is a significant issue with respect to providing a true, fair and reliable picture, especially with respect to accounting for the impact of different methods of production, including many agroecological practices designed to address problem- and case-specific issues. It is beyond the scope of this review to determine all the uncertainties this introduces into the picture, but there is scope for them to be significant. For example, Corrado *et al*. (2018) identified that datasets (including Agri-footprint, Ecoinvent and AGRIBALYSE) differed greatly depending on the definition of system boundaries and modelling of agricultural practices, characteristics of inventory data, agricultural operations, fertiliser application and fate, plant protection products application and fate, heavy metal inputs to the agricultural system and fate, irrigation assumptions, land use and transformation. Thus, the reliance on secondary and/or modelled data has the potential to be a significant issue.

Some Group 1 schemes are seeking to utilise more primary data and some have attempted to extend the scope of the impacts covered with novel metrics (this is also the case for some Group 3 schemes (Appendix B), e.g. HowGood claim to account for location and on the ground practices). Similarly, there is a desire amongst the Group 2 schemes to gather evidence to verify environmental outcomes. In both instances, progress in their respective endeavours has been limited, however further development and innovation should be encouraged. Technologies and understanding are evolving at a rapid pace. Many emissions can now be directly measured, remote sensing can be used to derive data, in-field sensors for real-time monitoring, machine learning, AI, etc. (see Section 4.3.2). Such technologies need to be explored alongside methods and processes for handling data to develop advances that have the potential to facilitate a true and fair view of the environmental impact of food. On a related note, taking a wider perspective, it is important to remember that data is often collected for more than one purpose. As discussed in Section 4.3.4, there are

potentially many other uses for environmental data such as for demonstrating the delivery of public goods (for policy), delivery of ecosystem services in PES schemes, or trading schemes for carbon, nutrients and biodiversity. A consistent picture of the environmental impact of food and land management needs to be presented across all these use cases. Any inconsistencies or contradictions due to different perspectives, metrics, models or data could damage the credibility of all the schemes concerned and thus the perception of their reliability (which could be counterproductive with respect to achieving progress towards environmental targets).

A common challenge for both Group 1 and 2 ecolabels is communication; how to convey environmental benefits and burdens within the confines of a label. The Group 1 schemes have adopted an approach of aggregating the outputs from all the impact metrics in a single score or rating. This is problematic both in terms of potentially hiding detail (e.g. burden shifts) but also conveying impacts relative to benchmarks such as planetary boundaries. This is further exacerbated by the omissions outlined above. For the Group 2 schemes, there is no aggregation; if the farm achieves the required standards, it is 'rubber stamped' via certification. The communication of what this means in terms of environmental performance and impact is then down to the communication of the 'brand' in the associated documentation. On balance, the more significant issue is aggregation within the Group 1 schemes. When LCA is applied in other contexts, aggregation is not usually undertaken, indeed it is considered an optional step in the ISO 14040 (ISO, 2006) standards for LCA (often termed damage characterisation) due to its problematic nature. It could be argued that LCA data is perhaps best used business to business (e.g. for Environmental Product Declarations (EPDs) (Del Borghi, 2013; Moré *et al*., 2022)), rather than business to consumer, as businesses can understand and utilise detailed data; whereas aggregating the data to aid communication to consumers can result in something that is meaningless. This is assuming that consumers are unable to utilise complex data, such as an environmental profile, for a product in their decision-making associated with purchasing. The psychology of this has not been reviewed within this study, but different approaches to the communication of environmental data should not be overlooked (especially when technology and its use is rapidly evolving). An alternative approach, in theory, would be a system where each impact is judged to see if it is within an acceptable limit (such as a planetary boundary). If a product ticks all the boxes, then it is given the rubber stamp / label. However, given the complexities, it is likely that few products would achieve this and defining limits (such as planetary boundaries) has to date not been possible for all impacts.

It has been recognised for many years that agricultural production systems need to adopt practices that have a lower environmental footprint and transition to a system based on agroecological principles (Prost *et al*., 2023; Schiavo *et al*., 2023; Schwarz *et al*., 2022). The drivers for this transition are complex and include scientific understanding, social, cultural and personal values, government regulation, environmental pressures and market forces. Ecolabelling as a tool overlaps with many of these as a mechanism to communicate impacts. The picture that is communicated must be a true and fair view of the environmental impact of food. If it is not, then it risks skewing the picture and driving the system in the wrong direction. This is also recognised by the FDTP (Defra, 2024) who identify that the incorrect choice of metrics has the potential to result in unintended consequences, including perverse incentives or trade-offs with other issues. Businesses demand efficient and economic solutions, and hence why standardised methods and databases of impacts are appealing, but this must not be pursued at the expense of creating a true and fair picture of the environmental impacts of food production. As highlighted in this review, there is a risk of falling into the same trap that causes many of the world's environmental problems, in that there is a risk of externalising important impacts, such as biodiversity, in pursuit of a standardised and/or simplified approach to ecolabelling, which could be counterproductive with respect to its aims. The complexity needs to be embraced to truly resolve the challenges society faces.

In the light of this perspective, this review has revealed the strengths and weaknesses of the schemes reviewed. The scope of the environmental impacts needs to be extended for all schemes, but especially for the Group 1 schemes. Issues such as wildlife species populations and biodiversity cannot be overlooked simply because they are difficult to measure in a standardised way. The need for more outcome-based metrics (to demonstrate progress towards environmental targets desired by society) was a finding over a

decade ago (Tzilivakis *et al*., 2011 & 2012) and this need remains. The practices adopted on farms to improve environmental performance must deliver that performance, and this can only be determined by measuring the outcomes. Additionally, many impacts are site-specific, so the demand for metrics that capture this detail persists. As mentioned above, the Group 1 and Group 2 schemes can have a positive role despite the weaknesses outlined in this study. In many respects, they have opposite attributes. Group 1 schemes use more outcome metrics, but with significant omissions; a lack of accounting for site-specific factors; and largely using secondary and/or modelled data. Whereas Group 2 schemes have greater coverage of environmental impacts; account for site-specific factors; and use primary data, but rely on practice-based metrics. Thus, neither approach is currently providing a comprehensive ecolabelling solution that provides a true and fair view of environmental impacts, supports the transition to agroecology, and supports meeting national environmental targets.

There is a push by many organisations (see Section 4.3.1) to develop a more unified approach to ecolabelling, but this is largely from product-based (top-down) perspectives and motivations. There appears to be an assumption that a standardised LCA product-based approach is the only solution (possibly driven by the EU Unfair Commercial Practices Directive (EC, 2005) and PEF approach (Courtat *et al*., 2023)). This could be interpreted as accepted practice, rather than establishing what is acceptable to provide a true and fair view of the environmental impact of a food product. There is also a risk that the Group 1 approach becomes interpreted as synonymous with outcome-based metrics, which is potentially misleading, more so if Group 2 schemes continue to encourage the measurement of environmental outcomes on farms. Many Group 1 schemes also utilise LCA as a methodological framework for environmental impact assessment, but as outlined in Section 4.1.3, key environmental impacts are omitted from LCA due to a lack of standardised metrics. Metrics for other environmental outcomes do exist, and the technology for measuring and handling the data are evolving at a rapid pace (see Section 4.3.2), so the opportunity to gather primary data on environmental outcomes in the future should be exploited (rather than relying on secondary and/or modelled data). This could also result in improved secondary data for use as background data in LCA studies and will hopefully be UK based and production system specific. The transition to sustainable production and consumption systems will rely on having the most accurate and reliable picture of the environmental impacts of food, which in turn will facilitate the adoption of agroecological practices that deliver the outcomes desired. This needs to be coupled with appropriate governance to ensure primary producers are empowered and incentivised to engage with this transition (ranging from those just embarking on this journey to those regarded as advocates). Food production systems are socio-ecological (Andersson *et al*., 2024; Hoek *et al*., 2021; Lamine & Marsden, 2023); hence this must be an integral part in any ecolabelling scheme.

There is scope for further research and development on ecolabelling of food products. The FDTP policy paper (Defra, 2024) has outlined areas of research and development to help improve the consistency, accuracy and accessibility of quantified environmental impact data for the agri-food industry. However, this is largely from a product-oriented perspective. Thus, there is scope to complement this programme of work with additional research and development to facilitate the development of ecolabels that provide a true and fair view of the environmental impact of food and more effectively supporting the transition to agroecology, food sovereignty and meeting national environmental targets (as outlined above). This includes identifying novel metrics that could plug gaps in coverage of key environmental impact categories; seeking practical options for measuring environmental outcomes on farms; exploring new technologies to generate data; exploring the utilisation of data collected (and verified) within assurance / certification schemes to improve data in other supply chain initiatives; enhanced systems for data governance and control to improve food sovereignty; exploring and identifying benchmarks or targets for all metrics within the context of what needs to be achieved for the transition to agroecology; exploring alternative approaches to aggregation that do not hide important detail and/or avoid the issue of burden shift; and explore the viability of multi-component (environmental profile) labels. This work needs to be undertaken by ecolabel developers and practitioners, be that industry; government, regulators, academic institutions, or third sector organisations, in collaborative fashion to ensure a harmonised solution emerges.

Finally, there is perhaps an opportunity to explore hybrid approaches across the schemes (drawing upon the ideas above). This could be a combination of a Group 2 approach to encourage the adoption of best practices and utilisation of its primary farmgate data to feed into a Group 1 approach to support the quantification of outcome-based metrics; thus providing an improved basis to confirm whether the practices are delivering the environmental outcomes society demands. This could result in a picture of the environmental impacts of food that is true and fair, which supports the transition to agroecology and meeting national environmental targets, and, if coupled with enhanced systems for data governance and control, has the potential to improve food sovereignty by improving the connections between producers and consumers.

Appendices

A Impact category framework

A.1 Introduction

The document outlines a framework for classifying all the possible environmental impacts (and associated metrics) that could potentially be covered by an ecolabel for food. This needs to include impacts and metrics at both the product and farm level, accounting for the different approaches between labels, especially those that take a Life Cycle Assessment (LCA) approach; those which are practice-based; and those which are outcome-based.

Several existing frameworks have been considered, including the standard impact categories in LCA (Figure A.1) (e.g. Hauschild *et al*., 2011), planetary boundaries (Figure A.2) (e.g. Rockström *et al*., 2009a&b; Steffen *et al*., 2015) and ecosystem services classifications (Figure A.3) (e.g. Haines-Young & Potschin, 2018), but none are comprehensive enough to adopt as a single solution. LCA impact categories tend to be limited to those that are emission-based and/or regional/global impacts, with biodiversity related impacts being a known weakness (Winter *et al*., 2017). The planetary boundaries concept defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth system, thus inherently tends to cover major global issues and struggles to account for regional or local impacts also including impacts on biodiversity (Biermann & Kim, 2020; Erlandsson *et al*., 2023; Lewis, 2012; Mace *et al*., 2014; Wolff *et al*., 2017). Ecosystem service frameworks are by design focused on the goods and services the ecosystems provide to humans and although there are elements which focus on biodiversity within those services, they are anthropocentric and thus do not directly account for the needs of wildlife species, albeit with the acknowledgement that biodiversity generally is important for many goods and services (Macfadyen *et al*., 2012; Muradian & Gómez-Baggethun, 2021; Sandifer *et al*., 2015; Schröter *et al*., 2014). The ecosystem services approach is, however, the most holistic and thus it has been adapted to address these issues. This echoes and extends the approach developed by Hardaker *et al*. (2022), and the classification below attempts to provide a more holistic and comprehensive approach to understanding the environmental impacts of food production systems from the perspective of human and wildlife species (acknowledging that the two are inherently interlinked).

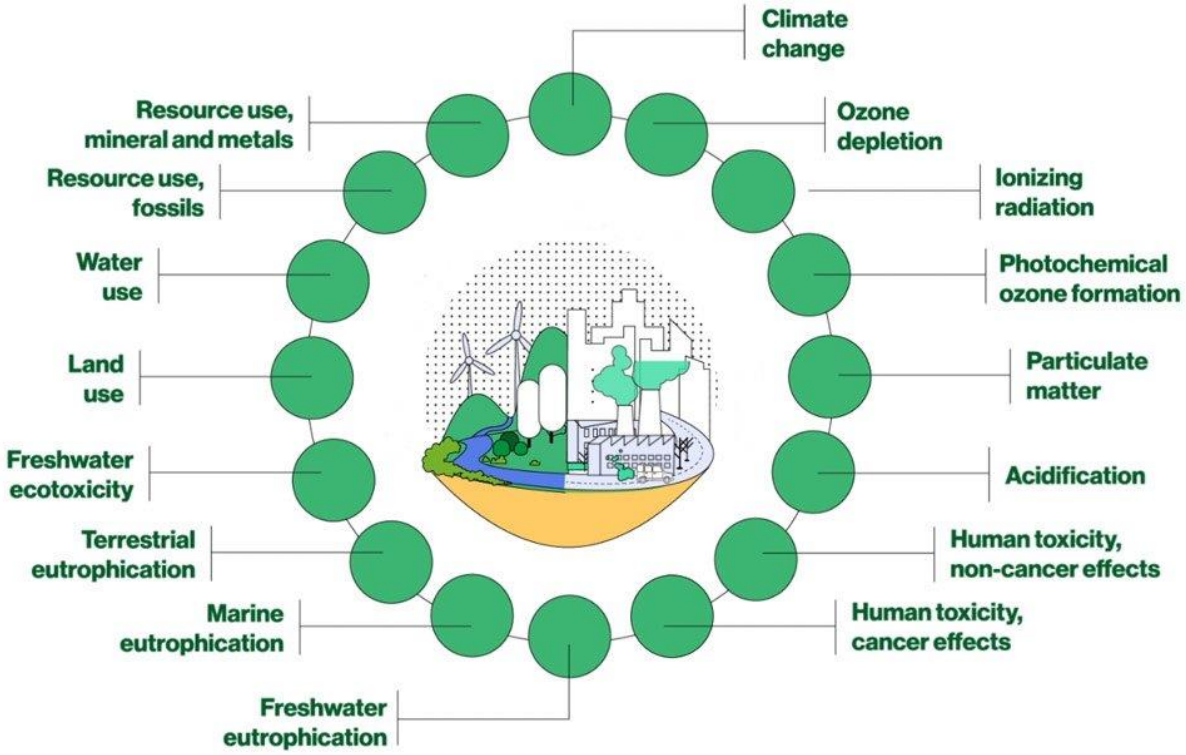


Figure A.1: Typical LCA impact categories
Source: ENVIROSCORE (2024)

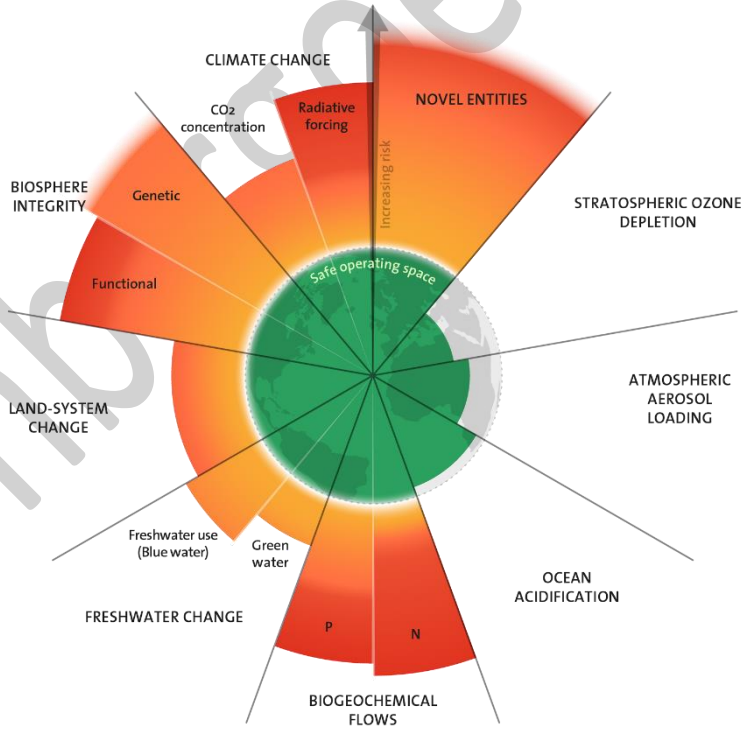


Figure A.2: Planetary boundaries
Source: SRC (2024)

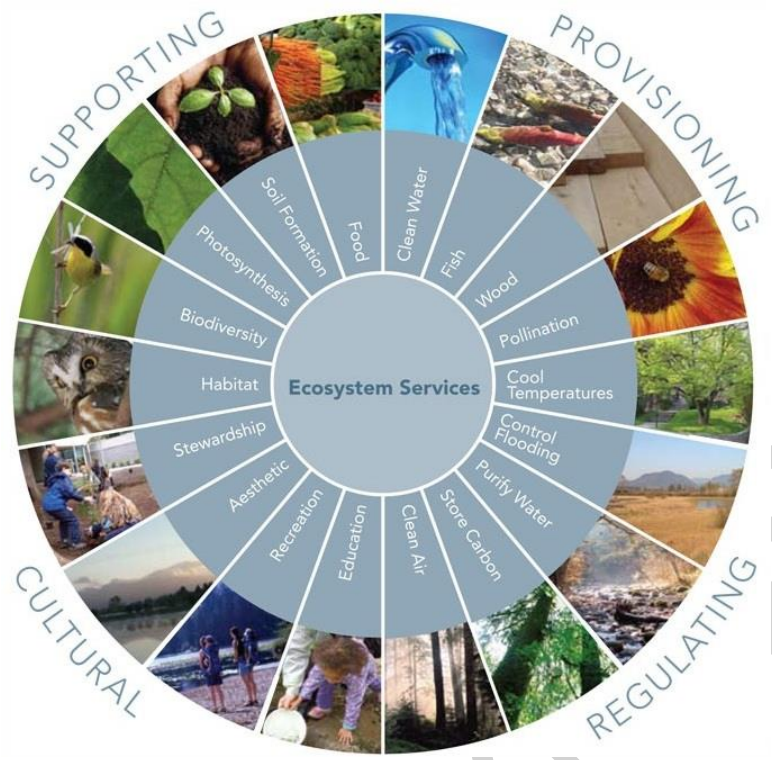


Figure A.3: Ecosystem services
Source: SSLLC (2024)

The approach adopted for this review takes an ecosystem services approach but explores it from the perspective of two end receptors (Table A.1) to differentiate where a service or impact differs with respect to the receptor. Additionally, a secondary classification has been implemented where the impacts are classified into four groups shown in Table A.2 following the four Earth spheres (which partially relate to planetary boundaries – see Table A.4).

Table A.1: Receptors

Group	Icon
Humans	
Wildlife*	

* Acknowledging that services and impacts will vary between species.

Table A.2: Earth spheres

Group	Icon
Atmosphere	
Biosphere	
Geosphere (aka lithosphere)	
Hydrosphere	

A common structure for each impact category has been developed as shown in Table A.3.

Table A.3: Structure for impact category description

Title:	Title of the impact category	Relevant icons (Tables A.1 & A.2)
CICES:	The classification following the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2018)	
Description:	An overview of the key issues for this impact category	
Receptor category:	Human and/or Wildlife	
Negative impacts:	A brief description of the main negative impacts that have been observed.	
Objective:	The desirable outcome with respect to addressing the impact.	
Key metrics:	A list of the key metrics ranging from activities (source of the impact), the environmental effects; through to the environmental outcomes. This can include practices and activities; mid-point effects and impacts; and outcomes and endpoint impacts.	
Normalisation:	Can the outputs of any metrics be contextualised to indicate relative magnitude or importance, e.g. the value relative to a defined reference point. This includes, where appropriate, reference to the nine planetary boundaries (Table A.4).	

Table A.4: Planetary boundaries

Earth sphere	**Planetary boundaries**	**Parameters**
Atmosphere	Climate change	Atmospheric concentration of GHGs
Atmosphere	Loss of stratospheric ozone (previously stratospheric ozone depletion)	Concentration of ozone (Dobson unit)
Atmosphere	Atmospheric aerosol loading	Particulate concentration in the atmosphere
Atmosphere; Hydrosphere	Release of novel entities (previously: chemical pollution)	Multiple boundaries, yet to be determined
Biosphere	Loss of biosphere integrity (previously: biodiversity loss)	Extinction rate
Biosphere	Land use change (previously: change in land use)	Percentage of global forests converted to croplands, roads and cities
Hydrosphere; Geosphere	Change to biochemical flows – Nitrogen and Phosphorus	Quantity of nitrogen applied to land
		Quantity of phosphorus applied to land
Hydrosphere	Ocean acidification	Global mean saturation state of aragonite in surface seawater (%)
Hydrosphere	Freshwater abstraction (previously: global freshwater use)	Annual consumption of freshwater

Source: Adapted from Rockström *et al*. (2009a&b); Sala *et al*. (2016); and Steffen *et al*. (2015)

Global planetary boundaries and per capita values can be found in Doka (2015); Rockström *et al*. (2009a&b); Sala *et al*. (2016 & 2020); and Steffen *et al*. (2015).

A.2 Atmosphere

A.2.1 Climate regulation

Title:	Climate regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Atmospheric composition and conditions > Regulation of chemical composition of atmosphere and oceans
Description:	Emissions of greenhouse gases (GHGs) and sequestration of carbon (C) from the atmosphere. Key GHGs are carbon dioxide (CO_2); methane (CH_4) and nitrous oxide (N_2O).
Receptor category:	Human and wildlife.
Negative impacts:	Climate change; extreme weather events; rising temperatures and sea levels; melting glaciers; exacerbation of other impacts. Consequent impacts on human health. Consequent impacts on wildlife and habitat suitability; more favourable conditions for exotic species; need for migration (latitude and/or altitude) in response to temperature changes (exacerbated by habitat fragmentation); phenological impacts such as modification of timing of activity of species, e.g. earlier emergence or flowering in temperate climates, disrupting biological/life cycles.
Objective:	Net zero emissions of GHGs; limiting global temperature increase to <1.5°C (compared to pre-industrial levels); prevent or minimise harmful climate change.
Key metrics:	Activity: • GHG emitting activities (e.g. combustion of fossil fuels, ruminant digestion, denitrification of nitrogen (N) fertiliser, storage of manures, etc.) • C sequestration activities (land use change, biomass accumulations, etc) Effect: • Modelled GHG and C sequestration using activity data • Measured emissions of GHGs • Measured sequestration of CO_2 (in biomass and soil) • Global Warming Potential (GWP) (CO_2e) Outcome: • Atmospheric concentration of GHGs • Radiative forcing • Changes in climate (temperature, rainfall, amounts and patterns) • Extreme weather events (frequency and severity) • Sea level rises • Human health and mortality • Habitat suitability • Species populations • Species health and mortality
Normalisation:	• Emissions as a percentage of per capita GHG emissions (UK, Europe, Globally). Example: Sala *et al*. (2017): - 8400 kg CO_2e per capita - Daily per capita = (8400/365.25) = 23 kg CO_2e • Planetary boundaries: Climate change Example from IGD for UK:

- Target of 50% reduction against 2015 baseline of 172 $MtCO_2e$.
- Emissions as a percentage of daily per capita target
- Daily per capita target = ((86 $MtCO_2e$ / 67000000)/365.25) = 3.5 kg CO_2e

(Note: per capita target may exist specifically for food and beverage products)
Example using EU data:
- PB = 985 kg CO_2e per capita (Sala *et al.*, 2016)
- Daily per capita target = (985/365.25) = 2.7 kg CO_2e

A.2.2 Air quality regulation

Title:	Air quality regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Atmospheric composition and conditions > Regulation of chemical composition of atmosphere and oceans
Description:	Emissions of pollutants to the atmosphere which can have negative impacts on humans and wildlife. This includes emissions of ammonia (NH_3); nitrogen oxides (NOx); Volatile Organic Compounds (VOCs); particulates; bioaerosols; and dust. NH_3 and NOx can contribute to smog formation, and NH_3, NOx, VOCs and particulates can contribute to photochemical ozone formation.
Receptor category:	Human and wildlife.
Negative impacts:	The pollutants above can impact on humans and wildlife, including respiratory problems, disruption of endocrine function, organ injury, increased vulnerability to stresses and diseases, lower reproductive success, and possible death. Deposition of the pollutants can also negatively impact on wildlife habitats (see Air quality regulation; Soil quality regulation, and Water conditions/quality regulation)
Objective:	Prevent or minimise emissions of polluting substances; prevent or minimise harmful effects of air pollutants.
Key metrics:	Activity: • Emitting activities. Practices that decrease (or increase) the risk of emissions (prevention and reduction) Effect: • Emissions of NH_3, NOx , VOCs, particulates; bioaerosols; and dust. • Atmospheric concentrations of NH_3, NOx , VOCs, particulates; bioaerosols; and dust Outcome: • Particulate Matter - disease incidence per kg of $PM_{2.5}$ emitted • Human Toxicity - cancer • Human Toxicity - non-cancer • Photochemical Ozone Formation - human health • Human health and mortality • Habitat suitability • Species populations • Species health and mortality
Normalisation:	• Emissions as a percentage of per capita emissions (UK, Europe, Globally). Examples: Sala *et al.* (2017): Particulate matter: - 0.00072 disease incidences per capita

- Daily per capita = (0.00072/365.25) = 0.000002 disease incidences
Photochemical ozone formation:
- 40.6 kg NMVOC eq. per capita
- Daily per capita = (40.6/365.25) = 0.11 kg NMVOC eq.
Human toxicity, cancer:
- 0.00004 CTUh per capita
- Daily per capita = (0.00004/365.25) = 0.0000001 CTUh
Human toxicity, non-cancer:
- 0.00048 CTUh per capita
- Daily per capita = (0.00048/365.25) = 0.0000013 CTUh
- Planetary boundaries: Atmospheric aerosol loading; Release of novel entities

A.2.3 UV-B radiation regulation

Title:	UV-B radiation regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Atmospheric composition and conditions > Regulation of chemical composition of atmosphere and oceans
Description:	The ozone layer absorbs harmful ultraviolet-B (UV-B) radiation from the sun. Emissions of pollutants that deplete this layer increases the amount of UV-B radiation reaching the surface of the Earth.
Receptor category:	Human and wildlife.
Negative impacts:	For humans, impacts on health, such as skin cancer and cataracts. For wildlife, impacts on plant growth and on phytoplankton.
Objective:	Zero emissions of ozone depleting substances; prevent or minimise harmful effects of UV-B radiation.
Key metrics:	Activity: • Ozone depleting substance emitting activities Effect: • Emissions of ozone depleting substances • Ozone depleting substance equivalents (CFC-11-e) • Ozone layer thickness. An ozone hole defined where column of ozone is below 220 Dobson Units: Target 276 (Sala *et al.*, 2016) Outcome: • UV-B radiation levels • Human health and mortality • Species health and mortality
Normalisation:	• Emissions as a percentage of per capita emissions (UK, Europe, Globally). Example: Sala *et al.* (2017): - 0.02 kg CFC-11e per capita - Daily per capita = (0.02/365.25) = 0.000064 kg CFC-11e • Planetary boundaries: Loss of stratospheric ozone Example using EU data: - PB = 0.078 kg CFC-11e per capita (Sala *et al.*, 2016) - Daily per capita target = (0.078/365.25) = 0.00021 kg CFC-11e

A.2.4 Gaseous flows regulation

Title:	Gaseous flows regulation
CICES:	Regulation & Maintenance (Abiotic) > Regulation of physical, chemical, biological conditions > Regulation of baseline flows and extreme events > Gaseous flows
Description:	The management of landscapes can have an impact on gaseous flows (e.g. such as wind).
Receptor category:	Human
Negative impacts:	Reductions in features that provide a barrier to wind or reduce its velocity (or features that result in channelling of wind) can result in damage to buildings, crops and wildlife habitats.
Objective:	Landscape configured to reduce wind velocity and/or prevent damage to buildings, crops and wildlife habitats.
Key metrics:	Activity: • Land management practices and activities that help reduce wind velocity Effect: • Modelled wind velocity • Measured wind velocity Outcome: • Incidence of wind damage • Severity of wind damage • Human health and mortality because of wind damage
Normalisation:	• None identified • Planetary boundaries: None identified

A.3 Biosphere

A.3.1 Animals for energy, food and materials provision

Title:	Animals for energy, food and materials provision
CICES:	Provisioning (Biotic) > Biomass > Wild animals (terrestrial and aquatic) for nutrition, materials or energy > Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)
Description:	Wild animals can be a source of fuel, food and materials (e.g. fibres) for humans as well as food and materials for wildlife species.
Receptor category:	Human and wildlife.
Negative impacts:	Where the harvest of the species results in the death (or a decrease in survival chances), over-exploitation (where the consumption rate exceeds the rate of replenishment) can result in species population decline and ultimately extinction.
Objective:	Sustainable consumption; conservation of species populations; sufficient populations to meet the needs of the consumer (human and wildlife)
Key metrics:	Activity: • Wild animal consuming activities; use of resource efficient practices and technologies.

- Land management activities to maintain or enhance populations of harvested species

Effect:

- Number of wild animals consumed (potentially accounting for the nutritional and/or energy benefits)
- Number of wild animals consumed relative to rate of replenishment

Outcome:

- Health and mortality of human populations dependent on harvested species
- Habitat suitability for species dependent on harvested species
- Populations of species dependent on harvested species
- Health and mortality of species dependent on harvested species

Normalisation:

- Change in species populations relative to a reference year.
- Planetary boundaries: Loss of biosphere integrity

A.3.2 Biomass for energy, food and materials provision

Title:	Biomass for energy, food and materials provision
CICES:	Provisioning (Biotic) > Biomass > Wild plants (terrestrial and aquatic) for nutrition, materials or energy
Description:	Wild plants can be a source of fuel, food and materials (e.g. fibres) for humans as well as food and materials for wildlife species.
Receptor category:	Human and wildlife.
Negative impacts:	Where the harvest of the species results in the death (or a decrease in survival chances), over-exploitation (where the consumption rate exceeds the rate of replenishment) can result in species population decline and ultimately extinction.
Objective:	Sustainable consumption; conservation of species populations; sufficient populations to meet the needs of the consumer (human and wildlife)
Key metrics:	Activity: • Wild plant consuming activities; use of resource efficient practices and technologies. • Land management activities to maintain or enhance populations of harvested species Effect: • Number of wild plants consumed (possibly accounting for the nutritional and/or energy benefits) • Number of wild plants consumed relative to rate of replenishment Outcome: • Health and mortality of human populations dependent on harvested species • Habitat suitability for species dependent on harvested species • Populations of species dependent on harvested species • Health and mortality of species dependent on harvested species
Normalisation:	• Change in species populations relative to a reference year. • Planetary boundaries: Loss of biosphere integrity

A.3.3 Habitat provision

Title:	Habitat provision
CICES:	NA
Description:	The management of biomass in landscapes can have a significant impact on habitats for different wildlife species, which in combination with the provision of different resources (Animals for energy, food and materials provision and Biomass for energy, food and materials provision) and the quality of resources (see Air quality regulation, Soil quality regulation, and Water conditions/quality regulation) will impact upon the health, mortality and populations of different wildlife species. The configuration of different landscape features (e.g. connectivity or fragmentation) and the complementation of different resources at various times of the year can be crucial to many species, especially in agricultural landscapes.
Receptor category:	Wildlife
Negative impacts:	Highly fragmented landscapes can prevent some species from moving easily through them to access the resources they need and/or some landscapes may be lacking specific resources (e.g. food or shelter) needed for a species within a given range to complete its lifecycle, resulting population decline and eventual extinction.
Objective:	Ensure landscapes and habitats are suitable for the needs of different wildlife species.
Key metrics:	Activity: • Land management design that helps ensure landscapes and habitats are suitable for the needs of different wildlife species. • Land use: ensuring land is provided for habitats (note: some LCAs use land use as a surrogate for biodiversity impact, but this is a poor metric in this respect (de Baan *et al*., 2013; Winter *et al*., 2017)). Effect: • Feature attributes • Landscape attributes • Connectivity • Fragmentation • Species richness • Species abundance • Habitat suitability indices for different or combinations of species Outcome: • Populations of species • Health and mortality of species
Normalisation:	• Change in species populations relative to a reference year. • Planetary boundaries: Loss of biosphere integrity

A.3.4 Pollination regulation

Title:	Pollination regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Lifecycle maintenance, habitat and gene pool protection > Pollination

Description:	The management of landscapes can have a significant impact on populations of pollinators and thus pollination of both crop and wild plant species.
Receptor category:	Human and wildlife.
Negative impacts:	Reduced crop yields, and reduced populations of plant species, with consequent impacts on other wildlife species, and humans that are dependent on those plants.
Objective:	Maintain or increase pollinator species populations; maintain or increase crop yields (dependent on pollination); maintain or increase populations of plant species.
Key metrics:	Activity: • Land management practices and activities that help maintain or increase populations of pollinators Effect: • Pollinator species populations • Amount of pollination in crops Outcome: • Crop yields (dependent on pollination) • Amount of pollination in wild plants ○ Quantity of pollen provided • Populations of wild plant species / number of species • Number of pollinator species supported
Normalisation:	• Change in species populations relative to a reference year. • Planetary boundaries: Loss of biosphere integrity

A.3.5 Seed dispersal regulation

Title:	Seed dispersal regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Lifecycle maintenance, habitat and gene pool protection > Seed dispersal
Description:	The management of landscapes can have a significant impact on populations of species that disperse plant seeds and thus populations of wild plant species.
Receptor category:	Wildlife
Negative impacts:	Reduced populations of plant species, with consequent impacts on other wildlife species that are dependent on those plants.
Objective:	Maintain or increase species populations that disperse plant seeds; maintain or increase populations of plant species.
Key metrics:	Activity: • Land management practices and activities that help maintain or increase populations of species that disperse plant seeds Effect: • Populations of species that disperse plant seeds Outcome: • Populations of wild plant species • Maintenance of wild plant species seedbank
Normalisation:	• Change in species populations relative to a reference year • Planetary boundaries: Loss of biosphere integrity

A.3.6 Pest control regulation

Title:	Pest control regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Pest and disease control > Pest control
Description:	The management of landscapes can have a significant impact on populations of species that are beneficial for the control of crop pests.
Receptor category:	Human
Negative impacts:	Decreases in populations of beneficial species; decreases in crops yields; and/or greater reliance on other crop protection options include cultural, chemical and biological intervention (and possible reduction in gross margins).
Objective:	Maintain or increase populations of beneficial species; maintain or increase crop yields/gross margins.
Key metrics:	Activity: • Land management practices and activities that help maintain or increase populations of beneficial species Effect: • Use of crop protection practices that are alternatives to beneficial species • Decrease in number / quantity of insecticide active ingredients used Outcome: • Populations of beneficial species • Populations of pest species • Crop yields / gross margins
Normalisation:	• Change in species populations relative to a reference year • Planetary boundaries: Loss of biosphere integrity

A.3.7 Disease control regulation

Title:	Disease control regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Pest and disease control > Disease control
Description:	The management of landscapes can have an impact on the risk and thus incidence of crop diseases. This includes the cropped environment and practices such as crop rotations which can help prevent the build-up of crop pathogens.
Receptor category:	Human
Negative impacts:	Decreases in crops yields; and/or greater reliance on other crop protection options include cultural, chemical and biological intervention (and possible reduction in gross margins).
Objective:	Reduce the risk, incidence and severity of crop diseases; maintain or increase crop yields/gross margins.
Key metrics:	Activity: • Land management practices and activities that help reduce the risk and incidence of crop diseases Effect:

- Use of crop protection / hygiene practices for disease control
- Decrease in number / quantity of fungicide active ingredients used

Outcome:

- Disease incidence and severity
- Crop yields / gross margins

Normalisation:

- None identified.
- Planetary boundaries: Loss of biosphere integrity

A.4 Geosphere

A.4.1 Fossil fuel provision

Title:	Fossil fuel provision
CICES:	NA
Description:	The consumption of fossil fuels is an issue of depleting a non-renewable resource. Although they are biotic in origin, the time required for their creation means they are considered non-renewable, thus are a diminishing resource.
Receptor category:	Human
Negative impacts:	Increasing scarcity can lead to increasing cost and ultimately unavailability (note: the negative impacts of combustion are covered under Climate regulation and Air quality regulation).
Objective:	Minimise or eliminate consumption; transition to renewable sources of energy.
Key metrics:	Activity: • Fossil fuel consuming activities; use of energy efficient practices and technologies. Effect: • Amount of fossil fuel consumed • Amount of fossil fuel consumed per unit of output (energy efficiency) Outcome: • Amount of fossil fuel consumed relative to scarcity of remaining reserves • Abiotic resource depletion potential (ADP)
Normalisation:	• Amount consumed relative the amount remaining (accounting for scarcity) Example: Sala *et al*. (2017): - 65300 MJ (ADP fossils) per capita - Daily per capita = (65300/365.25) = 178.8 MJ • Planetary boundaries: None identified.

A.4.2 Nutrient provision

Title:	Nutrient provision
CICES:	Provisioning (Abiotic) > Non-aqueous natural abiotic ecosystem outputs > Mineral substances used for nutrition, materials or energy > Mineral substances used for nutritional purposes
Description:	The consumption of nutrients (N, P & K) within fertilisers for crops is an issue of both depleting non-renewable resources and over-exploiting renewable resources.

Receptor category:	Human
Negative impacts:	Depletion of nutrient resources; higher fertiliser costs; reduced crop yields
Objective:	Sustainable consumption of renewable resources; minimise or eliminate consumption of non-renewable resources.
Key metrics:	Activity: • Nutrient consuming activities; use of nutrient efficient practices, crop varieties and technologies. Effect: • Amount of nutrients consumed • Amount of nutrients consumed per unit of output (nutrient use efficiency) Outcome: • Amount of nutrients consumed relative to scarcity of remaining reserves (non-renewable) • Amount of nutrients consumed relative to rate of replenishment (renewable)
Normalisation:	• Amount consumed relative the amount remaining (accounting for scarcity) Example: Sala *et al*. (2017): - 0.06 kg Sb eq. (ADP ultimate reserve) per capita - Daily per capita = (0.06/365.25) = 0.00017 kg Sb eq. • Planetary boundaries: None identified.

A.4.3 Soil provision

Title:	Soil provision 
CICES:	NA
Description:	Soil can be regarded as both an abiotic and biotic resource. However, for the purposes of this classification, it is regarded as an abiotic / physical resource that can be subject to erosion. Elements that relate to the degradation of the soil (including, for example, depletion of nutrients or organic matter) are dealt with under the regulation of soil quality (see Soil quality regulation; Soil quality regulation).
Receptor category:	Human and wildlife
Negative impacts:	Physical depletion of the soil. Note: impacts of the lost soil (sediment pollution) are covered under Mass flows regulation.
Objective:	Maintain or enhance soil to meet land use needs (human) and/or the needs of specific wildlife species.
Key metrics:	Activity: • Land management practices and activities that increase or decrease soil erosion Effect: • Modelled soil erosion (e.g. using the RUSLE) • Measured soil erosion / sediment losses • Agricultural production (e.g. crop yields) • Reduced soil habitat for wildlife species Outcome: • Human health and mortality • Wildlife species health and mortality • Wildlife species populations

Normalisation:
- Soil erosion as a percentage of per capita soil erosion (UK, Europe, Globally).
- Planetary boundaries: Land use
  Example using EU data:
  - PB = 1.83 tonnes of soil per capita (Sala *et al*., 2016 & 2020)
  - Daily per capita target = (1.83/365.25) = 0.005 tonnes of soil

A.4.4 Soil quality regulation

Title: Soil quality regulation

CICES: Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Regulation of soil quality

Description: The abiotic and biotic condition of the soil with respect to performing different functions and/or meeting the needs of humans and wildlife species. Includes mineral and nutrient content, physical condition, organic matter content, microbial communities and soil dwelling species.

Receptor category: Human and wildlife.

Negative impacts: Depletion of mineral/nutrient content; degraded physical structure; depletion of soil organic matter; degraded habitat and decreased population and diversity of microbial populations / soil dwelling species. Terrestrial eutrophication and acidification (N & P losses from agricultural land into terrestrial habitat and atmospheric N deposition). Also impacts of habitat suitability (see Habitat provision) with contaminated habitats being less suitable.

Objective: Maintain or enhance soil mineral/nutrient content, physical structure, soil organic matter, diversity and populations microbial communities and soil dwelling species and habitat to meet land use needs (human) and/or the needs of specific wildlife species.

Key metrics: Activity:
- Land use activities that impact on soil mineral, nutrient and physical condition, soil organic matter, diversity and populations microbial communities and soil dwelling species (especially those that are beneficial to human and other wildlife species, e.g. ecosystem engineers)

Effect:
- Soil metrics: Bulk density, NPK content, micronutrients, pH, soil organic matter, DNA analysis
- Atmospheric deposition of NH_3 and NOx
- Agricultural production (e.g. crop yields)
- Habitat suitability indices for soil fauna and flora

Outcome:
- Soil quality indices (for specific functions, land uses, species)
- Terrestrial eutrophication
- Terrestrial acidification
- Wildlife species health and mortality
- Wildlife species populations (incl. macrofauna e.g. worm counts)

Normalisation:
- Terrestrial Acidification:
  Example: Sala *et al*. (2017):
  - 55.5 mol H^+ eq. per capita

- Daily per capita = (55.5/365.25) = 0.15 mol H^+ eq.
Terrestrial Eutrophication:
- 177 mol N eq. per capita
- Daily per capita = (177/365.25) = 0.48 mol N eq.

- Planetary boundaries: Loss of biosphere integrity:
Terrestrial Acidification:
- PB = 145 mol H^+ eq. per capita (Sala *et al*., 2016)
- Daily per capita target = (145/365.25) = 0.397 mol H^+ eq.
Terrestrial Eutrophication:
- PB = 887 mol N eq. per capita (Sala *et al*., 2016)
- Daily per capita target = (887/365.25) = 2.43 mol N eq.

A.4.5 Mass flows regulation

Title:	Mass flows regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Regulation of baseline flows and extreme events > Control of erosion rates
Description:	The management of landscapes can have a significant impact on soil erosion. This impacts on the soil itself (as a resource) and sediment lost from fields can be a physical pollutant, e.g. causing sedimentation in rivers, with impacts on spawning grounds for fish or increased risk of flooding (see Water flows regulation); or deposition of sediment/mud on roads causing a hazard to road traffic.
Receptor category:	Human and wildlife.
Negative impacts:	Loss of productive capability of soil/land; sedimentation in watercourses increasing the risk of flooding; deposition of sediment on roads causing a hazard to road traffic; sedimentation of gravel beds in watercourses impacting on fish spawning grounds.
Objective:	Prevent or minimise loss of soil (losses greater than replenishment rate – see Soil provision); prevent or minimise harmful effects of sediment pollution.
Key metrics:	Activity: • Land management practices and activities that help reduce soil erosion Effect: • Modelled soil erosion (e.g. using the RUSLE) • Measured soil erosion / sediment losses. Outcome: • Incidence of floods where sedimentation is a key factor • Severity of floods where sedimentation is a key factor • Incidence of road traffic accidents because of sediment/mud on roads • Severity of road traffic accidents because of sediment/mud on roads • Damage to property where sedimentation is a key factor • Human health and mortality where sedimentation is a key factor • Wildlife species health and mortality where sedimentation is a key factor • Wildlife species populations where sedimentation is a key factor
Normalisation:	• Soil erosion as a percentage of per capita soil erosion (UK, Europe, Globally). • Planetary boundaries: Land use Example using EU data:

- PB = 1.83 tonnes of soil per capita (Sala *et al*., 2016 & 2020)
- Daily per capita target = (1.83/365.25) = 0.005 tonnes of soil

A.5 Hydrosphere

A.5.1 Water provision

Title:	Water provision
CICES:	Provisioning (Abiotic) > Water
Description:	The management of landscapes can have a significant impact on hydrology influencing both the flows (see Water flows regulation) and provision of water within a catchment, for both human and wildlife populations. With respect to humans, water provision primarily relates to the provision of drinking water, but also impacts on energy production (hydropower and cooling), material (non-drinking water), recreational and aesthetic services (cultural services). For wildlife species, water is also required for drinking, but also cooling, bathing, a habitat (for aquatic species) and a material for building (e.g. nests using soil/mud).
Receptor category:	Human and wildlife.
Negative impacts:	Reduction in flows and volumes that reduces the provision of water for the purposes above. In the case of human, lack of water can negatively impact on health (and in extreme circumstances human mortality). In the case of wildlife species, a lack of water can negatively impact species health and mortality and thus populations.
Objective:	Sustainable provision of water for humans and wildlife species
Key metrics:	Activity: • Land use activities that impact on water provision; use of water efficient practices, crop varieties and technologies. • Water capture • Water abstraction Effect: • Water abstraction relative to replenishment • Net water consumption • Agricultural production (e.g. crop yields) • Water consumption per unit of output (water efficiency) Outcome: • Water footprint • Water provision relative to water requirements (humans and wildlife species) • Human health and mortality • Habitat suitability • Species populations • Species health and mortality
Normalisation:	• Amount used relative to the amount available, e.g. using the AWARE 100 approach (WULCA, 2024) which attempts to account for water scarcity: Example: Sala *et al*. (2017): - 11500 m^3 world eq. of deprived water per capita - Daily per capita = (11500/365.25) = 31.5 m^3 world eq. of deprived water

- Planetary boundaries: Freshwater abstraction
  Example: Sala *et al*. (2016):
  - PB = 99.3 m^3 per capita
  - Daily per capita target = (99.3/365.25) = 0.27 m^3
  Example: Sala *et al*. (2020):
  - PB = 26300 m^3 world eq. per capita
  - Daily per capita target = (26300/365.25) = 72 m^3 world eq.

A.5.2 Water conditions/quality regulation

Title:	Water conditions/quality regulation
CICES:	Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Water conditions > Regulation of the chemical condition of freshwaters by living processes
Description:	Emissions of pollutants to surface and groundwater which can have negative impacts on humans and wildlife. This includes nutrients such as nitrate (NO_3^-), phosphorous/phosphate (PO_4^{3-}), emissions and deposition of ammonia (NH_3) and NOx; emissions of substances with a high Biochemical Oxygen Demand (BOD) (e.g. silage effluent, livestock slurry); emissions of pathogens (e.g. *Escherichia coli* and *Cryptosporidium parvum*); emissions of compounds with ecotoxic effects (e.g. pesticides, veterinary medicines and associated metabolites; oil; and plastics).
Receptor category:	Human and wildlife.
Negative impacts:	Aquatic eutrophication; increased costs for cleaning drinking water for humans; reduced oxygen in aquatic ecosystems; ecotoxic effects on specific species; aquatic acidification. Also impacts of habitat suitability (see Habitat provision) with contaminated habitats being less suitable.
Objective:	Prevent or minimise emissions of polluting substances; prevent or minimise harmful effects of water pollutants.
Key metrics:	Activity: • Emitting activities. Practices that decrease (or increase) the risk of emissions (prevention and reduction), and N and P balance • Properties of polluting substances (e.g. pesticide properties that impact on fate and ecotoxicity) Effect: • Emissions and pathways (e.g. leaching, runoff, etc.) of polluting substances (loss of NO_3^-, PO_4^{3-}, NH_3, NOx, substances with high BOD, pathogens, pesticides, oil, and plastics); emissions of PO_4^{3-} equivalents • Atmospheric deposition of NH_3 and NOx • Concentrations of pollutants in surface and groundwater (NO_3^-, PO_4^{3-}, total oil and grease / dissolved hydrocarbons, micro-plastics, faecal coliform levels, pathogens) Outcome: • Oxygen levels in surface water • Eutrophication in surface water • Acidification in surface water • Aquatic species health and mortality • Aquatic species populations • Aquatic species diversity

- Cost of cleaning water for human consumption
- Human health and mortality

Normalisation:

- Emissions as a percentage of per capita emissions (UK, Europe, Globally).
  Example: Sala *et al*. (2017):
  Eutrophication, freshwater
  - 0.734 kg P eq. per capita
  - Daily per capita = (0.734/365.25) = 0.002 kg P eq.
  Eutrophication, marine:
  - 28.3kg N eq. per capita
  - Daily per capita = (28.3/365.25) = 0.078 kg N eq.
- Planetary boundaries: Change to biochemical flows – Nitrogen and Phosphorus
  Example: Sala *et al*. (2016):
  Nitrogen:
  - PB = 3.5 kg N per capita
  - Daily per capita target = (3.5/365.25) = 0.0096 kg N
  Phosphorus:
  - PB = 1.1 g P per capita (Sala *et al*., 2016)
  - Daily per capita target = (1.1/365.25) = 0.003 g P
  Example: Sala *et al*. (2020):
  Eutrophication, marine:
  - PB = 29 kg N eq. per capita
  - Daily per capita target = (29/365.25) = 0.079 kg N eq.
  Eutrophication, freshwater:
  - PB = 0.84 kg P eq. per capita
  - Daily per capita target = (0.84/365.25) = 0.0023 kg P eq.

A.5.3 Water flows regulation

Title: Water flows regulation

CICES: Regulation & Maintenance (Biotic) > Regulation of physical, chemical, biological conditions > Regulation of baseline flows and extreme events > Hydrological cycle and water flow regulation (Including flood control, and coastal protection)

Description: The management of landscapes can have a significant impact on hydrology and the flows of water within a catchment. Land management practices will influence water retention and/or how quickly water enters watercourses, which can consequently contribute to flooding events downstream.

Receptor category: Human and wildlife.

Negative impacts: Flooding events can negatively impact both humans and wildlife.

Objective: Reduce the incidence of flooding events and/or reduce their severity/damage; prevent or minimise harmful effects of flooding.

Key metrics: Activity:

- Land management practices and activities that influence water drainage and retention, and thus flood peaks; use of Nature Based Solutions

Effect:

- Incidence of floods
- Severity of floods

Outcome:

- Damage to property (land and buildings)
- Human health and mortality
- Wildlife species health and mortality
- Wildlife species populations

Normalisation:

- None identified.
- Planetary boundaries: None identified.

B Group 3 ecolabelling schemes

Schemes in Group 3 are considered to have the potential to provide interesting concepts and ideas, but are either not related to food production; not UK or EU based; are very niche; or are conceptual and/or at early stages. These schemes and their reason for exclusion are shown in Table B.1.

Table B.1: Group 3 ecolabelling schemes

Name	Description	Website
Carbon Trust	A global consultancy firm specialising in carbon footprints who are supporting a diverse range of companies. Most food companies who have used the service are beverage producers. They are focussed on net zero rather than a broader range of environmental impacts. It was determined that only one carbon label needed to be included within the review – Foodsteps was considered more relevant and appropriate.	https://www.carbontrust.com/
Enviroscore	A Spanish-based ecolabel arising from pilot tests run by Foundation Earth. They are collecting data currently but do not yet have tools for on farm data measurement. Enviroscore are working to normalise the PEF score to a European food basket (Ramos *et al*., 2022). It is like Planet-Score and Eco-Score, but less developed and not currently seeking a UK market, so not included.	https://www.azti.es/enviroscore/en/
EU Ecolabel	EU scheme based on LCA data covering very few UK businesses, wide range of goods but no food, so not included.	https://environment.ec.europa.eu/topics/circular-economy/eu-ecolabel-home_en
Food Made Good Standard	Food service industry initiative to improve and recognise sustainable businesses with a label but does not go far enough to cover environmental impact of food production and therefore discarded for this study. The organisation running this standard is the Sustainable Restaurant Association.	https://thesra.org/the-food-made-good-standard/
Global G.A.P	Global umbrella organisation for smart farm assurance solutions with standards that certification bodies must adhere to. It is therefore not an ecolabel in the same sense as those in this study and so excluded.	https://www.globalgap.org/

Name	Description	Website
HowGood	USA-based database for LCA data from cradle to retail for 33,000 products. They use 600+ data sources for this but missing the primary sourcing from farm although they do account for location and "on the ground practices". HowGood have started to produce eco-labels accounting for carbon footprint, water use, and other climate impacts, biodiversity, processing, labour risk, land occupation, soil health and animal welfare. They create multiple labels displaying various information which is potentially overwhelming for the customer. Not yet in the UK and therefore discounted.	https://howgood.com/
Inoqo	An Austrian software application as a service platform supporting the food industry to understand their socio-environmental impacts of their products down to ingredient level using LCA. More sustainable alternatives are suggested, and scores can be used to communicate to consumers via labels and/or an app. Particularly relevant to reducing Scope 3 emissions and reaching net zero goals. Has low uptake currently and not yet in the UK so not included.	https://www.inoqo.com/
Klimato	A Swedish climate impact reporting business who produces carbon footprint (CO_2e) labels. Based on LCA data but have developed their own product database with Swedish research institutes. They have a small number of British and European businesses using it but still quite niche. It was determined that only one carbon label needed to be included within the review – Foodsteps was considered more relevant and appropriate.	https://www.klimato.co/
My Emissions	A carbon calculator and label producing business. It uses an A-E rating scheme and has a small number of UK and global food businesses using it. Allows identification of where emissions are highest in a product's supply chain and advises on how reductions could be made. It was determined that only one carbon label needed to be included within the review – Foodsteps was considered more relevant and appropriate.	https://myemissions.green/
Nutritics	Primarily focused on nutrition but does have a carbon footprint capability called Foodprint which is LCA-based (from literature) and created using their own database. This helps a business understand its carbon footprint better and can be put on packaging/menus etc. so customers can make better decisions. Foodprint will also include water footprint. It was not included in the review due to its narrow environmental impact focus.	https://www.nutritics.com/en/

Name	Description	Website
OF&G Organic label	Organic scheme to enable farmers to be recognised as organic producers as set out by EU legislation by adherence to standards. It was determined that only one organic scheme needed to be included within the review (for comparison purposes). The Soil Association was selected as organic symbol is the most widely recognised in the UK and it is the UK's largest and oldest organic certification body.	https://ofgorganic.org/
OmniAction project	UK initiative to create a unified ecolabel (covering environment, land, labour, safety, nutrition), invites data input, largely PEF based currently. This ecolabel is still in its infancy so was not included in the review.	https://omniaction.org/
One Blue Dot	Environmentally Sustainable Diets Toolkit: combining nutritional advice with environmental sustainability metrics to help consumers make better choices for their diets for both their health and the health of the planet. Output is not an ecolabel so not included in this study.	https://www.bda.uk.com/resource/one-blue-dot.html
Origin Green	Ireland's national food and drink sustainability programme led by Bord Bia. It is a voluntary scheme covering farmers, manufacturers and retail, and foodservice across the country. The impact categories used are GHG emissions, biodiversity, water use, energy efficiency, soil management and socio-economic factors. It has been widely taken up and covers 70-95% of key food production sectors. Origin Green is an Ireland based initiative, so not included in this study.	https://www.origingreen.ie/
Red Tractor Green Commitment	Food production standards label, adherence to standards allows display of label on products. A voluntary green label is being developed to include environmental impact of production. Currently subject to NFU review; limited information available; due for release 1st April 2024 but cancelled before release date, so discounted from the study.	https://redtractorassurance.org.uk/the-red-tractor-greener-farm-commitment/
Reewild	App-based carbon footprint of food and drink providers allowing the consumer to make low emissions choices and offset the remainder by planting trees. Their label rates the carbon footprint A-E. It was determined that only one carbon label needed to be included within the review – Foodsteps was considered more relevant and appropriate.	https://reewild.com/

C Scheme characterisation tables

C.1 Eco-Score

Sub-criterion	Answers
Aims & objectives	"The ambition of the Eco-score® is to be a decision-making tool to guide our food choices towards a more sustainable mode of consumption. By encouraging more virtuous agricultural practices and choosing food that preserves our environment, we can actively contribute to preserving resources, containing global warming below 2°C and preserving living things for future generations." Helping consumers make more sustainable food choices and encouraging better agricultural practices to care for the environment.
Ownership	The brand is owned by ADEME but is organised by a collective of 11 French companies. Not clear how this works. Primary producers are not involved.
Perspective	Top down
Market penetration	In addition to the 11 companies in the collective, Eco-Score has worked with 5 companies who display the label or have participated in experiments. France based with a little in Germany and expanding to Belgium, currently nothing in UK.
Scope	Single product (either single ingredient or recipe-based product).
Retail	Retailers, restaurants, websites.
Audience	B2B for B2C
Label location	On menu, on food product, on app, on website, depending on who is using it.
Label Type	Scores A-E and use RAG colours
Impact categories	16 PEF (weighted score for importance by PEF) indicators plus a score for production system, local supply, environmental policy, packaging and threatened species.
Reason	LCA indicators do not go far enough to cover all environmental issues and will not allow differentiation between products in the same category but does enable a baseline score. The additional indicators therefore allow for product differentiation and covers a wider range of environmental impacts.
Omissions	Animal welfare, biodiversity is only alluded to through their threatened species additional indicator.
Metrics	Based on LCA by AGRIBALYSE® so no measurements.
Outcomes	Environmental outcomes are by association of the environmental indicators used.
Data source	AGRIBALYSE®
Benchmarks	Unknown
Governance	Unknown
Qualification	No, the score given is what it is and displayed as is.
Levels	Products are rated A-E, with A being the highest rating achievable
Requirements	N/A
Discretion	N/A
Data verification	Done internally?
Independent verification	No
Inspections	N/A
Certification	N/A

Sub-criterion	Answers
Implementation	N/A
Risks	N/A
Actions plans	No
Evolution	No, but underlying data possibly is improving over time.
Public availability	Yes
Clarity	Yes (although they need to be translated from French).
Enforcement	No (N/A)
Limitations	No, they identify limitations with PEF approach and have added their own additional categories to score by to combat this.

C.2 Foodsteps

Sub-criterion	Answers
Aims & objectives	"Foodsteps is a UK based start-up which offers data and communication solutions for food businesses looking to measure, reduce and communicate their food's environmental impact." "We have a mission to help the food system measure, reduce and communicate its environmental impact." "Foodsteps helps food businesses and consumers to understand the environmental impact of their food. We are a passionate team working across the food sector to integrate environmental impact data into everyday decision-making." Helping the food system measure, reduce and communicate the environmental impact of food production, and improving the understanding of this for both consumers and businesses.
Ownership	Independent UK start up. No primary producers involved as it is all based on LCA data.
Perspective	Top down
Market penetration	Created in 2019. They have listed 19 businesses who use their label, including some food outlets, one retailer, a few major companies, assumed UK based.
Scope	Single product
Retail	Restaurants/food outlets
Audience	B2B for B2C
Label location	On menu
Label Type	Scores A-E for carbon footprint, uses RAG colouring and displays the actual value.
Impact categories	Carbon footprint/GHG emissions, with ambitions to extend the impact categories to cover land use, water use, eutrophication and acidification.
Reason	It is "one of humanity's biggest challenges".
Omissions	Land use, water use, pollution they state are missing but important.
Metrics	Carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, nitrogen trifluoride emissions.
Outcomes	N/A.
Data source	Poore and Nemecek (2018)
Benchmarks	None
Governance	N/A
Qualification	No

Sub-criterion	Answers
Levels	Products are rated A-E, with A being the highest rating achievable
Requirements	N/A
Discretion	N/A
Data verification	"Foodsteps performs a rigorous verification process to ensure the quality and reliability of the carbon labels".
Independent verification	No
Inspections	N/A
Certification	N/A
Implementation	N/A
Risks	N/A
Actions plans	No
Evolution	No
Public availability	Yes
Clarity	Yes
Enforcement	N/A
Limitations	They state that not all data is available for LCA so approximations/next nearest are used instead as well as a rating for data quality to account for this.

C.3 Foundation Earth

Sub-criterion	Answers
Aims & objectives	"Foundation Earth is an independent, non-profit organisation issuing front-of-pack environmental scores on food products, helping businesses build a more resilient and environmentally sustainable food system while giving consumers the tools they need to make sustainable buying choices. We bring together scientists and leading figures from food production and retailing who all share a vision of a food industry that does not destroy the planet." Want to create a more sustainable food industry by helping businesses and consumers to make more environmentally sustainable choices through on pack scores.
Ownership	Foundation Earth with a board of directors, scientific committee and industrial advisory group. No primary producers.
Perspective	Top Down
Market penetration	Began in 2019 in the UK. Trialled in 2021/2022 with a small number of UK retailers. Partners with 49 actors from across industry, academia and NGOs.
Scope	A single product
Retail	Retailers
Audience	B2C
Label location	On food product
Label type	Scores A+ to G, uses RAG colouring
Impact categories	Those from the PEF – climate change, ozone depletion, human toxicity (cancer and non-cancer), particulate matter, ionising radiation, photochemical ozone formation, acidification, eutrophication (terrestrial, freshwater and marine), ecotoxicity (freshwater), land use, water use, resource use (fossils, minerals and metals).
Reason	Originally used 4 (carbon, water use, water pollution, biodiversity) but did R&D and developed new methodology in line with PEF and consultation with

Sub-criterion	Answers
	scientists, LCA experts and industry. Goes further than standard PEF, using primary data where possible and allowing for similar product comparison.
Omissions	Animal welfare, biodiversity indirectly considered, carbon sequestration, nutrition. The categories are weighted for importance of impact on the environment and normalised against a group of products.
Metrics	"Each assessment has an indicator and a unit of measurement". Encourage the use of primary data sources across the supply chain.
Outcomes	Through the PEF, so not directly.
Data source	Ecoinvent, WFLDB, Agri-Footprint, AGRIBALYSE®, GFLI
Benchmarks	None
Governance	N/A
Qualification	No
Levels	Products are rated A+ to G, with A+ being the highest rating achievable
Requirements	Yes, they must report on all the metrics in the impact categories.
Discretion	If primary data cannot be found then secondary data is used but the data quality and source is encompassed in the scores.
Data verification	LCA based, so they verify the data for the products as they go along.
Independent verification	No
Inspections	N/A
Certification	N/A
Implementation	N/A
Risks	No
Actions plans	No
Evolution	The grading range should encourage food businesses to improve the environmental performance of their food over time, i.e. They can change grade.
Public availability	Scheme and LCA methodologies are publicly available.
Clarity	The information is clearly presented, with some information on their website plus several downloadable documents which go into more detail about approach and methodologies.
Enforcement	N/A
Limitations	Our interpretation that their limitations are: Encourages and expects primary data from farm for food producers with no 'middle people' between (Category 1). Those with 'middle people' (category 2), no primary data from farm is required but primary data from food production and packaging is expected. Primary data that is collected is done so via sampling to get an average of results rather than being from a specific farm so no direct traceability. They also weight the contribution of each production stage for total score.

C.4 Institute of Grocery Distribution (IGD)

Sub-criterion	Answers
Aims & objectives	"Help consumers make more sustainable purchasing decisions by providing more transparent information about the environmental impact of products" and "Enable business decisions around supply chain efficiencies and sourcing by providing more transparent information about the environmental impact of supply chains"

Sub-criterion	Answers
	Increasing the transparency of the environmental impact of products and supply chain in the food system, so consumers and businesses are more informed and better able to make sustainable decisions.
Ownership	IGD with a steering group (14 members from across the food industry in the UK) and robust governance. Primary producers are not involved.
Perspective	Top down
Market penetration	Began developing a solution to environmental labelling in 2021. Working with 111 organisations including industry, academia, NGOs, government, and other ecolabels to review and feedback on progress. UK but currently no market penetration as process not completed.
Scope	Single product
Retail	Likely retailers as no mention of restaurant outlets being a target so far.
Audience	B2B and B2C
Label location	On food product
Label type	Not confirmed yet, but research showed that scoring A-G and RAG scale is the most likely to be understood and accepted.
Impact categories	Selected 4 from the 16 PEF categories based on 3 credibility criteria – climate change, land use, water use, water quality (both freshwater and marine eutrophication).
Reason	"Accurately reflect the greatest impacts on the food system".
Omissions	Biodiversity – assume it will be covered in above categories until a better measure is found.
Metrics	LCA based, so no measurements made.
Outcomes	Set against planetary boundaries.
Data source	Working with data partners Mondra, Oracle, and ADEME but looking to create their own UK specific database of ingredients with the support of Anthesis.
Benchmarks	N/A
Governance	See governance as a key component of an ecolabel so are also developing this aspect.
Qualification	No
Levels	Products are rated A-E, with A being the highest rating achievable
Requirements	N/A
Discretion	N/A
Data verification	Comes from their database which they created with Anthesis specifically for the UK food system.
Independent verification	No, all LCA based.
Inspections	N/A
Certification	N/A
Implementation	N/A
Risks	No
Actions plans	No
Evolution	Unknown
Public availability	Yes, but only if you sign up, and then access to some docs is not available. There is more going on than is being shared publicly due to the development process.

Sub-criterion	Answers
Clarity	Documents are reasonably clear but due to it still being in development, the clarity around some aspects is not as good as it could be.
Enforcement	Not sure they have decided yet.
Limitations	We see their limitations are that the scheme development process has not completed yet.

C.5 Planet-Score

Sub-criterion	Answers
Aims & objectives	Objectives – to "inform: consumers must be able to make their purchases in conscience, the Planet-Score provides them with clear information, guaranteed 0 greenwashing, on products" and "enhance: the planet-score makes visible and enhances the progress made by producers and agri-food companies, in order to make the offer evolve towards more virtuous practices for the planet" "The scoring system as we propose it aims to clarify the conditions for the success of an environmental display system which, as desired by the legislator, must make it possible to enlighten the citizen during their purchases, to accelerate the commitment of agri-food players to progress initiatives, and to fight against unfounded allegations and 'greenwashing'." Providing clear information to enable better consumer purchasing decisions and to help producers and agri-food companies make progress in improving agricultural practices and reducing greenwashing.
Ownership	Made up of a mission-led company (to get the label out) and non-profit public interest entity (to fund research). ITAB is a minority stakeholder of the company and sponsored by Emery Jacquillat. The entity is fully independent of ITAB. Primary producers are not involved.
Perspective	Top down
Market penetration	First registered as a brand in 2021. 214 companies are having their products and menus assessed (as of 14/03/24), which are predominantly French. Currently nothing in UK.
Scope	Single product
Retail	Retailers
Audience	B2C
Label location	On food product, websites and app.
Label type	Scores A-E and uses RAG colouring plus ratings for pesticides, biodiversity and climate, and an animal welfare indicator.
Impact categories	16 PEF, removing 4 (human toxicity x2, ecotoxicity and water use), remaining 12 collapsed into 4 - Environmental health and toxicity, biodiversity and ecosystems, climate (carbon), and resources. Pesticide on human health, biodiversity, climate are displayed on label with the score. Animal welfare is displayed but not included in the score.
Reason	Showing these separately to increase transparency and understanding of consumers.
Omissions	The removed 4 PEF indicators.
Metrics	LCA based, so no measurements made.
Outcomes	Trying to encourage system change by highlighting good and poor practice.
Data source	AGRIBALYSE®

Sub-criterion	Answers
Benchmarks	N/A
Governance	N/A
Qualification	No
Levels	Products are rated A-E, with A being the highest rating achievable. Pesticides, biodiversity and climate are also rated on the same scale and could differ from the overall score. Animal welfare ratings are good, medium, bad with corresponding colours to show achievement in this aspect.
Requirements	N/A
Discretion	N/A
Data verification	By Planet-Score according to their methodology .
Independent verification	No
Inspections	N/A
Certification	N/A
Implementation	N/A
Risks	No
Actions plans	No, but it is assumed that having the scores in place will force businesses and producers to do better environmentally as consumers will purchase things with better impacts.
Evolution	Unknown
Public availability	Yes, there is information on their website and a large number of downloadable supporting documents.
Clarity	Yes, but some documents are in French and information provided does not break down the score enough to really understand it.
Enforcement	N/A
Limitations	They acknowledge that the AGRIBALYSE® database does not go far enough in covering all the food products needed or the environmental impacts, which is likely why they have added additional categories/data and look to increase research where data is missing.

C.6 A Greener World - Certified Regenerative

Sub-criterion	Answers
Aims & objectives	"Covering all aspects of regenerative agriculture, Certified Regenerative by AGW meets you where you are as your partner on a regenerative journey." "This programme functions as a management tool that helps producers meet their own regenerative goals through an audited, regenerative plan—and offers early access to regenerative markets without being certified organic. As each plan requires measured progress, the process also serves as a tool for delivering quantitative data towards the regenerative goal." Supporting and rewarding producers moving to regenerative practices.
Ownership	A Greener World. Yes, primary producers are involved, it is targeted at them.
Perspective	Bottom up
Market penetration	Established in 2014 but launched in the UK in 2018. Most Certified Regenerative farms and products are in the USA and Australia. One farm in the UK has this certification, but currently no retail of products (Grass-fed and animal welfare certified only).
Scope	Whole farm programme which enables single products to bear the scheme logo.

Sub-criterion	Answers
Retail	Retailers, online shops, restaurants, assuming the regenerative label will operate in the same way to their other labels.
Audience	B2C
Label location	On food product
Label type	Presence or absence
Impact categories	Soil, water, air quality, biodiversity (also covers cropping systems, livestock, wild harvested resources and human/societal factors and the positive management of all of these).
Reason	Largely are what is targeted by regenerative agriculture.
Omissions	Climate change aspect is not obvious.
Metrics	Fossil fuel usage, water, water quality if it is at risk, soil health, air, biodiversity.
Outcomes	Largely indirectly.
Data source	Record keeping, test results if any are undertaken.
Benchmarks	That the baseline standards are reached.
Governance	A Greener World set the standards, but the plan is developed between them and the farmer.
Qualification	Yes, there is a baseline for practices/standards that must be met (animal welfare).
Levels	No
Requirements	No, some are recommended instead.
Discretion	No
Data verification	A Greener World have their own independent trained auditors.
Independent verification	No, just recommended that the certification is taken on for at least 5 years but best 10 to make a real difference.
Inspections	Once a year where auditors visit the farm.
Certification	Yes
Implementation	It is not a pass/fail scheme but work with users to find a workable solution.
Risks	Yes, to an extent as part of the plan creation.
Actions plans	Yes
Evolution	Unknown
Public availability	Yes
Clarity	Yes
Enforcement	Yes, through site visits by auditors.
Limitations	Our interpretation is that a limitation of the scheme is that animal welfare certification needs to be gained first.

C.7 Fair to Nature

Sub-criterion	Answers
Aims & objectives	"Fair to Nature is the only UK certification scheme with a focus on biodiversity and a proven approach to restoring the balance of nature in farming. Working with people across the supply chain, we help to protect and restore nature on farmland while making it easier for people to recognise sustainable products and support businesses that are committed to making a genuine difference."

Sub-criterion	Answers
	Utilising a proven approach to restore nature on farms and helping consumers recognise sustainable products and support businesses who are caring for their land.
Ownership	Owned and operated by RSPB. Standards are reviewed by a technical advisory panel and there is also a steering group. Primary producers are involved as scheme is geared towards farmers making changes on their farms.
Perspective	Bottom up
Market penetration	Relaunched in 2022, now with a wider remit to cover dairy, livestock, horticulture and viticulture. It is UK based but still quite niche and mostly animal feed/bird seed.
Scope	Whole farm as requirement is to have at least 10% of farmed land changed into high quality habitats.
Retail	Retailers and online but only by approved licensees.
Audience	B2C
Label location	On product
Label type	Presence or absence
Impact categories	Biodiversity
Reason	They see it as the most important impact farming has on the environment.
Omissions	All the rest!
Metrics	Percentage of land manged for habitats and farming practices that benefit wildlife.
Outcomes	Well-managed habitats and wildlife friendly methods should boost biodiversity levels on farm.
Data source	Record keeping, wildlife survey results, carbon footprint result (every 4 years).
Benchmarks	Minimum required percentage of land set to habitat creation/management.
Governance	RSPB
Qualification	Yes, but farmers are supported by the scheme to get there.
Levels	No.
Requirements	No, the scheme includes some recommended points as well.
Discretion	Can go beyond standards (e.g. more than required 10% land in wildlife habitat management) and/or practice all the recommended standards in addition to the required ones. No additional benefit from the scheme for doing so but greater benefit to environment.
Data verification	N/A
Independent verification	By Fair to Nature advisors/auditors rather than farmers themselves.
Inspections	Inspections happen every 2 years, but a wildlife survey is requested to be done on farm every year. A soil management plan is required to be done annually with improvements expected to be made within that year. A carbon footprinting assessment is required to be done when joining the scheme and every 4 years after that. An IPM plan is required to be done every 2 years, with particular focus on reducing pesticide use.
Certification	Yes, every 2 years.
Implementation	Non-conformance to a major standard, results in membership suspension. Non-conformance to a minor standard comes with 28 days to rectify the issue, but if this is not done or there are multiple minors breached, membership suspension will occur.
Risks	Yes, for water quality

Sub-criterion	Answers
Actions plans	Yes, this is an important part of the scheme. The plan is developed with a Fair to Nature advisor and is reviewed every 2 years.
Evolution	Yes, the standards are revised regularly by the technical advisory panel and steering committee.
Public availability	Yes.
Clarity	Yes.
Enforcement	Yes, by advisor/auditor visits to farm.
Limitations	No.

C.8 LEAF Marque

Sub-criterion	Answers
Aims & objectives	"LEAF Marque is an environmental assurance system recognising more sustainably farmed products. It is based on LEAF's nine Integrated Farm Management (IFM) principles." "When you see produce and products with the LEAF Marque logo, you can be sure it comes from a farm practising sustainable agriculture and meeting our Standard." "LEAF aims to inspire and enable more circular approaches to farming through integrated, regenerative, and vibrant nature- based solutions, that deliver productivity and prosperity among farmers, enriches the environment, and positively engages young people and wider society." Enabling the improvement of farming practices to be more sustainable, regenerative, and nature-based by adhering to Integrated Farm Management principles.
Ownership	LEAF and has a dedicated team to run it, and a board of trustees and other stakeholders. Yes, primary producers are involved, the scheme is aimed at them.
Perspective	Bottom up
Market penetration	Launched in 2003 in the UK. Global (19 countries have certified businesses) but in UK it has been taken up by major retailers e.g. Tesco, Waitrose, Lidl.
Scope	Whole farm but it is the specific products which have the label.
Retail	Retailers
Audience	B2C
Label location	On food product
Label type	Presence or absence
Impact categories	Soil health, crop health, pollution control, animal husbandry, water, landscape/nature conservation.
Reason	Integrated Farm Management principles.
Omissions	Climate change, air quality.
Metrics	Soil organic matter, other soil tests, waste audit, energy audit, water quality monitoring, water use efficiency.
Outcomes	Generally proxies
Data source	Record keeping and test results from metrics taken.
Benchmarks	N/A
Governance	LEAF

Sub-criterion	Answers
Qualification	Need to have completed the LEAF Sustainable Farming Review and products need to be certified to a LEAF Marque approved baseline certification (e.g. Red Tractor).
Levels	No
Requirements	No, some are recommended and a few might be not applicable.
Discretion	No
Data verification	"LEAF Marque certification is third party verified by LEAF Marque approved and accredited Certification Bodies".
Independent verification	A specialist advisor is needed to review the landscape and nature conservation audit.
Inspections	Once a year on farm by independent auditor (difficult to tell if these are LEAF people or not).
Certification	Unknown
Implementation	Yes, standards are enforced, and timeframes and repeated audits are done if non-conformances are discovered. Certificates can be suspended and eventually withdrawn if non-conformances are not fixed.
Risks	Yes
Actions plans	Yes, and reviewed annually.
Evolution	Yes
Public availability	Yes, on the website and through downloadable standards and other documents.
Clarity	Information is across various documents so may not be straightforward.
Enforcement	Yes, through farm visits and audits.
Limitations	"Within the LEAF Marque system, the majority of indicators are based on the degree of adoption of practices. While these are useful proxies for assessing impact across the standard, there is a need to develop more evidence on actual outcomes and impacts on farm."

C.9 Pasture for Life

Sub-criterion	Answers
Aims & objectives	"The leading and only certification mark for 100% grass-fed/pasture-fed, grain-free ruminant meat and dairy in the UK, A trusted brand recognised alongside other major UK assurance schemes, Quality product renowned for its highly nutritious properties and benefits to the environment and animal welfare". To provide certification for 100% grass-fed/pasture-fed, grain-free ruminant meat and dairy production to benefit consumers, the environment and animal welfare.
Ownership	Pasture for Life, run by a small staff team and overseen by a board of directors. Scheme is aimed at primary producers.
Perspective	Bottom up
Market penetration	Created in 2009 in the UK (PFLA). UK – niche but covers meat and dairy. Not yet available in major retailers. 900+ members.
Scope	Single enterprise with specified products.
Retail	Retailers (butchers and farm shops) and directly from farmers.
Audience	B2C
Label location	On food product

Sub-criterion	Answers
Label type	Presence or absence
Impact categories	Animal welfare, biodiversity
Reason	It is all about what the animals are fed so animal welfare is critical and biodiversity is a beneficial by-product of the practise.
Omissions	Air, water, GHG emissions.
Metrics	Recommended standard of monitoring soil health, required standards for welfare outcome assessments.
Outcomes	It should lead to an improvement in soil health.
Data source	Record keeping, soil health monitoring and welfare outcome assessment results.
Benchmarks	N/A
Governance	Pasture-Fed Livestock Association.
Qualification	Yes
Levels	No
Requirements	No, some are recommended.
Discretion	No
Data verification	Verified by auditor.
Independent verification	Yes
Inspections	Yes, annual and both paperwork and site visit. Aims to tie in with visits for other assurance schemes e.g. Red Tractor to be most efficient.
Certification	Yes, at a minimum once a year.
Implementation	Minor compliance has a timeframe to resolve it. Major non-compliance or manifest infringement will mean an immediate suspension of certification.
Risks	It is assumed that this is done anyway.
Actions plans	Yes, particularly in the conversion process to become a Pasture for Life enterprise.
Evolution	Yes, they are reviewed regularly.
Public availability	Yes, information on website and downloadable standards document.
Clarity	Yes
Enforcement	Yes
Limitations	No

C.10 Soil Association Organic label

Sub-criterion	Answers
Aims & objectives	"The Soil Association standards put the principles of organic production into practice. These organic standards encompass EU Regulations 834/2007, 889/2008 and 1235/2008." "The Soil Association has higher organic standards than required by the GB Organic Regulations in key areas: delivering the highest levels of animal welfare, protecting human and animal health, safeguarding the environment and protecting the interests of organic consumers. These reflect our mission and vision as a charitable organisation." To encourage higher organic standards than the UK requirements particularly in the areas of animal welfare, human and animal health, safeguarding the environment, and consumer interests.

Sub-criterion	Answers
Ownership	Soil Association Certification is owned by Soil Association charity which is registered with Defra to certify organic production. Yes, primary producers are involved as scheme is targeted at them.
Perspective	Bottom up
Market penetration	Have been setting organic standards for food since 1967, with the certification part of the business launched in 1973. 70% of all UK organic food and drink products are certified by Soil Association.
Scope	Single enterprise and single products within this.
Retail	Retailers
Audience	B2C
Label location	On food product, on website.
Label type	Presence or absence
Impact categories	Animal welfare, protecting human and animal health, safeguarding the environment, and protecting interests of organic consumers.
Reason	These are organic requirements.
Omissions	Safeguarding the environment is very broad but covers biodiversity, soil, preventing environmental contamination, responsible use of resources.
Metrics	Largely record keeping not measurements, but does cover standards around biodiversity conservation and enhancement, preventing environmental contamination, resource use, soil management (including some testing), restrictions on agrochemical use, animal welfare.
Outcomes	Farming according to the organic standards should largely lead to positive environmental outcomes.
Data source	Record keeping and soil test results.
Benchmarks	N/A but there is a conversion period.
Governance	EU Regulations 834/2007, 889/2008 and 1235/2008, Soil Association themselves and in line with ISEAL codes.
Qualification	Yes
Levels	No
Requirements	Yes, SA sets a higher standard than EU/UK regulatory organic requirements.
Discretion	Yes, if farms need to achieve higher standards but in a different way, they can commission a research project to demonstrate that this is possible. SA will then decide if the Organic label will be available to them.
Data verification	Certification bodies verify compliance.
Independent verification	No
Inspections	Yes, a physical visit once a year.
Certification	Yes, which is renewed annually.
Implementation	Yes, and breaches are rated for severity which could suspend or withdraw licence. An Action Summary Form is written following inspection and includes requests for information about correcting non-compliances. This is then approved by SA and is satisfactory will enable licence renewal.
Risks	No
Actions plans	Yes, and checked as part of yearly inspection.
Evolution	Yes
Public availability	Yes, information is on the website and standards are downloadable.

Sub-criterion	Answers
Clarity	Yes, but it can be difficult to navigate the website to find the information needed.
Enforcement	Yes
Limitations	Our interpretation of limitations to the scheme is that it takes time for a farm to convert over to organic before certification is possible.

D Supplementary information: Data quality processes

D.1 AGRIBALYSE®

Data quality section in the AGRIBALYSE® methodology paper from pg33:

"the database, in constant evolution, follows advances in science; it is enriched and updated regularly, and validated within the framework of a partnership ensuring their quality and transparency."

"A quality rating - the Data Quality Ratio (DQR) - from 1, very good, to 5, very bad - is associated with each agricultural and food product for which Agribalyse provides life cycle inventories and impact indicators. The European Commission recommends caution in the use of data with DQRs greater than 3. In the AGRIBALYSE database, 67% of the data have a DQR considered good or very good (1 to 3)."

"Agribalyse® work systematically seeks to rely on available international standards (FAO, European Commission, ISO, etc.). The data is intended to evolve in line with new knowledge, the strengthening of methodologies and the integration of new products. Regular updates are carried out (every 18/24 months). Even if every effort is made to ensure data quality, there remain several sources of uncertainty.

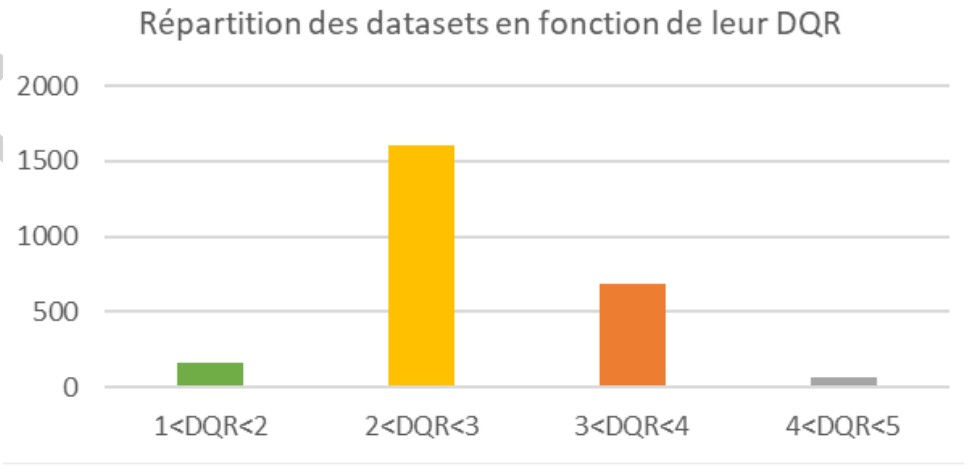
The uncertainty regarding the data used for impact calculations is highlighted through a reliability rating associated with each data (the DQR, "Data Quality Ratio"). This rating (from 1, very good quality to 5, poor quality) is calculated according to the method recommended by the European Commission. It is not possible at this stage to provide quantitative uncertainty data (standard deviation): estimating these uncertainties would require unavailable data.

Uncertainty concerning the models used for impact calculations through a ranking of robustness of indicators developed by the European Commission. (see previous paragraph)."

"16. What is DQR (Data Quality Ratio)?

The data quality rating (DQR), between 1 (very good) and 5 (very poor), is a reliability rating associated with each agricultural and food product for which Agribalyse provides life cycle inventories and data indicators. 'impacts. This score is calculated according to the method recommended by the European Commission and takes into account several criteria: temporal (TiR) and technological (TeR) representativeness, precision (P), and geographical specificity (GR).

A score below 2 considers data reliable, while a score above 4 considers data unreliable."



"17. Is the Agribalyse methodological framework compatible with the PEF (Product Environmental Footprint), a European-wide LCA harmonization program?

Agribalyse is closely linked to the PEF recommendations, but presents some significant differences for certain products, this being linked to slightly different temporalities and scopes between these two programs. The two methodologies are generally very similar and are intended to be harmonized.

Among the recommendation guides given by the PEF, we differentiate:

- *the general PEF guide giving general methodological recommendations on carrying out LCAs (stages of the life cycle, impact calculation method, etc.);*
- *and PEFCR (Product Environmental Footprint Category Rules) guides defining rules for specific products. Not all Agribalyse products currently have PEFCR.*

Agribalyse follows several recommendations from the PEF general guide: assumptions to be used during the distribution and supermarket stages for example, calculation method to use. The differences identified relate in particular to the following points:

- *The biophysical allocation of the impacts of livestock farming, particularly cattle, between milk and meat, is different between Agribalyse and the PEFCR dairy products;*
- *The allocation of fertilizers to the different crops in the crop rotation;*
- *The modelling of pesticide emissions is different (OLCA-Pest model in Agribalyse, simplified model in the PEF);*
- *The databases used in the background in Agribalyse (Ecoinvent, WFLDB) are different from those recommended by the PEF (dedicated database, harmonization work in progress)."*

D.2 Foundation Earth

Part 2: Defining total score

Per life cycle stage	Foreground accuracy				Background accuracy			
	Contribution to single score	Good	Estimate	Default	Primary	Good	Middle	Low
Cultivation	**37%**			100,0%				
Feed production	**4%**			100,0%				
Animal production	**4%**	83,0%		17,0%		60,0%	20,0%	
Ingredient production	**20%**	86,1%	8,0%	5,9%	9,4%	55,9%	28,8%	
Food production	**10%**	100,0%			80,0%	15,0%		5,0%
Packaging	**15%**	100,0%			0,0%	85,0%	15,0%	
Distribution & retail	**2%**			100,0%				
Consumption	**7%**			100,0%				
EoL	**1%**			100,0%				

Overall foreground score		
Good	Estimate	Default
45,5%	1,6%	52,9%

Figure D.1: Foundation Earth PEF friendly methodology for data quality example calculation table (FE, 2023a)

"PEF Data Quality Rating (DQR), detailed below."

Data quality is a measure of the condition of data based on parameters such as accuracy, completeness, consistency, reliability, etc.. Data quality is important as a complementary assessment of the accuracy of (LCA) environmental results. Importantly, consideration of data quality requires the assessment of both data source (primary/secondary) and the background data used in the LCA models.

According to the PEF, DQR is calculated as:

$$DQR = \frac{\overline{Te_R} + \overline{G_R} + \overline{Ti_R} + \overline{P}}{4}$$

*Where **TeR** is the Technical Representativeness, **GR** is the Geographical Representativeness, **TiR** is the Time Representativeness and **P** is the Precision, and values are 1 to 5.*

Within the PEF DQR method, precise, accurate data quality ratings can be calculated. However, the PEF DQR method is very time consuming, complex to apply and difficult to interpret results. Additionally, not all background databases contain DQR scores, which makes it impossible to apply them in a Foundation Earth assessment.

References

Arayess, S and de Boer, A. (2022) How to navigate the tricky landscape of sustainability claims in the food sector. *European Journal of Risk Regulation*, **13**(4), 643-664. DOI: 10.1017/err.2022.6

Abram, M. (2022) *6 soil carbon schemes for farmers to consider*. Farmers Weekly 25 October 2022. URL: https://www.fwi.co.uk/business/business-management/agricultural-transition/the-carbon-trading-conundrum-risk-or-revenue-generator (Last accessed: 26/06/23)

Agrimetrics (2022) *ClearSky: Cloud free satellite data for agriculture*. URL: https://www.agrimetrics.co.uk/news/clearsky-cloud-free-satellite-data-for-agriculture (Last accessed: 26/04/24)

Agroecology Europe (2024) *The 13 principles of Agroecology*. Agroecology Europe. URL: https://www.agroecology-europe.org/the-13-principles-of-agroecology/ (Last accessed: 17/04/24)

Agtelligence (2024) *Farmscore | Agtelligence*. URL: https://www.agtelligence.space/farmscore (Last accessed: 26/04/24)

AGW (2023) *Certified Regenerative by A Greener World Standards*. Version 1.1. A Greener World (AGW). Available at: https://agreenerworld.org.uk/certifications/certified-regenerative/certified-regenerative-standards/ (Last accessed: 26/04/24)

AGW (2024) *A Greener World - Our Food. Our Farms. Our Future. Let's Choose!* A Greener World (AGW). URL: https://agreenerworld.org.uk/ (Last accessed: 26/04/24)

Andersson, J, Lennerfors, T.T. and Fornstedt, H. (2024) Towards a socio-techno-ecological approach to sustainability transitions. *Environmental Innovation and Societal Transitions*, **51**, 100846. DOI: 10.1016/j.eist.2024.100846

ANSES (2024) *CIQUAL database*. The French food nutritional composition database. ANSES (the French agency for food, environmental and occupational health safety). URL: https://ciqual.anses.fr/ (Last accessed: 17/04/24)

Bambridge-Sutton, A. (2023) *Are new IGD guidelines on eco-labelling misleading? Organisations raise concerns about potential to cause ' unintended environmental outcomes'*. FoodNavigator Europe 19 December 2023. URL: https://www.foodnavigator.com/Article/2023/12/15/Eco-labelling-Are-IGD-guidelines-misleading (Last accessed: 10/04/24)

Bare, J.C. (2010) Life cycle impact assessment research developments and needs. *Clean Technologies and Environmental Policy*, **12**, 341-351. DOI: 10.1007/s10098-009-0265-9

BDA (2024) *One Blue Dot - the BDA's Environmentally Sustainable Diet Project*. British Dietetic Association (BDA). URL: https://www.bda.uk.com/resource/one-blue-dot.html (Last accessed: 17/04/24)

Beyer, B., Chaskel, R., Euler, S., Gassen, J., Großkopf, A.K. and Sellhorn, T. (2024) How Does Carbon Footprint Information Affect Consumer Choice? A Field Experiment. *Journal of Accounting Research*, **62**, 101-136. 10.1111/1475-679X.12505

Biermann, F. and Kim, R.E. (2020) The Boundaries of the Planetary Boundary Framework: A Critical Appraisal of Approaches to Define a "Safe Operating Space" for Humanity. *Annual Review of Environment and Resources*, **45**, 497-521. DOI: 10.1146/annurev-environ-012320-080337

Bielecki, Z., Stacewicz, T., Smulko, J. and Wojtas, J. (2020) Ammonia gas sensors: Comparison of solid-state and optical methods. *Applied Sciences*, **10**(15), 5111. DOI: 10.3390/app10155111

Boschiero, M., De Laurentiis, V., Caldeira, C. and Sala, S. (2023) Comparison of organic and conventional cropping systems: A systematic review of life cycle assessment studies. *Environmental Impact Assessment Review*, **102**, 107187. DOI: 10.1016/j.eiar.2023.107187

Boulay, A.M., Bare, J., Benini, L. Benini, L., Berger, M., Lathuillière, M.J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A.V., Ridoutt, B., Oki, T., Worbe, S. and Pfister, S. (2018) The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). *International Journal of Life Cycle Assessment*, **23**, 368–378. DOI: 10.1007/s11367-017-1333-8

Bragaglio, A., Braghieri, A., Pacelli, C. and Napolitano, F. (2020) Environmental Impacts of Beef as Corrected for the Provision of Ecosystem Services. Sustainability, **12**, 3828. 10.3390/su12093828

Broom, D.M. (2021) A method for assessing sustainability, with beef production as an example. *Biological Reviews*, **96**(5). 1836-1853. DOI: 10.1111/brv.12726

Brown, K.A., Harris, F., Potter, C. and Knai, C. (2020) The future of environmental sustainability labelling on food products. *The Lancet Planetary Health*, **4**(4), e137-e138. DOI: 10.1016/S2542-5196(20)30074-7.

Burns, F., Mordue, S., al Fulaij, N., Boersch-Supan, P.H., Boswell, J., Boyd, R.J., Bradfer-Lawrence, T., de Ornellas, P., de Palma, A., de Zylva, P., Dennis, E.B., Foster, S., Gilbert, G., Halliwell, L., Hawkins, K., Haysom, K.A., Holland, M.M., Hughes, J., Jackson, A.C., Mancini, F., Mathews, F., McQuatters-Gollop, A., Noble, D.G., O'Brien, D., Pescott, O.L., Purvis, A., Simkin, J., Smith, A., Stanbury, A.J., Villemot, J., Walker, K.J., Walton, P., Webb, T.J., Williams, J., Wilson, R. and Gregory, R.D. (2023). *State of Nature 2023*. the State of Nature partnership, Available at: https://stateofnature.org.uk/ (Last accessed: 17/04/24)

Burrows, D. (2021) *Food eco-labels are imperfect – but consumers want them*. Just Food, 2 July 2021. URL: https://www.just-food.com/features/food-eco-labels-are-imperfect-but-consumers-want-them/ (Last accessed: 10/04/24)

Burrows, D. (2022) *Eco-labels: sexy but no silver bullet for sustainable food sales*. Just Food, 20 June 2022. URL: https://www.just-food.com/features/eco-labels-sexy-but-no-silver-bullet-for-sustainable-food-sales/?cf-view (Last accessed: 10/04/24)

Case, P. (2023) *OFC 2023: Farmers told to back public money for public goods*. Farmers Weekly 6 January 2023. URL: https://www.fwi.co.uk/business/business-management/agricultural-transition/ofc-2023-farmers-told-to-back-public-money-for-public-goods (Last accessed: 26/06/23)

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. and Shrubb, M. (2000) Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of Applied Ecology*, 37(5), 771-788.

Chen, X., Gao, Z., Swisher, M., House, L. and Zhao, X. (2018) Eco-labeling in the Fresh Produce Market: Not All Environmentally Friendly Labels Are Equally Valued. *Ecological Economics*. **154**, 201–210. DOI: 10.1016/j.ecolecon.2018.07.014

Chiriacò, M.V., Castaldi, S. and Valentini, R. (2022) Determining organic versus conventional food emissions to foster the transition to sustainable food systems and diets: Insights from a systematic review. *Journal of Cleaner Production*, **380**(Part 2), 134937. DOI: 10.1016/j.jclepro.2022.134937

Choudhari, U. and Jagtap, S. (2023) A panoramic view of NO_x and NH_3 gas sensors. *Nano-Structures & Nano-Objects*, **35**, 100995. DOI: 10.1016/j.nanoso.2023.100995

Cleveland, D.A., Carruth, A. & Mazaroli, D.N. Operationalizing local food: goals, actions, and indicators for alternative food systems. *Agriculture and Human Values*, **32**, 281–297 (2015). 10.1007/s10460-014-9556-9

Cooper, T., Hart, K. and Baldock, D. (2009) *The Provision of Public Goods Through Agriculture in the European Union - Report Prepared for DG Agriculture and Rural Development, Contract No 30-CE-1233091/00-28.* Institute for European Environmental Policy, London.

Coppola, G., Costantini, M., Fusi, A., Ruiz-Garcia, L. and Bacenetti, J. (2022) Comparative life cycle assessment of conventional and organic hazelnuts production systems in Central Italy. *Science of The Total Environment*, **826**, 154107. DOI: 10.1016/j.scitotenv.2022.154107

Corrado, S., Castellani, V., Zampori, L. and Sala, S. (2018) Systematic analysis of secondary life cycle inventories when modelling agricultural production: A case study for arable crops. *Journal of Cleaner Production*, **172**, 3990-4000. DOI: 10.1016/j.jclepro.2017.03.179

Courtat, M., Joyce, P.J., Sim, S., Sadhukhan, J. and Murphy, R. (2023) Towards credible, evidence-based environmental rating ecolabels for consumer products: A proposed framework. *Journal of Environmental Management*, **336**, 117684. DOI: 10.1016/j.jenvman.2023.117684

Damiani, M., Sinkko, T., Caldeira, C., Tosches, D., Robuchon, M. and Sala, S. (2023) Critical review of methods and models for biodiversity impact assessment and their applicability in the LCA context. Environmental Impact Assessment Review, **101**, 107134. DOI: 10.1016/j.eiar.2023.107134

Ding, T., Steubing, B. and Achten, W.M.J. (2023) Coupling optimization with territorial LCA to support agricultural land-use planning. *Journal of Environmental Management*, **328**, 116946. DOI: 10.1016/j.jenvman.2022.116946

Dasgupta, P. (2021) *The Economics of Biodiversity: The Dasgupta Review*. HM Treasury, London. Available at: https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review (Last accessed: 30/04/24)

Davis, A.G., Huggins, D.R. and Reganold, J.P. (2023) Linking soil health and ecological resilience to achieve agricultural sustainability. *Frontiers in Ecology and the Environment*, **21**(3), 1540-9295. DOI: 10.1002/fee.2594

de Baan, L., Alkemade, R. and Koellner, T. (2013) Land use impacts on biodiversity in LCA: a global approach. *International Journal of Life Cycle Assessment*, **18**, 1216–1230. DOI: 10.1007/s11367-012-0412-0

Deconinck, K. and L. Toyama (2022) *Environmental impacts along food supply chains: Methods, findings, and evidence gaps*. OECD Food, Agriculture and Fisheries Papers, No. 185, OECD Publishing, Paris. DOI: 10.1787/48232173-en

Defra (2008) *A framework for pro-environmental behaviours*. Department for Environment, Food & Rural Affairs (Defra). PB13574. Available at: https://www.gov.uk/government/publications/a-framework-for-pro-environmental-behaviours (Last accessed: 14/048/24)

Defra (2022) *Environmental land management schemes: outcomes*. Department for Environment, Food & Rural Affairs (Defra). 06/01/22. URL: https://www.gov.uk/government/publications/environmental-land-management-schemes-outcomes/environmental-land-management-schemes-outcomes (Last accessed: 26/06/23)

Defra (2024) *Policy paper. FDTP: towards consistent, accurate and accessible environmental impact quantification for the agri-food industry*. Department for Environment, Food & Rural Affairs (Defra), 23 April 2024. Available at: https://www.gov.uk/government/publications/food-data-transparency-partnership-agri-food-environmental-data/fdtp-towards-consistent-accurate-and-accessible-environmental-impact-quantification-for-the-agri-food-industry (Last accessed: 25/04/24)

Del Borghi, A. (2013) LCA and communication: Environmental Product Declaration. *International Journal of Life Cycle Assessment*, **18**, 293–295. DOI: 10.1007/s11367-012-0513-9

Delmas, M.A. and Gergaud, O. (2021) Sustainable practices and product quality: Is there value in eco-label certification? The case of wine. *Ecological Economics*, **183**, 106953. DOI: 10.1016/j.ecolecon.2021.106953

Desjardins, R.L., Worth, D.E., Vergé, X.P.C., Maxime, D., Dyer, J. and Cerkowniak, D. (2012) Carbon Footprint of Beef Cattle. *Sustainability*, **4**, 3279-3301. 10.3390/su4123279

de Vries, M., van Middelaar, C.E. and de Boer, I.J.M. (2015) Comparing environmental impacts of beef production systems: A review of life cycle assessments. *Livestock Science*, **178**, 279-288. DOI: 10.1016/j.livsci.2015.06.020.

Doka, G. (2015) *Combining life cycle inventory results with planetary boundaries: the planetary boundary allowance impact assessment method PBA'05*. Doka Life Cycle Assessment, Zürich.

Drone Ag (2024) *Drone Ag: Farmers Who Know Drones - Software | Training | Sensors*. URL: https://droneag.farm/ (Last accessed: 26/04/24)

D'Souza, C., Taghian, M., Apaolaza, V., Hartmann, P., Brouwer, A. and Chowdhury, B. (2022) Consumer Self-Confidence in Green Foods: An Investigation of the Role of Ecolabels Using the Theory of Planned Behavior and Market Segmentation. *Journal of International Food & Agribusiness Marketing*. **34**(5), 457-487. DOI: 10.1080/08974438.2021.1901826

EB (2023) *Farm Diversification | Habitat Bank Creation*. Environment Bank (EB). URL: https://environmentbank.com/landowners/habitat-bank-creation (Last accessed: 26/06/23)

EC (2005) *Directive 2005/29/EC of the European Parliament and of the Council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market and amending Council Directive 84/450/EEC, Directives 97/7/EC, 98/27/EC and 2002/65/EC of the European Parliament and of the Council and Regulation (EC) No 2006/2004 of the European Parliament and of the Council ('Unfair Commercial Practices Directive')*. European Commission (EC). Official Journal of the European Union, 11.6.2005, L 149/22-39

Ecoinvent (2024) *Ecoinvent*. URL: https://ecoinvent.org/ (Last accessed: 22/04/24)

ENVIROSCORE (2024) *Environmental impact categories*. Available at: https://www.azti.es/enviroscore/en/environmental-indicators/ (Last accessed: 01/02/24)

Erlandsson, J., Bergmark, P. and Höjer, M. (2023) Establishing the planetary boundaries framework in the sustainability reporting of ICT companies – A proposal for proxy indicators. *Journal of Environmental Management*, **329**, 117032. DOI: 10.1016/j.jenvman.2022.117032

ES (2024) *Présentation | Français | Eco-score*. Eco-Score (ES). URL: https://docs.score-environnemental.com/ (Last accessed: 30/04/24)

EU (2024) *Product groups*. European Union (EU) EU Ecolabel website: URL: https://eu-ecolabel.de/en/for-companies/product-groups (Last accessed: 08/04/24)

Fairtrade (2024) *Fairtrade*. URL: https://www.fairtrade.org.uk/ (Last accessed: 22/04/24)

FAO (2018) *The 10 elements of agroecology*. Food and Agriculture Organization of the United Nations (FAO). Available at: https://www.fao.org/family-farming/detail/en/c/1147761/ (Last accessed: 17/04/24)

FAO (2024) *FAOSTAT*. Food and Agriculture Organization of the United Nations (FAO). URL: https://www.fao.org/faostat/ (Last accessed: 17/04/24)

FCT (2023) *Supporting accurate measurement of soil carbon through the use of remote sensing and other novel technologies*. Farm Carbon Toolkit (FCT). Available at: https://farmcarbontoolkit.org.uk/2023/02/09/supporting-accurate-measurement-of-soil-carbon/ (Last accessed: 17/04/24)

FE (2023a) *LCA methodology for environmental food labelling*. Foundation Earth (FE). March 2023. Available at: https://www.foundation-earth.org/wp-content/uploads/2023/03/Foundation-Earth-LCA-Methodology-Beta-Version-1.0.pdf (Last accessed: 09/04/24)

FE (2023b) *Translating environmental impact assessments into scores: the Foundation Earth grading system*. Foundation Earth (FE). March 2023. Available at: https://www.foundation-earth.org/wp-content/uploads/2023/03/Paper-2-Development-of-a-grading-System-appropriate-for-the-Foundation-Earth-PEF-Methodology.pdf (Last accessed: 09/04/24)

FE (2023c) *Foundation Earth farm-to-fork method: an overview. Position paper 1*. Foundation Earth (FE). March 2023. Available at: https://www.foundation-earth.org/wp-content/uploads/2023/03/Paper-1-Foundation-Earth-Farm-to-Fork-Method-an-Overview.pdf (Last accessed: 12/04/24)

FE (2023d) *Ensuring minimum data quality thresholds when assessing the environmental impact of food products. Position paper 4*. Foundation Earth (FE). March 2023. Available at: https://www.foundation-earth.org/wp-content/uploads/2023/03/Paper-1-Foundation-Earth-Farm-to-Fork-Method-an-Overview.pdf

FS (2023a) *How Foodsteps helped Compass Group UK&I become the first food company to align to The Transition Plan Taskforce*. Foodsteps (FS). URL: https://www.foodsteps.earth/post/foodsteps-compass-uk-i-transition-plan-tpt (Last accessed: 09/04/24)

FS (2023b) *The Food Footprint 100 report*. Foodsteps (FS). Available at: https://www.foodsteps.earth/post/food-footprint100 (Last accessed 16/04/24)

FS (2023c) *The answers to your most frequently asked questions*. Foodsteps (FS). Available at: https://www.foodsteps.earth/faqs (Last accessed 23/04/24)

Fraser, R. (2023) *Opinion: Be wary when it comes to natural capital markets*. Farmers Weekly 25 June 2023. URL: https://www.fwi.co.uk/news/opinion-be-wary-when-it-comes-to-natural-capital-markets (Last accessed: 26/06/23)

FtN (2023) *Fair to Nature – The RSPB standard for nature positive products*. Fair to Nature (FtN). URL: https://fairtonature.org/ (Last accessed: 26/04/24)

FtN (2024) *Fair to Nature Standard*. Version 3.1a. June 2023. Fair to Nature (FtN). Available at: https://fairtonature.org/farmers/ (Last accessed: 26/04/24)

Futtrup, R., Tsalis, G., Pedersen, S., Dean, M., Benson, T. and Aschemann-Witzel, J. (2021) Is the whole more than the sum of its parts? Challenges and opportunities for a holistic consumer-friendly sustainability label on food. *Sustainable Production and Consumption*, **28**, 1411-1421. DOI: 10.1016/j.spc.2021.08.014

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P. and Merah, O. (2023) Role of organic farming for achieving sustainability in agriculture. *Farming System*, **1**(1), 100005. DOI: 10.1016/j.farsys.2023.100005

Garrett, R.D., J. Ryschawy, L.W. Bell, O. Cortner, J. Ferreira, A.V.N. Garik, J.D.B. Gil, L. Klerkx, M. Moraine, C.A. Peterson, J.C. dos Reis and J.F. Valentim. (2020) Drivers of decoupling and recoupling of crop and livestock systems at farm and territorial scales. *Ecology and Society* 25(1), 24. DOI: 10.5751/ES-11412-250124

Garvey, A.M., Parte, L., McNally, B. and Gonzalo-Angulo, J.A. (2021) True and Fair Override: Accounting Expert Opinions, Explanations from Behavioural Theories, and Discussions for Sustainability Accounting. *Sustainability*, **13**, 1928. DOI: 10.3390/su13041928

Gawęda, A. (2021) Sustainability Reporting: Case of European Stock Companies. *European Journal of Sustainable Development*, **10**(4), 41. DOI: 10.14207/ejsd.2021.v10n4p41

Gerber, P.J., Mottet, A., Opio, C.I., Falcucci, A. and Teillard, F. (2015) Environmental impacts of beef production: Review of challenges and perspectives for durability. *Meat Science*, **109**, 2-12. DOI: 10.1016/j.meatsci.2015.05.013

Goulson, D., Lye, G.C. and Darvill, B. (2008) Decline and conservation of bumble bees. *Annual Review of Entomology*, 53, 191-208.

Gröfke, N., Duplat, V, Wickert, C. and Tjemkes, B. (2021) A Multi-Stakeholder Perspective on Food Labelling for Environmental Sustainability: Attitudes, Perceived Barriers, and Solution Approaches towards the "Traffic Light Index". *Sustainability*, **13**(2), 933. DOI: 10.3390/su13020933

Haines-Young, R. and Potschin, M.B. (2018) *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure*. Available at: https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf (Last accessed: 16/01/24)

Hardaker, A., Styles, D., Williams, P., Chadwick, D. and Dandy, N. (2022) A framework for integrating ecosystem services as endpoint impacts in life cycle assessment. *Journal of Cleaner Production*, **370**, 133450. DOI: 10.1016/j.jclepro.2022.133450.

Hart, K., Allen, B., Lindner, M., Keenleyside, C., Burgess, P., Eggers, J. and Buckwell, A. (2013) *Land as an Environmental Resource. Report Prepared for DG Environment, Contract No ENV.B.1/ETU/2011/0029.* Institute for European Environmental Policy, London.

Hauschild, M., Goedkoop, M., Guinee, J., Heijungs, R., Huijbregts, M., Jolliet, O., Margni, M., De Schryver, A., Pennington, D., Pant, R., Sala, S., Brandao, M. and Wolf, M. (2011) *Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors (International Reference Life Cycle Data System - ILCD handbook)*. EUR 24571 EN. Luxembourg (Luxembourg): Publications Office of the European Union. JRC61049. DOI: 10.2788/33030

Henriksen, T., Astrup, T.F. and Damgaard, A. (2021) Data representativeness in LCA: A framework for the systematic assessment of data quality relative to technology characteristics. *Journal of Industrial Ecology*, **25**(1), 51-66. DOI: 10.1111/jiec.13048

HMG (2018) *A Green Future: Our 25 Year Plan to Improve the Environment*. HM Government (HMG). Available at: https://www.gov.uk/government/publications/25-year-environment-plan (Last accessed: 18/04/2024)

HMG (2021) *Net Zero Strategy: Build Back Greener*. HM Government (HMG). Available at: https://www.gov.uk/government/publications/net-zero-strategy (Last accessed: 18/04/2024)

HMG (2023) *Environmental Improvement Plan 2023. First revision of the 25 Year Environment Plan*. HM Government (HMG). Available at: https://www.gov.uk/government/publications/environmental-improvement-plan (Last accessed: 18/04/2024)

Hoek, A.C., Malekpour, S., Raven, R., Court, E. and Byrne, E. (2021) Towards environmentally sustainable food systems: decision-making factors in sustainable food production and consumption. *Sustainable Production and Consumption*, **26**, 610-626. DOI: 10.1016/j.spc.2020.12.009

Hort News (2024) *Sensors enable accurate crop management*. Hort News, 29 March 2024. Available at: https://hortnews.com/sensors-enable-accurate-crop-management/ (Last accessed: 26/04/24)

IGD (2023a) *Environmental Labelling for the UK Food Industry – A summary of evidence and recommendation to date*. Institute of Grocery Distribution (IGD), December 2023.

IGD (2023b) *Draft Methodology for Environmental Labelling*. Institute of Grocery Distribution (IGD), October 2023.

Impey, L. (2022) *Water company offers funding for regen farming practices*. Farmers Weekly 31 July 2022. Available at: https://www.fwi.co.uk/business/business-management/agricultural-transition/water-company-pays-farmers-to-tackle-pollution

IPBES (2019) *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Brondizio, E.S., Settele, J., Díaz, S. and Ngo, H.T. (eds). Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) secretariat, Bonn, Germany. DOI: https://doi.org/10.5281/zenodo.3831673

ISO (2006) *ISO 14040:2006 - Principles and framework*. International Organisation for Standardization (ISO), Geneva, Switzerland

Jackson, R.D. (2022) Grazed perennial grasslands can match current beef production while contributing to climate mitigation and adaptation. *Agricultural & Environmental Letters*, **7**, e20059. DOI: 10.1002/ael2.20059

Kadish, D. and Stoy, K. (2022) BioAcoustic Index Tool: long-term biodiversity monitoring using on-sensor acoustic index calculations. *Bioacoustics*, **31**(3), 348–378. DOI: 10.1080/09524622.2021.1939786

Kamble, S.S., Gunasekaran, A. & Gawankar, S.A. (2020) Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, **219**, 179-194. DOI: 10.1016/j.ijpe.2019.05.022

Kay, P., Blackwell, P.A. and Boxall, A.B.A. (2005) A lysimeter experiment to investigate the leaching of veterinary antibiotics through a clay soil and comparison with field data. *Environmental Pollution*, 134(2), 333-341.

Kingsbury-Smith, L., Willis, T., Smith, M., Boisgontier, H., Turner, D., Hirst, J., Kirkby, M. and Klaar, M. (2023). Evaluating the effectiveness of land use management as a natural flood management intervention in reducing the impact of flooding for an upland catchment. *Hydrological Processes*, **37**(4), e14863. DOI: 10.1002/hyp.14863

Kohlberg, A.B., Myers, C R. and Figueroa, L.L. (2024) From buzzes to bytes: A systematic review of automated bioacoustics models used to detect, classify and monitor insects. *Journal of Applied Ecology*, In press. DOI: 10.1111/1365-2664.14630

Kudsk, P., Jørgensen, L.N. and Ørum, J. E. (2018) Pesticide load: A new Danish pesticide risk indicator with multiple applications. *Land Use Policy*, **70**, 384–393. DOI: 10.1016/j.landusepol.2017.11.010

Kumar, A., Mangla, S.K. & Kumar, P. (2022) An integrated literature review on sustainable food supply chains: Exploring research themes and future directions. *Science of The Total Environment*, **821**, 153411. DOI: 10.1016/j.scitotenv.2022.153411

Lahoz-Monfort, J.J. and Magrath, M.J.L. (2021) A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation, *BioScience*, **71**(10), 1038–1062. DOI: 10.1093/biosci/biab073

Lami, O., Mesías, F.J., Balas, C., Díaz-Caro, C., Escribano, M. and Horrillo, A. (2022) Does Carbon Footprint Play a Relevant Role in Food Consumer Behaviour? A Focus on Spanish Beef. *Foods*, **11**, 3899. 10.3390/foods11233899

Lamine C. and Marsden T. (2023) Unfolding sustainability transitions in food systems: Insights from UK and French trajectories. *Proceedings of the National Academy of Sciences of the United States of America*, **120**(47), e2206231120. DOI: 10.1073/pnas.2206231120

Lanzoni, L., Whatford, L., Atzori, A.S., Chincarini, M., Giammarco, M., Fusaro, I., Vignola, G. (2023) Review: The challenge to integrate animal welfare indicators into the Life Cycle Assessment. *animal*, **17**(5), 100794. DOI: 10.1016/j.animal.2023.100794

Life Cycle Initiative (2022) *Pilot projects on Guidelines for Social Life Cycle Assessment of products and organizations 2022*. Life Cycle Initiative. Available at: https://www.lifecycleinitiative.org/social-lca-final-report-on-pilot-studies-published/ (Last accessed: 25/04/24)

LEAF (2023) *LEAF Marque Standard. Version 16.1*. Linking Environment And Farming (LEAF). Available at: https://leaf.eco/leafmarque/standard (Last accessed: 05/02/24)

LEAF (2024) *LEAF Marque | LEAF (Linking Environment and Farming)*. URL: https://leaf.eco/leafmarque/ (Last accessed: 05/04/24)

Lewis, K.A., Green, A., Tzilivakis, J. & Warner, D.J. (2010) The contribution of UK farm assurance schemes towards desirable environmental policy outcomes. *International Journal of Agricultural Sustainability*, **8**(4), 237–249. DOI: 10.3763/ijas.2010.0495

Lewis, S.L. (2012) We must set planetary boundaries wisely. *Nature*, **485**, 417. DOI: 10.1038/485417a

Louwagie, G., Gay, S.H. and Burrell, A. (2009) *Final report on the project 'Sustainable Agriculture and Soil Conservation (SoCo)', JRC Scientific and Technical report*. Publications Office of the European Union, Luxembourg.

LVC (1996) *The Right to Produce and Access to Land*. La Via Campesina (LVC). Available at: https://safsc.org.za/wp-content/uploads/2015/09/1996-Declaration-of-Food-Sovereignty.pdf (Last accessed: 29/04/24)

Lynch, J. (2019) Availability of disaggregated greenhouse gas emissions from beef cattle production: A systematic review. *Environmental Impact Assessment Review*, **76**, 69-78. DOI: 10.1016/j.eiar.2019.02.003

Mace, G.M., Reyers, B., Alkemade, R., Biggs, R., Chapin, F.S., Cornell, S.E., Díaz, S., Jennings, S., Leadley, P., Mumby, P.J., Purvis, A., Scholes, R.J., Seddon, A.W.R., Solan, M., Steffen, W. and Woodward, G. (2014) Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change*, **28**, 289-297. DOI: 10.1016/j.gloenvcha.2014.07.009

Macfadyen, S., Cunningham, S.A., Costamagna, A.C. and Schellhorn, N.A. (2012) Managing ecosystem services and biodiversity conservation in agricultural landscapes: are the solutions the same? *Journal of Applied Ecology*, **49**, 690-694. DOI: 10.1111/j.1365-2664.2012.02132.x

Majer, J.M., Henscher, H.A., Reuber, P., Fischer-Kreer, D. and Fischer, D. (2022) The effects of visual sustainability labels on consumer perception and behavior: A systematic review of the empirical literature. *Sustainable Production and Consumption*, **33**, Pages 1-14. DOI: 10.1016/j.spc.2022.06.012

Monciardini, D., Mähönen, J.T. and Tsagas, G. (2020) Rethinking Non-Financial Reporting: A Blueprint for Structural Regulatory Changes. *Accounting, Economics, and Law: A Convivium*, **10**(2), 20200092. DOI: 10.1515/ael-2020-0092

Mondière, A., Corson, M.S., Auberger, J., Durant, D., Foray, S., Glinec, J-F, Green, P., Novak, S, Signoret, F. and van der Werf, H.M.G. (2024) Trade-offs between higher productivity and lower environmental impacts for biodiversity-friendly and conventional cattle-oriented systems. *Agricultural Systems*, **213**, 103798. DOI: 10.1016/j.agsy.2023.103798

Moré, F.B., Galindro, B.M. and Soares, S.R. (2022) Assessing the completeness and comparability of environmental product declarations. *Journal of Cleaner Production*, **375**, 133999. DOI: 10.1016/j.jclepro.2022.133999

Mottet, A., Bicksler, A., Lucantoni, D., De Rosa, F., Scherf, B., Scopel, E., López-Ridaura, S., Gemmil-Herren, B., Bezner Kerr, R., Sourisseau, J-M., Petersen, P., Chotte, J-L., Loconto, A. and Tittonell, P. (2020) Assessing Transitions to Sustainable Agricultural and Food Systems: A Tool for Agroecology Performance Evaluation (TAPE). *Frontiers in Sustainable Food Systems*, **4**, 579154. DOI: 10.3389/fsufs.2020.579154

Mouchet, M.A., Paracchini, M.L., Schulp, C.J.E., Stürck, J., Verkerk, P.J., Verburg, P.H. and Lavorel, S. (2017) Bundles of ecosystem (dis)services and multifunctionality across European landscapes. *Ecological Indicators*, **73**, 23-28. DOI: 10.1016/j.ecolind.2016.09.026

Movilla-Pateiro, L., Mahou-Lago, X. M., Doval, M. I. and Simal-Gandara, J. (2021) Toward a sustainable metric and indicators for the goal of sustainability in agricultural and food production. *Critical Reviews in Food Science and Nutrition*, **61**(7), 1108–1129. DOI: 10408398.2020.1754161

Muller, A., Schader, C., El-Hage Scialabba, N., Brüggemann, J., Isensee, A., Erb, K-H., Smith, P., Klocke, P., Leiber, F., Stolze, M. and Niggli, U. (2017) Strategies for feeding the world more sustainably with organic agriculture. *Nature Communications*, **8**, 1290. DOI: 10.1038/s41467-017-01410-w

Muradian, R. and Gómez-Baggethun, E. (2021) Beyond ecosystem services and nature's contributions: Is it time to leave utilitarian environmentalism behind? *Ecological Economics*, **185**, 107038. DOI: 10.1016/j.ecolecon.2021.107038

Nemecek, T., Antón, A., Basset-Mens, C. Gentil-Sergent, C., Renaud-Gentié, C., Melero, C., Naviaux, P., Peña, N., Roux, P. and Fantke, P. (2022) Operationalising emission and toxicity modelling of pesticides in LCA: the OLCA-Pest project contribution. *International Journal of Life Cycle Assessment*, **27**, 527–542. DOI: 10.1007/s11367-022-02048-7

Nemecek, T., Roesch, A., Bystricky, M., Jeanneret, P., Lansche, J., Stüssi, M. and Gaillard, G. (2024) Swiss Agricultural Life Cycle Assessment: A method to assess the emissions and environmental impacts of agricultural systems and products. *International Journal of Life Cycle Assessment*, **29**, 433-455. DOI: 10.1007/s11367-023-02255-w

O'Mara, F.P. (2011) The significance of livestock as a contributor to global greenhouse gas emissions today and in the near future. *Animal Feed Science and Technology*, 166-167**,** 7-15.

OmniAction (2024) *OmniAction. The agreed food metric*. URL: https://omniaction.org/ (Last accessed: 25/04/24)

Open Food Facts (2024) Open Food Facts. URL: https://world.openfoodfacts.org/ (Last accessed: 26/04/24)

Outfield (2024) *Outfield - Orchard Management Platform*. URL: https://outfield.xyz/ (Last accessed: 26/04/24)

Parte, L., Garvey, A.M, McNally, B. and Gonzalo-Angulo, J.A. (2023) True and fair view/fair presentation as a nexus between conventional accounting, sustainability accounting and Islamic accounting: unifying three frameworks? *Economic Research-Ekonomska Istraživanja*, **36**(2), 2147564. DOI: 10.1080/1331677X.2022.2147564

Pasture for Life (2022) *Certification Standards for Ruminant Livestock and Products from Ruminant Livestock. Version 4.4*. August 2022. Available at: https://www.pastureforlife.org/certification/ (Last accessed: 06/12/2023)

Pasture for Life (2024) *Pasture for Life - Certified 100% grass-fed meat, milk and dairy*. URL: https://www.pastureforlife.org/ (Last accessed: 30/04/24)

Pedersen, S., Benson, T., Tsalis, G., Futtrup, R., Dean, M. and Aschemann-Witzel, J. (2024) What consumers want in a sustainability food label: Results from online co-creation workshops in the United Kingdom, Ireland and Denmark. *Frontiers in Sustainability*, **4**, 1342215. DOI: 10.3389/frsus.2023.1342215

Pennington, D.W., Potting, J., Finnveden, G., Lindeijer, E., Jolliet, O., Rydberg, T. and Rebitzer, G. (2004) Life cycle assessment Part 2: Current impact assessment practice. *Environment International*, **30**(5), 721–739. DOI: 10.1016/j.envint.2003.12.009

Planet-Score (2021) *Affichage environnemental: rapport d'expérimentation*. Available at: https://www.planet-score.org/en/documents/planet-score-publications/ (Last accessed: 30/04/24)

Planet-Score (2022) *Webinaire méthodologie 15 Décembre 2022*. Available at: https://www.planet-score.org/en/documents/planet-score-publications/ (Last accessed: 30/04/24)

Planet-Score (2024) *Planet-score | Take care of the planet while shopping*. URL: https://www.planet-score.org/ (Last accessed: 30/04/24)

Potter, C., Bastounis, A., Hartmann-Boyce, J., Stewart, C., Frie, K., Tudor, K., Bianchi, F., Cartwright, E., Cook, B., Rayner, M. and Jebb, S.A. (2021) The Effects of Environmental Sustainability Labels on Selection, Purchase, and Consumption of Food and Drink Products: A Systematic Review. *Environment and Behavior*, **53**(8), 891-925. DOI: 10.1177/0013916521995473

Potter, C., Pechey, R., Cook, B., Bateman, P., Stewart, C., Frie, K., Clark, M., Piernas, C., Rayner, M. and Jebb, S.A. (2023) Effects of environmental impact and nutrition labelling on food purchasing: An experimental online supermarket study. Appetite, 180, 106312. DOI: https://doi.org/0.1016/j.appet.2022.106312

Pimentel, D. and Kounang, N. (1998) Ecology of soil erosion in ecosystems. *Ecosystems*, 1, 416-426.

Poore, J., and Nemecek, T. (2018) Reducing food's environmental impacts through producers and consumers. *Science*. 360, 987-992. DOI: 10.1126/science.aaq0216

Prost, L., Martin, G., Ballot, R., Benoit, M., Bergez, J-E., Bockstaller, C., Cerf, M., Deytieux, V., Hossard, L., Jeuffroy, M-H., Leclère, M., Le Bail, M., Le Gal, P-Y., Loyce, C., Merot, A., Meynard, J-M., Mignolet, C., Munier-Jolain, N., Novak, S., Parnaudeau, V., Poux, X., Sabatier, R., Salembier, C., Scopel, E., Simon, S., Tchamitchian, M., Toffolini, Q. and van der Werf, H. (2023) Key research challenges to supporting farm transitions to agroecology in advanced economies. A review. *Agronomy for Sustainable Development*, **43**, 11). DOI: 10.1007/s13593-022-00855-8

Quantis (2024) World Food LCA Database. URL: https://quantis.com/who-we-guide/our-impact/sustainability-initiatives/wfldb-food/ (Last accessed: 21/04/24)

Rainford, J, Tzilivakis, J., Garthwaite, D., Jones, G. & Lewis, K.A. (2023) *Finalising a Pesticide Load Indicator for the UK: Phase 4 Report.* Prepared for the Department for Environment, Food and Rural Affairs (Defra), UK, for project PC0116, by FERA Science Ltd and the Agriculture and Environment Research Unit (AERU), University of Hertfordshire, UK. Available at: https://randd.defra.gov.uk/ProjectDetails?ProjectId=21074 (Last accessed: 18/04/24)

Ramos, S., Segovia, L., Melado-Herreros, A., Cidad, M., Zufía, J., Vranken, L. and Matthys, C. (2022) Enviroscore: normalization, weighting, and categorization algorithm to evaluate the relative environmental impact of food and drink products. *npj Science of Food*, **6**(1), 54. DOI: 10.1038/s41538-022-00165-z

Reap, J., Roman, F., Duncan, S. and Bras, B. (2008) A survey of unresolved problems in life cycle assessment. *International Journal of Life Cycle Assessment*,**13**, 374–388. DOI: 10.1007/s11367-008-0009-9

Rey Benayas, J.M. and Bullock, J.M. (2012) Restoration of biodiversity and ecosystem services on agricultural land. *Ecosystems*, 15, 883-899.

Rezazga, A., Ruiz, C., Montanaro, G., Falcone, G. and Koubouris, G. (2024) Driving the Ecological Transition of Agriculture through Voluntary Certification of Environmental Impacts: An Exploratory Literature Review on the Olive-Oil Sector. *Sustainability*, **16**, 1227. DOI: 10.3390/su16031227

Ritchie, H. (2020) *The carbon footprint of foods: are differences explained by the impacts of methane?* OurWorldInData.org. URL: https://ourworldindata.org/carbon-footprint-food-methane (Last accessed: 16/04/24)

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., III, Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M, Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. (2009a) Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, **14**(2), 32.

Rockström, J., Steffen, W., Noone, K. Persson, A., Chapin, F.S., III, Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M, Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. (2009b) A safe operating space for humanity. *Nature*, **461**, 472-475. DOI: 10.1038/461472a

RSPB (2016) *RSPB and Conservation Grade affirm partnership*. Royal Society for the Protection of Birds (RSPB). URL: https://community.rspb.org.uk/ourwork/farming/b/farming-blog/posts/rspb-and-conservation-grade-affirm-partnership (Last accessed: 19/04/24)

RSPCA (2024) *RSPCA Assured UK - Farm Animal and Chicken Welfare*. Royal Society for the Prevention of Cruelty to Animals (RSPCA). URL: https://www.rspcaassured.org.uk/ (Last accessed: 22/04/24)

Ryberg, M.W., Andersen, M.M., Owsianiak, M. and Hauschild, M.Z. (2020) Downscaling the planetary boundaries in absolute environmental sustainability assessments – A review. *Journal of Cleaner Production*, **276**, 123287. DOI: 10.1016/j.jclepro.2020.123287

SA (2023) Soil *Association Organic Standards for Great Britain Farming and growing*. Version 1.3: published on 25 May 2023. Soil Association (SA). Available at: https://www.soilassociation.org/our-standards/read-our-organic-standards/organic-standards-for-great-britain/ (Last accessed: 11/01/24)

SA (2024) *Soil Association*. Soil Association (SA) website. URL: https://www.soilassociation.org/ (Last accessed: 11/04/24)

Sala, S., Vasta, A., Mancini, L., Dewulf, J. and Rosenbaum, E. (eds.) (2015) *Social Life Cycle Assessment - State of the art and challenges for supporting product policies*. European Commission, Joint Research Centre, Institute for Environment and Sustainability, Publications Office of the European Union, Luxemburg

Sala, S., Benini, L., Crenna, E. and Secchi M. (2016) Global environmental impacts and planetary boundaries in LCA. Data sources and methodological choices for the calculation of global and consumption-based normalisation factors. JRC Technical Report EUR 28371 EN. DOI: 10.2788/64552

Sala S., Cerutti A.K. and Pant R. (2018) *Development of a weighting approach for the environmental footprint*. Publications Office of the European Union, Luxembourg. DOI: 10.2760/945290

Sala S., Crenna E., Secchi M. and Pant, R. (2017) Global normalisation factors for the Environmental Footprint and Life Cycle Assessment. EUR (28984); JRC109878. Publications Office of the European Union, Luxembourg. DOI: 10.2760/88930

Sala, S., Crenna, E., Secchi M. and Sanyé-Mengual, E. (2020) Environmental sustainability of European production and consumption assessed against planetary boundaries. *Journal of Environmental Management*, **269**, 110686,. DOI: 10.1016/j.jenvman.2020.110686

Sandifer, P.A., Sutton-Grier, A.E. and Ward, B.P. (2015) Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services*, **12**, 1-15. DOI: 10.1016/j.ecoser.2014.12.007

Scarborough, P., Clark, M., Cobiac, L., Papier, K., Knuppel, A., Lynch, J., Harrington, R., Key, T. and Springmann, M. (2023) Vegans, vegetarians, fish-eaters and meat-eaters in the UK show discrepant environmental impacts. *nature food*. **4**, 565–574. DOI: 10.1038/s43016-023-00795-w

Schiavo, M., Le Mouël, C., Poux, X. and Aubert, P.M. (2023) The land use, trade, and global food security impacts of an agroecological transition in the EU. *Frontiers in Sustainable Food Systems*, **7**, 1189952. DOI: 10.3389/fsufs.2023.1189952

Schickler III, P.E., Debiase, F., Rockey, S., Goldston, J., Yih, P.T. and Burdsall, N. (2023) *Bridging the gap: A "Sustainable Food Seal" needed to improve transparency between farmers and consumers about sustainable food production*. Report by The Chicago Council on Global Affairs. Available at: https://globalaffairs.org/research/report/bridging-gap-sustainable-food-seal (Last accessed: 10/04/24)

Schröter, M., van der Zanden, E.H., van Oudenhoven, A.P.E., Remme, R.P., Serna-Chavez, H.M., de Groot, R.S. and Opdam, P. (2014) Ecosystem services as a contested concept: A synthesis of critique and counter-arguments. *Conservation Letters*, **7**, 514-523. DOI: 10.1111/conl.12091

SCM (2023) *Solent Catchment Market*. Solent Catchment Market (SCM). URL: https://www.solentnutrientmarket.org.uk/ (Last accessed: 26/06/23)

Schulze, C., Matzdorf, B., Rommel, J., Czajkowski, M., García-Llorente, M., Gutiérrez-Briceño, I., Larsson, L., Zagórska, K. and Zawadzki, W. (2024) Between farms and forks: Food industry perspectives on the future of EU food labelling. *Ecological Economics*, **217**, 108066. DOI: 10.1016/j.ecolecon.2023.108066

Schwarz, G., Vanni, F., Miller, D., Helin, J., Pražan, J., Albanito, F., Fratila, M., Galioto, F., Gava, O., Irvine, K., Landert, J., Quero, A.L., Mayer, A., Monteleone, D., Muller, A., Röös, E., Smyrniotopoulou, A., Vincent, A., Vlahos, G. and Zīlāns, A. (2022) Exploring Sustainability Implications of Transitions to Agroecology: a Transdisciplinary Perspective. *EuroChoices*, **21**, 37-47. DOI: 10.1111/1746-692X.12377

Sharma, S., Sato, K. and Gautam, B.P. (2022) *Bioacoustics Monitoring of Wildlife using Artificial Intelligence: A Methodological Literature Review*. International Conference on Networking and Network Applications (NaNA), Urumqi, China, 2022, pp. 1-9, DOI: 10.1109/NaNA56854.2022.00063

Silici, L. (2014) *Agroecology: What it is and what it has to offer*. International Institute for Environment and Development (IIED) Issue Paper, London, UK.

Singh, P., Singh, M.K., Beg, Y.R. and Nishad, G.R. (2019). A review on spectroscopic methods for determination of nitrite and nitrate in environmental samples. *Talanta*, **191**, 364-381. DOI: 10.1016/j.talanta.2018.08.028

Skinner, J.A., Lewis, K.A., Bardon, K.S., Tucker, P., Catt, J.A. and Chambers, B.J. (1997) An Overview of the Environmental Impact of Agriculture in the U.K. *Journal of Environmental Management*, 50, 111–128.

SRC (2024) *Planetary boundaries*. Stockholm Resilience Centre (SRC). Available at: https://www.stockholmresilience.org/research/planetary-boundaries.html (Last accessed: 01/02/24)

SSLLC (2204) *Ecosystem Services*. Sustainable Solutions, LLC (SSLRC). Available at: https://sustainablesolutionsllc.net/about/ecosystem-services/ (Last accessed: 01/02/24)

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., Sörlin, S. (2015) Planetary boundaries: Guiding human development on a changing planet. *Science*, **347**(6223), 1259855. DOI: 10.1126/science.1259855

Stein, A.J. and de Lima, M. (2022) Sustainable food labelling: considerations for policy-makers. *Review of Agricultural, Food and Environmental Studies*, **103**, 143–160. DOI: 10.1007/s41130-021-00156-w

Stella, G., Coli, R., Maurizi, A., Famiani, F., Castellini, C., Pauselli, M., Tosti, G. and Menconi, M. (2019) Towards a National Food Sovereignty Plan: Application of a new Decision Support System for food planning and governance. *Land Use Policy*, **89**, 104216. DOI: 10.1016/j.landusepol.2019.104216.

Stephen, A. (2024) *Personal communication*. Meeting with Andrew Stephen, Chief Impact Officer, Foodsteps, 24 April 2024

Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., de Snooc, G.R. and Eden, P. (2001) Ecological impacts of arable intensification in Europe. *Journal of Environmental Management*, 63(4), 337-365.

Tahat, M.M.; Alananbeh, K.M., Othman, Y.A. and Leskovar, D.I. (2020) Soil Health and Sustainable Agriculture. *Sustainability*, **12**, 4859. DOI: 10.3390/su12124859

Tiboni-Oschilewski, O., Abarca, M., Santa Rosa Pierre, F., Rosi, A., Biasini, B., Menozzi, D. and Scazzina, F. (2024) Strengths and weaknesses of food eco-labeling: a review. *Frontiers in Nutrition*, **11**, 1381135. DOI: 10.3389/fnut.2024.1381135

Tokede, O. and Traverso, M. (2020) Implementing the guidelines for social life cycle assessment: past, present, and future. *International Journal of Life Cycle Assessment*, **25**, 1910–1929. DOI: 10.1007/s11367-020-01814-9

Tzilivakis, J., Lewis K.A., Warner, D.J., Green. A. and Coles A.J.C. (2009) *A content analysis of assurance scheme standards*. Report prepared by Agriculture and Environment Research Unit (AERU), University of Hertfordshire for the Department for Environment, Food and Rural Affairs for project IF0131. March 2009

Tzilivakis, J., Green, A., Warner, D.J., McGeever,K. and Lewis, K.A. (2012) A framework for practical and effective eco-labelling of food products. *Sustainability Accounting, Management and Policy Journal*, **3**(1), 50-73. DOI. 10.1108/20408021211223552

Tzilivakis, J., Lewis, K.A., Green, A., Warner, D.J., MacMillan, T & McGeevor, K. (2011) *Effective approaches to environmental labelling of food products*. Final Report for Defra Project FO0419. January 2011. Available at: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=17104 (Last accessed: 23/04/24)

UNEP (2024a) *Convention of Biological Diversity*. United Nations Environment Programme (UNEP). URL: https://www.cbd.int/ (Last accessed: 18/04/2024)

UNEP (2024b) *Kunming-Montreal Global Biodiversity Framework*. United Nations Environment Programme (UNEP). URL: https://www.cbd.int/gbf (Last accessed: 18/04/2024)

van der Werf, H.M.G., Knudsen, M.T. and Cederberg, C. (2020) Towards better representation of organic agriculture in life cycle assessment. *Nature Sustainability*, **3**, 419–425. DOI: 10.1038/s41893-020-0489-6

van Oudenhoven, A.P.E., Petz, K., Alkemade, R., Hein, L. and de Groot, R.S. (2012) Framework for systematic indicator selection to assess effects of land management on ecosystem services. *Ecological Indicators*, **21**, 110-122. DOI: 10.1016/j.ecolind.2012.01.012

van Zanten, B.T., Verburg, P.H., Espinosa, M., Gomez-y-Paloma, S., Galimberti, G., Kantelhardt, J., Kapfer, M., Lefebvre, M., Manrique, R., Piorr, A., Raggi, M., Schaller, L., Targetti, S., Zasada, I. and Viaggi, D. (2014) European agricultural landscapes, common agricultural policy and ecosystem services: a review. *Agronomy for Sustainable Development*, **34**(2), 309-325. DOI: 10.1007/s13593-013-0183-4

Vermeulen, S.J., Campbell, B.M. and Ingram, J.S.I. (2012) Climate change and food systems. *Annual Review of Environment and Resources*, **37**, 195-222. DOI: 10.1146/annurev-environ-020411-130608

von Greyerz, K., Tidåker, P., Karlsson, J.O. and Röös, E. (2023) A large share of climate impacts of beef and dairy can be attributed to ecosystem services other than food production. *Journal of Environmental Management*, **325**(Part A), 116400. DOI: 10.1016/j.jenvman.2022.116400

Warren, N., Allan, I.J., Carter, J.E., House, W.A. and Parker, A. (2003) Pesticides and other micro-organic contaminants in freshwater sedimentary environments: a review. *Applied Geochemistry*, 18(2), 159-194.

Weidema, B.P., Bauer, C., Hischier, R., Mutel, C., Nemecek, T., Reinhard, J., Vadenbo, C.O. and Wernet, G. (2013) *Overview and methodology: Data quality guideline for the ecoinvent database version 3*. Swiss Centre for Life Cycle Inventories. Ecoinvent Report Vol. 3 No. 1

Weidema, B. P., Cappellaro, F., Carlson, R., Notten, P., Pålsson, A-C., Patyk, A., Regalini, E., Sacchetto, F. and Scalbi, S. (2004) *Procedural guideline for collection, treatment, and quality documentation of LCA data*. (LC-TG-23-001). CASCADE Project. Available at: https://lca-net.com/files/V2004_ProceduralLCA.pdf (Last accessed: 22/04/24)

Weidema, P. and Wesnæs, M.S. (1996) Data quality management for life cycle inventories - an example of using data quality indicators. *Journal of Cleaner Production*, **4**(3-4), 167-174. DOI: 10.1016/S0959-6526(96)00043-1

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E. and Weidema, B. (2016) The ecoinvent database version 3 (part I): overview and methodology. *International Journal of Life Cycle Assessment*, **21**, 1218–1230. DOI: 10.1007/s11367-016-1087-8

Wezel, A., Bellon, S., Doré, T. Francis, C., Vallod, D. and David, C. (2009) Agroecology as a science, a movement and a practice. A review. *Agronomy for Sustainable Development*, **29**, 503–515. DOI: 10.1051/agro/2009004

Wezel, A., Herren, B.G., Kerr, R.B. Barrios, E., Gonçalves, A.L.R. and Sinclair, F. (2020) Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development*, **40**, 40. DOI: 10.1007/s13593-020-00646-z

Wheater, H. and Evans, E. (2009) Land use, water management and future flood risk. *Land Use Policy*, **26**(S1), S251-S264. DOI: 10.1016/j.landusepol.2009.08.019

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, D., Cornell, S.E., Reddy, K.S., Narain, S., Nishtar, S. and Murray, C.J.L. (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet*, **393**(10170), 447-492. DOI: 10.1016/S0140-6736(18)31788-4

Williams, V., Flannery, O. and Patel, A. (2023) Eco-score labels on meat products: Consumer perceptions and attitudes towards sustainable choices. *Food Quality and Preference*. **111**, 104973. DOI: 10.1016/j.foodqual.2023.104973

Winter, L., Lehmann, A., Finogenova, N. and Finkbeiner, M. (2017) Including biodiversity in life cycle assessment – State of the art, gaps and research needs. *Environmental Impact Assessment Review*, **67**, 88-100. DOI: 10.1016/j.eiar.2017.08.006.

Wolff, A., Gondran, N. and Brodhag, C. (2017) Detecting unsustainable pressures exerted on biodiversity by a company. Application to the food portfolio of a retailer. *Journal of Cleaner Production*, **166**, 794-797. DOI: 10.1016/j.jclepro.2017.08.057

Woods, J., Williams, A., Hughes, J.K., Black, M. and Murphy, R. (2010) Energy and the food system. *Philosophical Transactions of the Royal Society B,* 365, 2991-3006.

WRAP (2022) *Scope 3 GHG Management and Reporting Protocols: Sector Guidance for Food and Drink Businesses*. Waste and Resources Action Programme (WRAP). Available at: https://wrap.org.uk/resources/guide/scope-3-ghg-measurement-and-reporting-protocols-food-and-drink (Last accessed: 30/04/24)

WRAP (2024) *The Courtauld Commitment 2030*. Waste and Resources Action Programme (WRAP). Available at: https://wrap.org.uk/taking-action/food-drink/initiatives/courtauld-commitment (Last accessed: 29/04/2024)

WULCA (2024) *What is AWARE?* Water Use in LCA (WULCA). URL: https://wulca-waterlca.org/aware/what-is-aware/ (Last accessed: 18/04/24)

Yakovleva, N, Sarkis, J. & Sloan, T. (2012) Sustainable benchmarking of supply chains: the case of the food industry, *International Journal of Production Research*, **50**(5), 1297-1317, DOI: 10.1080/00207543.2011.571926

Yan, M-J., Humphreys, J. and Holden, N.M. (2011) An evaluation of life cycle assessment of European milk production. *Journal of Environmental Management*, **92**(3), 372-379. DOI: 10.1016/j.jenvman.2010.10.025