Regenerative agriculture
& sustainable land use

→ Scaling impact through effective measurement, reporting & verification (MRV)

World Business Council *for Sustainable Development*

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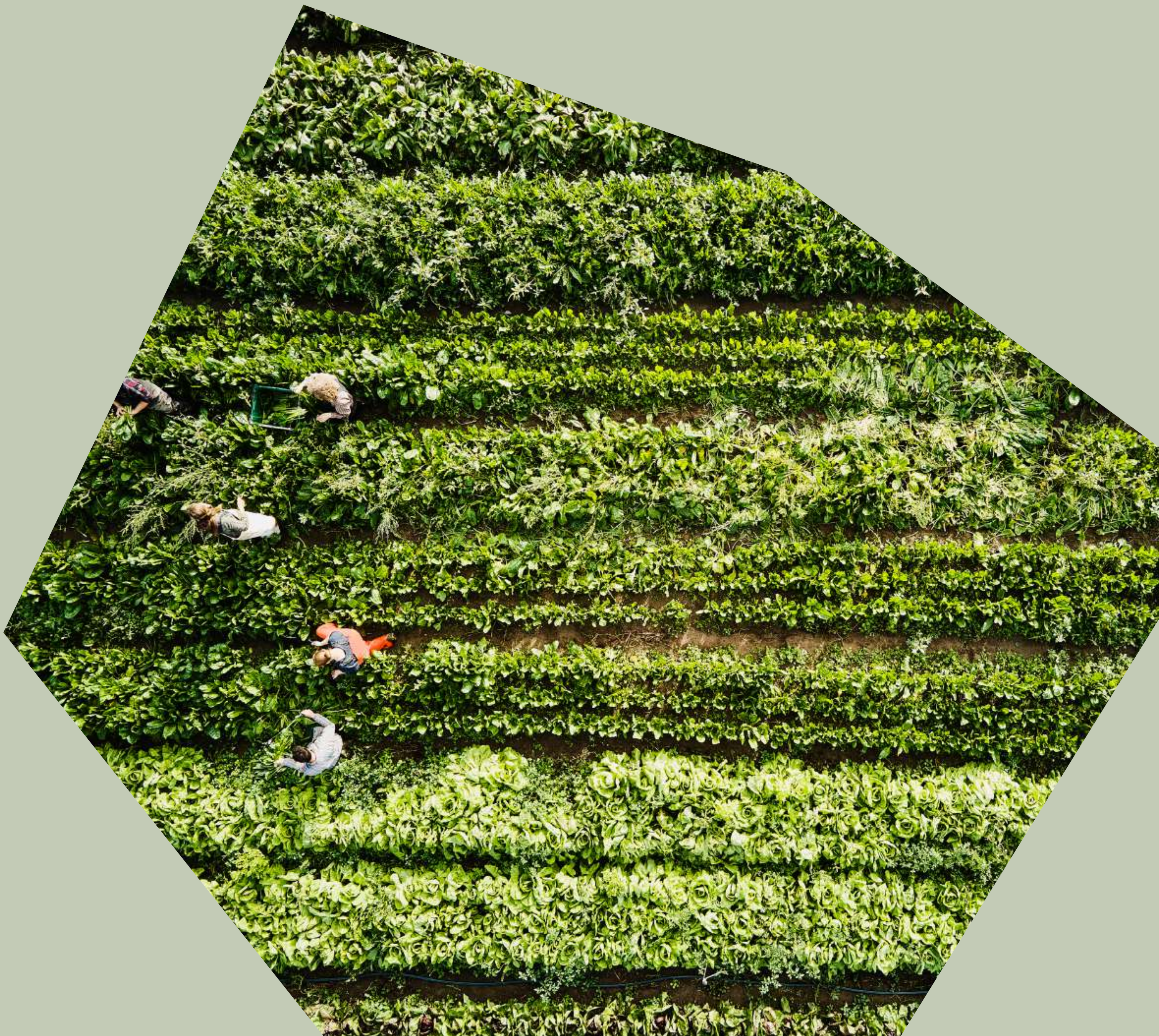
Introduction



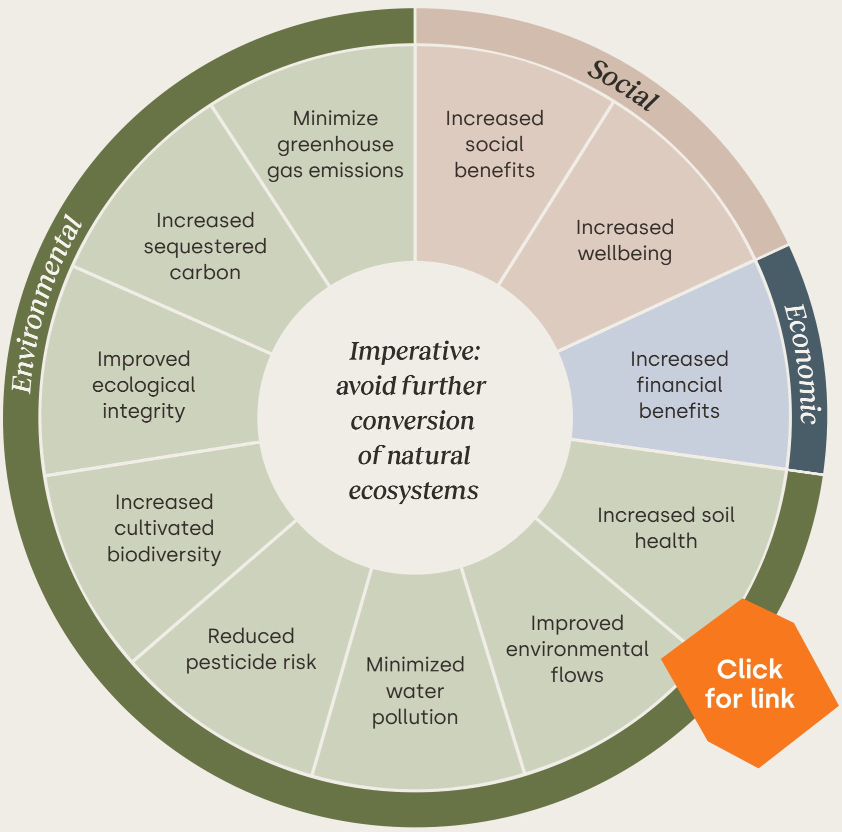
01.

Introduction

Through WBCSD, leading businesses have converged on a core set of outcomes and indicators for regenerative agriculture & sustainable land use

- WBCSD and OP2B brought together 52 companies and 33 partner organizations **representing 1100+ businesses** to align on **outcome-based indicators for regenerative agriculture.**
- This is designed to **converge the way in which agricultural value chain players measure, report, and get incentivized for the positive impacts** on environmental, social and economic outcomes of agrifood production.
- **This is a holistic approach** encompassing environmental, social, and economic outcomes. Not a prescriptive, practice-based definition - **a results-oriented model.**
- The approach does not reinvent the wheel. It **draws on existing frameworks** (e.g. ISSB, TNFD), planetary boundaries and areas of consensus.
- The shared indicators are designed for use at a **corporate ESG level and are aligned with key frameworks used for landscape and farm-level action** (e.g. SAI Platform).

Figure 1: Alignment on core outcomes for regenerative agriculture



Convergence on outcomes and indicators drives business value: turning measurement into strategy and capital

A strategic priority for WBCSD is the alignment of robust data and metrics, and the development of protocols and standards for broad adoption by corporates and recognition by investors and policy-makers. Companies face growing demands for more credible sustainability insights that guide resource allocation and accelerate transformation. WBCSD helps companies use this sustainability data to drive meaningful action.

Science-informed framework and metrics
Convergence on a robust and outcome-based indicators

Business decision-making
Use data for better management decisions, risk management and strategic resource allocation

Capital allocation
Data and disclosures are clear, comparable and decision-useful to influence capital markets, investors and lenders

Competitive, sustainable and resilient agrifood systems
Accelerate the transition to regenerative agriculture and sustainable land use

The shared outcomes and indicators are already being used by 30+ companies to support corporate decision-making and value chain collaboration

Use cases: Companies are using the framework to drive business value

1. **Streamline corporate reporting:** Consistent corporate impact monitoring and reporting
2. **Enable decision-making:** Integrate a shared set of environmental and social outcomes into corporate strategies
3. **Scale financing:** Shared measurement architecture underpins aligned incentives for farmers and valorization of ecosystem services
4. **Support meaningful value chain collaboration:** Coordinated demand signals across value chains through alignment on shared goals
5. **Support policy design:** Integration of outcome-based metrics that companies are already starting to use into national, regional, and international policy frameworks

Why effective measurement, reporting and verification (MRV) matters:

- → Effective MRV has been identified by WBCSD members as a critical enabler for implementing outcome-based-indicators for Regenerative Agriculture and Sustainable Land Use.
- → The agrifood sector urgently requires harmonized MRV approaches to credibly measure impact, track progress against outcomes, and inform strategic decision-making.
- → Without harmonization, meaningful impact assessment is undermined, creating uncertainty for businesses, investors, and other stakeholders.
- → Robust and scalable MRV systems are essential to support credible claims, reduce resource burden across the value chain, and unlock finance to accelerate action and outcomes on the ground.

This guidance is designed to equip organizations to leverage MRV in decision-making to support more competitive, sustainable and resilient value chains by:

- → Establishing MRV approaches with the highest potential to deliver reliable and integrated information.
- → Identifying key opportunities to maximize the uptake of these MRV approaches in a way which is cost-effective, accurate and scalable.
- → Identifying opportunities for simplification and harmonization of approaches across key metrics.

Table 1: 12 core regenerative agriculture and nature positive indicators by outcome and impact area

	Outcome	*Core indicator*	*Climate*	*Biodiversity*	*Soil health*	*Water*	*Socioeconomic*
WBCSD regenerative agriculture metrics	Minimize GHG emissions	Agricultural GHG emissions	■				
	Increase sequestered carbon	Soil carbon sequestration	■	□	■	□	
		Total carbon sequestration	■	□	■	□	
	Increase cultivated biodiversity	Crop diversity		■	■	□	
	Reduce pesticide risk	Pesticide risk		■	■	■	
	Improve environmental flows	Blue water withdrawal				■	
	Minimize water pollution	Nutrient use efficiency	■	■	■	■	
	Increase financial benefits	Farm net income					■
	Improve ecological integrity	Natural/semi-natural habitat in agricultural land		■	□	□	
Nature positive metrics		Land / freshwater ecosystem use change	■	■	□	□	
		Land / freshwater ecosystem restored	□	■			
		Land / freshwater ecosystem conserved	□	■			

Key insights

02.

Three principles for effective MRV

Scalable MRV requires consideration across multiple factors. WBCSD members have aligned on **three key criteria for effectiveness** at the global level:

Figure 3: Three key criteria for effective MRV

Technological & quality readiness

- **Technological readiness**
- **Scientific consensus** on the approach
- **Quality and accuracy** of tools and methods
- **Comparability and compatibility** of outputs with other approaches

Cost effectiveness

- **CAPEX costs:** Unit costs, costs to scale
- **OPEX costs:** Tool licensing fees, data, resource and expertise requirements
- **Options for cost sharing**
- Cost implications of **future innovation**

Scalability

- Potential to scale **geographically**
- Potential to scale **cross-commodity**
- Potential to scale across **different farm types**
- Scalability in contexts **without physical traceability**

This guidance signposts MRV approaches with the greatest potential to balance trade-offs and synergies between these three principles:

High TQR = High costs

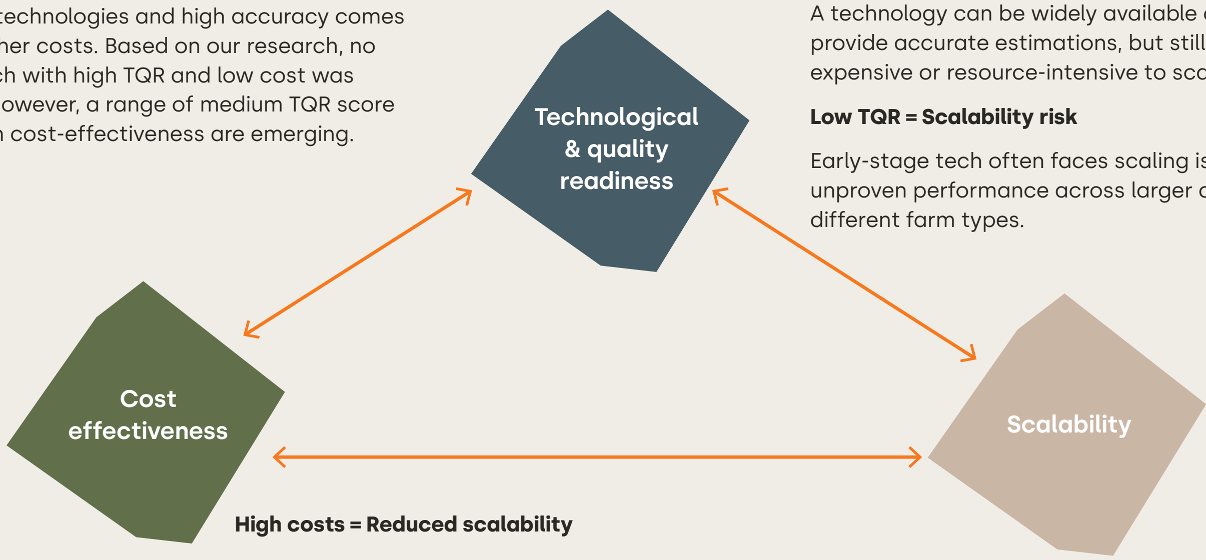
Mature technologies and high accuracy comes with higher costs. Based on our research, no approach with high TQR and low cost was found. However, a range of medium TQR score and high cost-effectiveness are emerging.

High TQR ≠ High scalability

A technology can be widely available and provide accurate estimations, but still expensive or resource-intensive to scale.

Low TQR = Scalability risk

Early-stage tech often faces scaling issues like unproven performance across larger areas or different farm types.



High costs = Reduced scalability

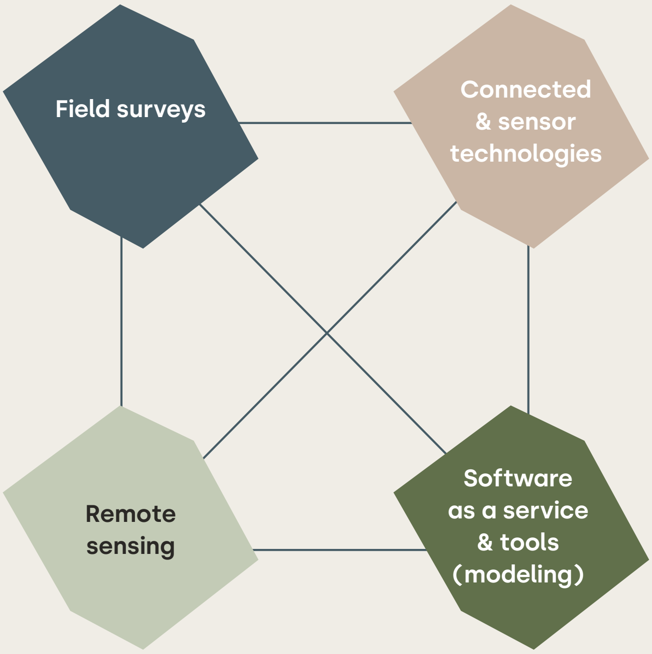
If MRV is too expensive or complex, scaling the solution becomes financially and logistically challenging, especially across landscapes with disaggregated or smaller farms.

High scalability = Cost reduction

As technologies enable scalability of MRV approach across geographies, commodities and farm archetypes, economies of scale and operational efficiencies can reduce overall MRV costs.

This research focuses on four measurement categories

Figure 5: Four measurement approaches



Primary data collection, surveying farmers or fields through manual and/or digital forms and questionnaires. Includes collection of samples for laboratory analysis.

Deployment of sensors which collect **'point in space'** data on farm practices or soil. Data collected is used to estimate a desired metric digitally e.g., statistical models for spectral analyses and can be automated via AI.

Use of **satellite data** (imagery, atmospheric data) to estimate desired metrics via proxies and/or indices. Increasingly leveraging **Artificial Intelligence (AI)** and automatization for metrics estimation.

Digital, **model-based** estimation of a metric by inputting farm processes, atmospheric and other biophysical primary data. Includes process-based models that simulate biological and chemical processes.

These four approaches are not mutually exclusive; they are interconnected and complementary to one another. Where there is complementarity, it is likely that companies will combine different approaches for more robust, scalable, and cost-effective MRV. For example, Field surveys, Connected and Sensor Technologies, and Remote sensing are typically used to collect primary data which is used as input for modeling software and tools.

Each measurement approach operates at different scales (local vs. regional), has different **temporal resolutions** (snapshot vs. continuous), and can capture **different data types** (quantitative sensor readings vs. qualitative field insights).

Figure 6: Key insights for each measurement category

Field surveys

(+)
- → Highly accurate data tailored to specific local conditions.
- → Presents opportunities to engage with farmers, enabling greater transparency.
- → Depending on design, may contribute data relevant to several outcomes

(−)
- → Time-consuming, resource and labor-intensive, and hard to scale for large areas.

Best use case(s):

- → Measure outcomes of selected programs to make informed changes to management practices.
- → Complement other measurement approaches by providing 'ground-truth' validation.

Connected & sensor technologies

(+)
- → Provide continuous, real-time data with minimal human intervention. Emerging, high potential technology.

(−)
- → High unit costs, require significant upfront investment and ongoing maintenance, and may have limited spatial coverage.

Best use case(s):

- → To detect changes and conditions and respond in real time, due to the inability of periodic inspections to capture continuous operational data and early fault indicators.

Remote sensing

(+)
- → Enables large-scale, frequent and repeatable monitoring over broad geographic areas.
- → Typically, an effective method for obtaining large amounts of data in a quick and cost-effective way.

(−)
- → Can lack ground-level detail and may be affected by cloud cover or resolution limitations, limiting accuracy of estimations.

Best use case(s):

- → To monitor large-scale environmental changes due to the impracticality of collecting consistent on-the-ground data over vast or inaccessible areas.

Software as a service & tools (modeling)

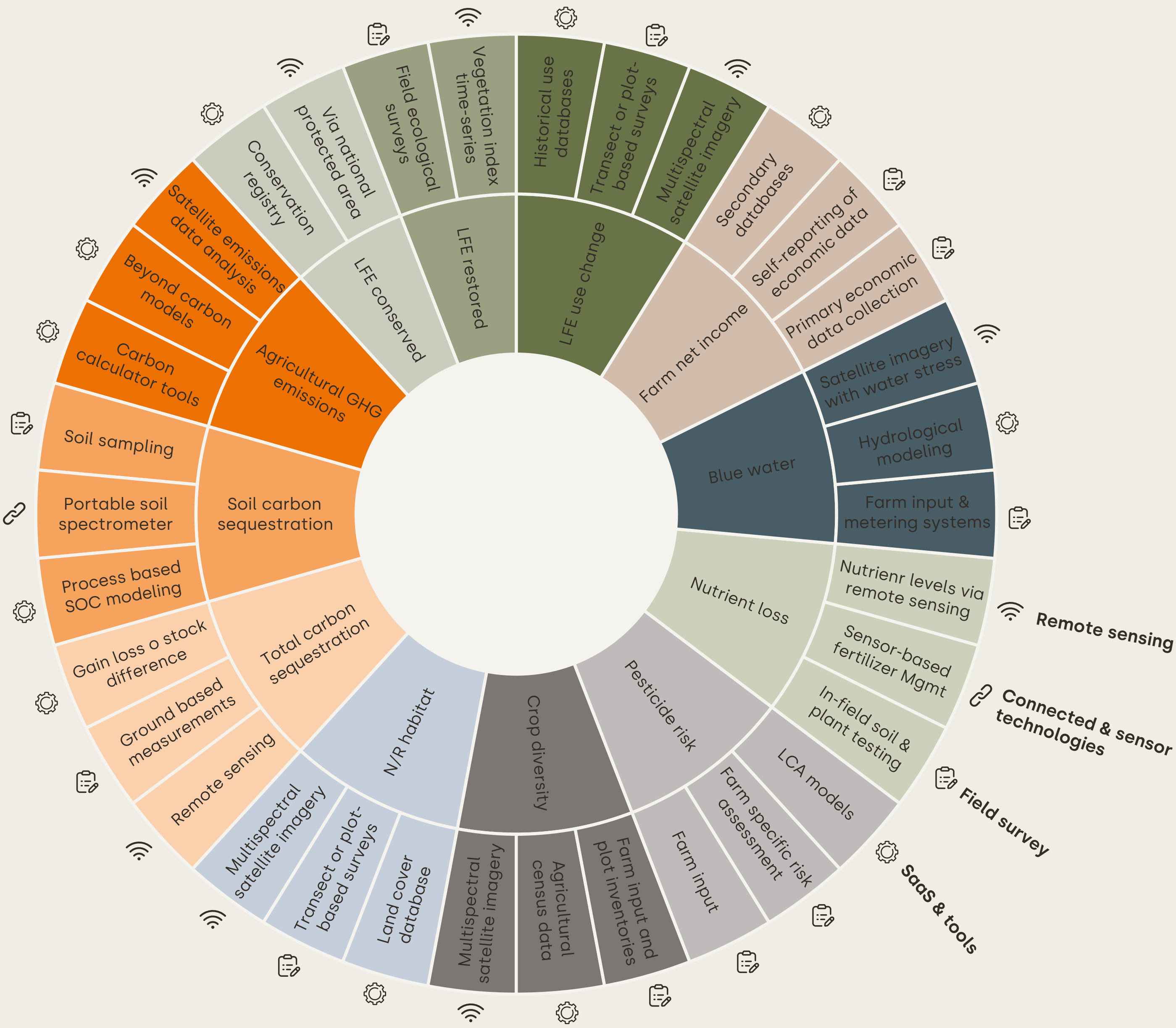
(+)
- → Offer user-friendly data processing, analytics, and visualization at scale.

(−)
- → Are highly specific and rely on either primary data, which is challenging to obtain, or third-party data, which can limit granularity, transparency and customization.

Best use case(s):

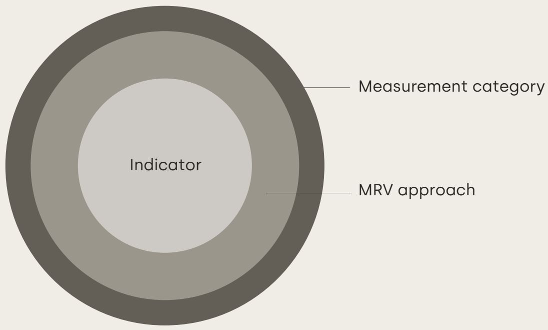
- → To deliver broader implementation and scaling due to the unavailability or inaccessibility of consistent primary data.

Figure 2: Summary of the MRV approaches for 12 core regenerative agriculture and nature positive indicators



Legend: Field survey SaaS & tools Remote sensing Connected & sensor technologies

- → This visual shows main MRV approaches for each of the 12 indicators
- → Each MRV approach is categorized under a broader measurement category: Remote sensing, SaaS & Tools, Field surveys, or Connected & sensor technologies



The MRV ecosystem: Best practice MRV approaches for 12 indicators

For each indicator the highest potential MRV approaches have been identifed through a benchmarking process. Approaches are ranked as Good-Better-Best based on their performance against the 3 criteria for effective MRV.

Table 2: Overview of good, better and best MRV approaches for 12 core regenerative agriculture and nature positive indicators

Outcome	*Core indicator*	*Good*	*Better*	*Best*
Minimize GHG emissions	Agricultural GHG emissions	Remote sensing: satellite emissions data analysis	Saas & tools: beyond carbon process-based models	Saas & tools: carbon calculator tools
Increase sequestered carbon	Soil carbon sequestration	Field survey: soil sampling	Connected & sensor technologies: portable soil spectrometer for in field use	Saas & tools: process based soc modeling
	Total carbon sequestration	Saas & tools: gain loss or stock difference method	Field survey: ground based measurements	Remote sensing: active or optical (passive) remote sensing
Increase cultivated biodiversity	Crop diversity	Remote sensing: multispectral satellite imagery combined with land cover classification algorithms	Saas & tools: agricultural census data	Field survey: farm input and plot inventories
Reduce pesticide risk	Pesticide risk	Field survey: farm input surveys	Saas & tools: lifecycle assessment models	Field survey: farm specific risk assessment
Improve environmental flows	Blue water withdrawal	Field surveys + Connected & sensor technologies: farm input and water metering systems	Saas & tools: hydrological modeling	Remote sensing + saas & tools: combine satellite imagery with water stress data
Minimize water pollution	Nutrient use efficiency	Connected & sensor technologies: sensor-based fertilizer management	Remote sensing: nutrient levels assessed via remote sensing	Field survey: in-field soil & plant testing
Increase financial benefits	Farm net income	Field survey + saas & tools : self-reporting of farm economic data	Field survey: primary farm economic data collection	Saas & tools: secondary databases
Improve ecological integrity	Natural/semi-natural habitat in agricultural land	Remote sensing: multispectral satellite imagery combined with land cover classification algorithms	Field survey: transect or plot-based surveys	Saas & tools: land cover database
	Land / freshwater ecosystem use change	Field survey: transect or plot-based surveys	Remote sensing: multitemporal satellite-based land cover change detection	Saas & tools: historical land/ water use databases
	Land / freshwater ecosystem restored	Remote sensing: vegetation index time-series	Field survey: Field Ecological Surveys of Restored Sites	-
	Land / freshwater ecosystem conserved	Remote sensing: monitoring conservation areas via national protected area boundaries	Remote sensing + SaaS & Tools: Protected Area and Conservation Registry Data	-

Recommendations for companies

- **Tailor your MRV strategy to the use case:** What level of data is needed to provide the right level of insight to drive key decision making? MRV has a critical role in driving transparency, accountability and trust – as well as driving action. How will your organization use the data – for example i) improving on farm best management practices, ii) incentivising the transition to improved regenerative agriculture and nature outcomes, iii) policy development that accelerates access to technology and innovation.
- **Leverage MRV approaches which can measure impact across multiple metrics** and report against multiple frameworks, creating opportunities to drive efficiencies of scale.
- **Combine primary and secondary data approaches:** It is likely that a combination of primary and secondary data approaches is needed to scale. Organizations should firstly consider the role of existing on farm systems that collect data to avoid duplication, before considering what combination of further primary and secondary data sources are needed to provide the right level of insight to drive key decision making. For example, where primary data collection at scale is unfeasible given supply chain complexity or cost, can representative samples of primary data be collected and modelled representatively in rural areas that are less accessible?
- **Test and learn:** Organizations should consider trialling several technologies through pilot programmes to assess their viability to monitor specific, and combinations of, metrics.
- **Whatever the approach, transparency is key:** Ultimately the approach organizations choose to close data gaps should ensure that data collected is well-documented, auditable and traceable including transparency on any data methods, limitations and assumptions made to report progress.
- **Training and upskilling:** The MRV approaches alone are not enough to drive consistent and credible data points that organizations can use for ESG disclosure. Organizations must consider implementing relevant training required to upskill key stakeholders in the agronomic theory, application and interpretation of the MRV approach to drive robust and consistent high-quality outcomes.
- **Identify opportunities for shared investment in MRV across the value chain**: Risks and opportunities are shared across commodity value chains. Greater pre-competitive collaboration and investment in similar high potential MRV approaches can unlock efficiencies of scale and minimise farmers' data collection burdens. Considerations need to be made in how this pre-competitiveness may be incentivised and how policy development may lower the barriers to accelerate adoption.

Future needs and opportunities for an effective MRV ecosystem

Scaling high potential MRV approaches requires action from the broader ecosystem:

1. Making them more commercially viable, accessible to adopt and farmer-centric

→ Targeted financial incentives (e.g., subsidies, blended finance, tax credits) to lower high setup and operational costs for MRV solutions.

→ Regulatory frameworks that lower barriers to entry and encourage consistent MRV requirements, thereby creating predictable demand and economies of scale.

→ Pricing models and technology licensing structures from providers that enable affordability for small and mid-sized actors, not just large corporates.

2. Ensuring they are mature and interoperable enough both scientifically and technologically

→ Financial and regulatory support to drive more integrated governance and harmonized operating standards

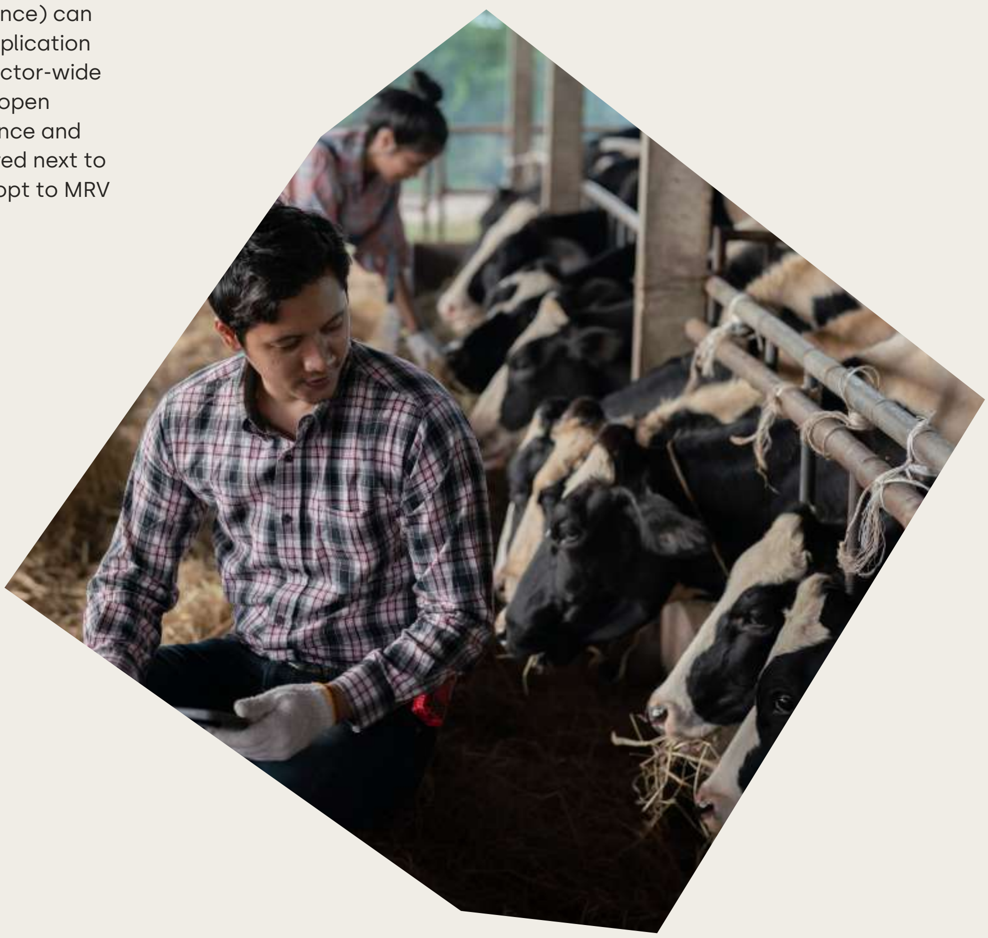
→ Implementation support to improve the consistency of data quality through training MRV users.

→ Improved interoperability of technological solutions (including the scientific methods used to monitor progress against indicators and metrics as well as investment in science) can drive greater efficiency, less data duplication and more credible and consistent sector-wide ESG disclosure. To enable this, more open and harmonized standards, governance and cross sector collaboration are required next to ensuring local infrastructure can adopt to MRV (e.g. rural connectivity).

3. Evolving their capabilities to assess impact across geographies, commodities and different levels of supply chain transparency

→ The MRV landscape continues to evolve and there are several cross-cutting future innovation opportunities. While these opportunities could expand the potential for timely, cost-effective and credible holistic sustainability monitoring at local and global scales, they still need interpretation and verification. Opportunities include:

- Leveraging AI to enhance classification or calculations (e.g. of remote sensing outputs)
- Automated biodiversity monitoring via in field eDNA sensors, bio-acoustic monitors, and networked camera traps.
- Development of participatory monitoring tools to crowdsource data from local actors.
- Digital twins of nature being build to ensure the interrelationships of the different aspects of nature are taken into account.
- Collaboration between technology providers and commodity-specific sustainability initiatives to ensure solutions meet diverse sector needs.



Methodology

03.

How this guidance was developed

Whilst the subject matter is complex, the goal of this guidance is to provide the sector with actionable insights to support decision making. Research and findings throughout this process have therefore been routinely socialized and tested with core WBCSD working groups, members and stakeholders, with 360º feedback integrated into iterations of the findings and practical sector specific case studies developed.

Indicators

In 2023-24 WBCSD worked with members towards alignment on a coherent and consistent understanding of which outcomes and indicators are important for decision making 11 core outcomes and 12 core indicators for regenerative agriculture and sustainable land use were identified identified through this process were used as the basis for this research.

Frameworks

Ten of the most prominent ESG frameworks Organizations are using to disclose performance on these outcomes were identified and agreed through bilateral conversations between Anthesis and WBCSD.

Pre-existing MRV requirements or criteria within these frameworks also assessed to create a baseline of current status.

MRV

A benchmarking framework and scoring methodology were developed to assess MRV approaches for each indicator, with an immediate focus on those MRV solutions with the highest potential to scale.

Relevant MRV approaches were first identified through desktop research and then validated with key stakeholders. These were then assessed within the benchmarking framework as 'good, better, best solutions' through secondary research.

45 measurement approaches were assessed in total during the research process.

During this process, considerations were also made on the gaps within MRV that inhibit scale and opportunities for the sector to act to close them.

The 10 ESG frameworks

ESG frameworks are designed to serve as standards that guide the sector to identify, measure, manage and disclose their sustainability practices and progress. This in turn delivers greater transparency on value chain risks, and investor, consumer and wider stakeholder confidence on the progress being made by organizations to mitigate them. The short list ranges from accounting standards, to target-setting guidance and regulatory frameworks and whilst the list is non-exhaustive, frameworks have been prioritised to consider their significance and uptake by the sector, and their relevance to regenerative agriculture and nature.

1. Greenhouse Gas Protocol – Corporate Standard
2. Greenhouse Gas Protocol – Land Sector and Removals Guidance (DRAFT) Part 1 and 2
3. SBTi FLAG
4. IFRS S1 & S2
5. SBTN Step 1, 2 and 3 Land
6. SBTN Step 1, 2 and 3 Freshwater
7. TNFD
8. CSRD
9. CSDDD
10. GRI

Click for links

Mapping indicators to ESG frameworks

The chosen 10 ESG frameworks require monitoring of a wide range of indicators and metrics. This visual illustrates how the 12-core regenerative agriculture and nature indicators link with the frameworks.

Table 3: Mapping of the core regenerative agriculture and nature positive indicators to ESG frameworks

Core indicator	*SBTi FLAG*	*GHGP*	*CSRD*	*GRI*	*CSDDD*	*TNFD*	*SBTN land*	*SBTN freshwater*	*IFRS*
Agricultural GHG emissions	■	■	■	■					■
Soil carbon sequestration	■	■	■	■					
Total carbon sequestration	■	■	■	■					
Natural/ restored habitat			■	■		■	■		
Crop diversity			■			■	■		
Pesticide risk	■	■	■	■					
Blue water			■	■		■		■	■
Nutrient loss		■	■	■		■			
Farm net income			■		■				
Land / freshwater ecosystem use change				■		■	■	■	
Land / freshwater ecosystem restored				■		■	■	■	
Land / freshwater ecosystem conserved						■	■	■	■

The MRV scoring approach

A score of 1-3 with 1 indicating low, 2 – medium and 3 – high was assigned to each criterion for each measurement approach. The score was then used to categorize MRV approaches into **good, better or best** solution for each indicator via the logic outlined below, so that organizations can compare potential across MRV approaches in an intuitive way.

Scoring and insights were shared for review with WBCSD Agriculture & Food members.

Figure 8: Defining low, medium and high for the benchmarking criteria

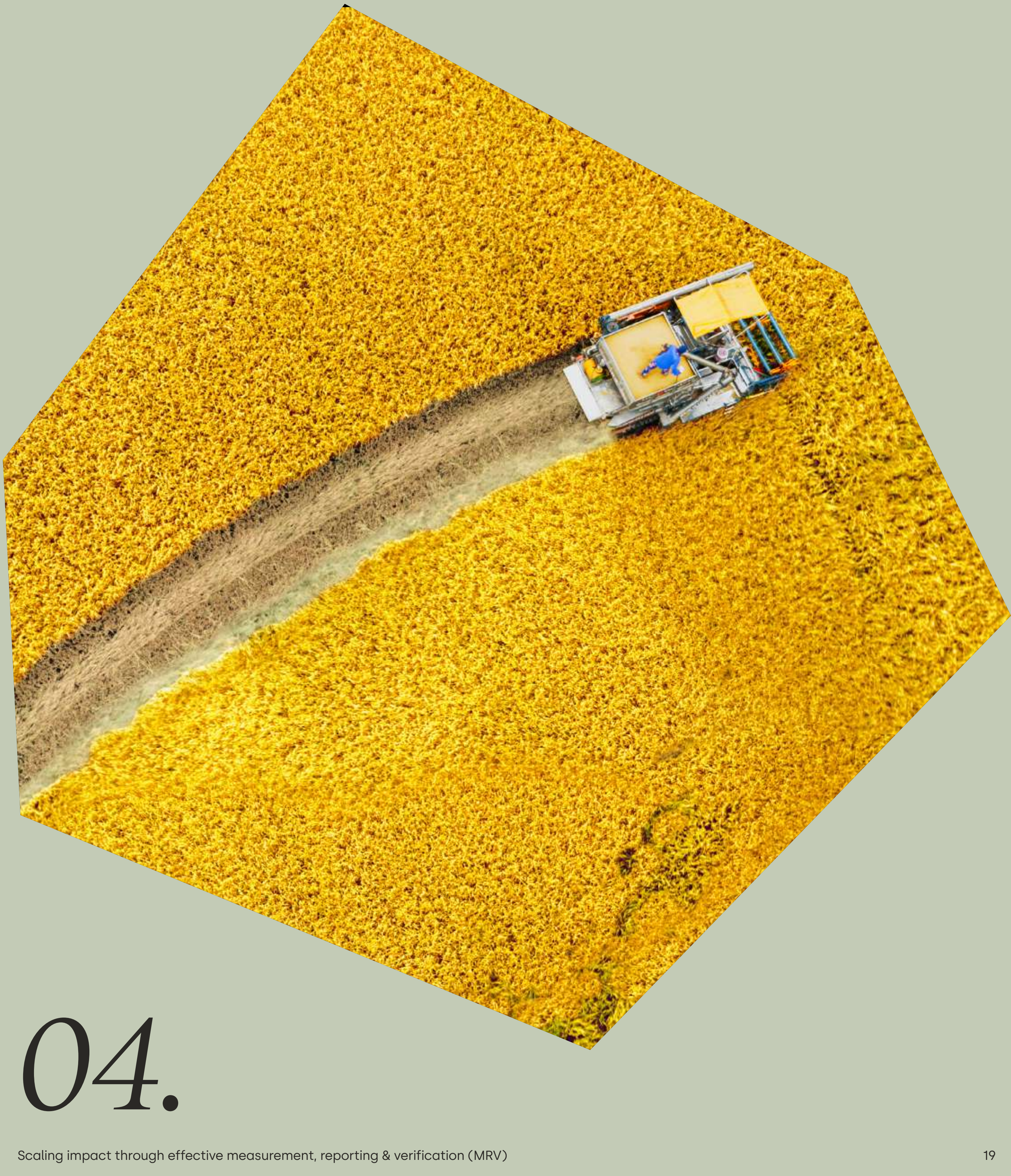
	"Good": Low ★☆☆	"Better": Medium ★★☆	"Best": High ★★★
Technological & quality readiness	= TRL 1-3, only little usage and unclear scientific consensus, accuracy issues.	= TRL 4-6, scientifically acknowledged and peer reviewed but not widely used.	= TRL 7-9, widely used, proven accuracy and quality, outputs are comparable with others
Cost effectiveness	= Expensive OPEX and CAPEX costs, expensive, complex data / input and time requirements, long-term investment required.	= Moderate OPEX and CAPEX costs, with some data and input / time requirements.	= Inexpensive CAPEX and OPEX costs, and quick to generate reliable results with minimal data / input requirements and processing post measurements.
Scalability	= Only scalable across 1 level	= Scalable across 2 out of 3 levels.	= Scalable across all levels.

Use cases

- The methodology has been designed to outline good, better, best MRV approaches for estimating impact through the use case of **corporate inventory accounting, reporting and target setting**.
- Other use cases exist, for which different set of MRV approaches may be better suited or the good, better and best ranking may vary.

Note: Scores have been assigned depending on specific use cases that are considered to be relevant and/or in demand, Other use cases could require different indicators and/or the good, better, best ranking may differ.

Analysis of MRV *approaches*



04.

4.1. Outcome: *minimize GHG emissions*

Indicator: Agricultural GHG emissions

Metric: MT CO_2 eq ; MT CO_2 eq / yield or product

Agricultural GHG emissions

Read more on this indicator **here**

Good

Satellite emissions data analysis
Remote sensing

Description: Use remote sensing of vegetation, land use, biological productivity, human energy use, and spectral proxies to feed emissions estimations models.

Benchmarking: Low-cost, subscription-based tools - some free - are used in research and commercial contexts for national-scale GHG estimates across commodities and large farms, though coarse data resolution and expert processing limit product-level accuracy.

TQR	Cost effectiveness	Scalability
★☆☆	★★★	★★★

Reporting: N/A

Verification: Ground truthing via Field survey.

Better

Beyond carbon process-based models
SaaS & Tools

Description: Process based models that predict the carbon and nitrogen biogeochemical cycles / fluxes occurring in agricultural systems.

Benchmarking: Widely adopted and highly accurate, this scalable approach simulates soil processes using detailed field data, requires expert knowledge and computing power, is free for research but commercially licensed, and not directly usable by farmers.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★★

Reporting: GHGP Corporate Standard, GHGP-LSRG, IFRS, CSRD, SBTi FLAG

Verification: Ground truthing via Field survey.

Best

Carbon calculator tools
SaaS & Tools

Description: Digital platforms / tools / software estimating emissions based on modeling and proxies via farm management practices, inputs, and outputs.

Benchmarking: Commercially available and widely used, these tools vary in cost, often rely on secondary data and lower-tier models with field-level uncertainties, but accuracy improves with primary data; they are scalable, support integration via APIs, and suit most farm types and commodities.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★★

Reporting: GHGP Corporate Standard, GHGP-LSRG, IFRS, CSRD, SBTi FLAG

Verification: Third party verification.

Key considerations and gaps

- Science and methods to measure agricultural GHG emissions is complex given the breadth of production systems, geographies and natural environmental variability of weather, soil, crop and farming practices.
- Whilst primary data collection via Field surveys increases the quality of measurements, it is costly to scale and a barrier to most businesses especially in rural areas. Nevertheless, it enables effective farmer engagement that in turn can allow greater transparency across the whole value chain and for positive impact to be communicated all the way to consumers.
- There are well established carbon calculator tools to record and process primary data for estimation of emissions, the challenge is to i) match their development with emerging science, regulation and standards, ii) harmonize their methodologies to enable better comparability across tools, systems and progress reporting (DEFRA, 2024) iii) train those using them to drive data quality.

Future innovation opportunities:

Evolution of satellite-based sensors can increase data quality and accuracy of assessments.

R&D of in field spectrometer based GHG sensors to analyse in real time, point space GHG emissions from CO_2, N_2O and CH_4

Good

Metric: **MT CO2 eq ; MT CO2 eq / yield or product**

Indicator: **Agricultural GHG emissions**

Approach category: **Remote sensing**

Multispectral satellite imagery combined with land cover classification algorithms

Description	Apply time-series analysis of the Normalized Difference Vegetation Index (NDVI) or other indices from [Sentinel-2] or [MODIS] data to detect phenological patterns unique to different crop types, then classify them using machine learning. The temporal signatures allow identification and quantification of individual crop types in each grid cell. The modified Hill-Shannon Index is computed using the relative abundance of each crop class, reflecting both richness and evenness of crop diversity.

Technology and quality readiness ★☆☆

Operational in multiple regions, trained models exist for many crops and used in government and research.

Cost effectiveness ★★★

Requires image processing capacity and some software/data subscription costs. Training in remote sensing and hardware for analysis is needed.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Helps monitor landscape-level functional diversity.

SBTN Land: Monitors diversity as a key nature target.

CSRD: Supports disclosure of sustainable farming practices.

Verification

Approach: Cross-validation with high-res imagery and field plots

Description: Crop-specific phenological patterns analyzed and verified with local cropping system data.

Better

Metric: **MT CO2 eq ; MT CO2 eq / yield or product**

Indicator: **Agricultural GHG emissions**

Approach category: **Software as a service & tools**

Beyond carbon process-based models

Description	Process based models that predict the carbon and nitrogen biogeochemical cycles / fluxes occurring in agricultural systems. Examples are Denitrification Decomposition models (DNDC); Agricultural Production System Simulator (APSIM) & Environmental Policy Integrated Climate (EPIC) model.

Technology and quality readiness ★★★

Widely adopted internationally.

The simulation of soil processes enables this approach to have high granularity and low uncertainties enabling assessments of the highest accuracy.

Secondary data can be used to achieve scale but may be at the expense of data quality (license to use, available data, relevance of data etc..)

Cost effectiveness ★☆☆

It requires comprehensive field and spatial data. Model complexity means high computation and expertise requirements. The more complex and the bigger the scale of the model, the more expensive it will be.

Licensing costs for commercial use, free for research purposes.

Scalability ★★★

Vertical/ Horizontal: Works best for annual crops as opposed to perennia. Has potential to be scaled, but would need model adaptation / calibration through field data.

Farm Archetypes: Suitable for any farm archetype.

Not usable by farmers.

Reporting

Correct calibration of model parameters with use of primary data inputs can lead to alignment with GHGP Corporate Standard and SBTi FLAG

Verification

Approach: Field surveys.

Description: Validating model estimations using field level data measurements.

Best

Metric: **MT CO2 eq ; MT CO2 eq / yield or product**

Indicator: **Agricultural GHG emissions**

Approach category: **Software as a service & tools**

Carbon calculator tools

Description	Digital platforms / tools /software estimating emissions based on modeling via farm management practices, inputs, and outputs. See next slide for specific examples.

Technology and quality readiness ★★☆

Commercially available, widely adopted in the industry.

Most of tools use secondary data sources and IPCC Tier 1-2 and simple Tier 3 models meaning that there are uncertainties at field and farm level. The greater the number and quality of primary data used, the more accurate the estimation will be.

Tools with the highest scientific consensus are backed up by scientific committee or by credible governmental institutions. Independent review of their methodology by credible third party is a good indicator.

Cost effectiveness ★★★

Cost licensing costs depending on use / options; some are available free of cost.

Generally tools require primary data on agronomic activities - yield, residue management, fertilizers, pesticides, fuel use, tillage, cropping practices. When this is not available, secondary data or proxies can be used.

Some have API for leveraging Farm Management Information software which make tools easier to integrate.

Scalability ★★★

Vertical: Despite majority of tools have been initially designed to test different farm management practices at the field level, they can be used for scaling up across geographies. Some tools are better suited for project monitoring purposes.

Horizontal: Generally suitable for variety of commodity types.

Farm Archetypes: Generally approach suitable to any farm archetype, with some tools specifically designed for certain types of farmers.

Reporting

GHGP LRSG requires whole value chain measurements, meaning tools can align with it if complemented with assessments of whole value chain GHG emissions impact. Compliance with GHGP would make approach compliant with IFRS and CSRD.

Some tools provide outputs which can enable manual separation of FLAG vs non FLAG GHG emissions to be compliant with SBTi FLAG.

Verification

Approach: Third party verification / validation.

Description: Validation of data entered into tools by an independent third party. Farm visits can be conducted by independent auditors.

Best

Metric: **MT CO2 eq ; MT CO2 eq / yield or product**

Indicator: **Agricultural GHG emissions**

Approach category: **Software as a service & tools**

Carbon calculator tools: Examples

Example of calculator tools considered for review: Cool Farm Tool, Agrecalc, Farm Carbon Calculator, Sandy, COMET Farm, FAO Ex-ACT, Carbon Benefits Project, USAID AFOLU Farm Carbon Calculator, SHAMBA.

Technology and quality readiness

Tools in scaling phase and widely used across industry: CFT, Agrecalc, Farm Carbon Toolkit, Sandy,COMET Farm.

CFT has a dedicated scientific committee; USAID AFOLU FCC is developed by Winrock. SHAMBA has been validated by Plan Vivo.

CFT & Sandy have high interoperability with other tools. Currently CFT / Agrecalc / Farm Carbon Toolkit methodologies are being harmonized.

Cost effectiveness

Tools that have different licensing costs depending on use / options: CFT, Agrecalc, Farm Carbon Toolkit, Sandy

Free to use tools: FAO Ex-ACT; Carbon Benefits Project, SHAMBA, COMET Farm, USAID AFOLU FCC.

Tools that hae API for Farm Management Information Softwares e.g. CFT & Sandy are easier to use.

Scalability

VVertical: CFT is suitable for providing product level GHG data at the field level; Agrecalc, Sandy, COMET Farm, Farm Carbon Toolkit suitable for farm and whole enterprise assessments. Generally, can be used across geographies – except COMET Farm which is USA only - but it is time consuming. FAO Ex-ACT, Carbon Benefits Project, USAID AFOLU FCC are more suitable for project implementation monitoring but can be scaled at sector / country level.

Farm Archetypes: SHAMBA has been specifically developed for smallholder farmers.

Reporting

Sandy and CFT provide a breakdown of outputs that enable manual split of FLAG vs non-FLAG GHG emissions.

Case study

Nutrien

Introduction

Nutrien calculates Agricultural GHG Emissions adopting the Climate Action Reserve Nitrogen Management Project Protocol (NMPP) & Nitrous Oxide Emission Reduction Protocol (NERP) methodologies in the US and Canada. The calculation supports the adoption of practices to maximize crop yield per unit of applied nitrogen, which contribute to reduced nitrogen losses.

Benefits

Tools are based on global standards and widely used.

The Agrible data platform is continually evolving and currently supports growers in the US and Canada, with potential for future expansion into additional regions.

Established grower relationships facilitated by Nutrien crop consultants support program buy-in, ensure alignment between protocols and promoted practices like 4R, and foster transparent, trustworthy partnerships across the value chain for long-term success.

Measuring

Data is collected through SaaS & Tool approach category with the in-house tool Agrible as well as Fieldprint® Platform and Cool Farm Tool. The data can be entered by growers, crop consultants, customer success team, and direct APIs from farm equipment to Agrible throughout the growing season or after harvest. Agrible has internal data flags and data entry restrictions which ensure data quality. The data is used to estimate N2O emissions which are expressed as tCO2e. Fieldprint and Cool Farm Tool incorporate national data sets into their metric calculations.

Reporting

Outcome metrics are shared with our partners at each stage of the process. The methodology is based NMPP and NERP.

Verification

Anonymized grower data and calculations based on NERP and NMPP protocols are submitted to an independent third-party for verification and audit. In the US, Nutrien has initiated third-party verification in alignment with the Climate Action Reserve's NMPP, while in Canada, they are actively validating a GHG outcome pathway and verifying emission reductions through an independent verifier.

DIRECT ADVICE

"Don't expect everything to work the way you thought in year 1.

Understand that enrolment will not directly translate to outcomes when you start a new program.

4.2. Outcome: *increase sequestered carbon*

Indicator: Soil carbon sequestration

Metric: MT CO_2 eq

Soil carbon sequestration

Read more on this indicator **here**

Good

Soil sampling
Field survey

Description: Physical sampling of soil at multiple depths, followed by lab analysis of soil organic carbon (SOC) via dry combustion, oxidation or IR spectroscopy.

Benchmarking: Most accurate method for measuring SOC but is costly and labor-intensive. Essential for generating primary data to support models and remote sensing validation. The method can be widely used where lab infrastructure exists, across all farm types and commodities.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★☆

Reporting: GHGP-LSRG / SBTi FLAG; CSRD, GRI

Verification: Third party verification

Better

Portable soil spectrometer for in field use
Connected & sensor technologies

Description: Use of portable near- or mid-infrared spectrometers to analyse SOC in soil samples. .

Benchmarking: Offering faster, lower-expertise SOC assessments than lab analysis but remain costly. They are commercially available but still evolving, with accuracy reliant on expanding global spectral data repositories. The method is scalable across geographies, commodities, and farm types but requires local calibration.

TQR	Cost effectiveness	Scalability
★★☆	★★☆	★★★

Reporting: : GHGP-LSRG / SBTi FLAG; CSRD, GRI

Verification: Soil Sampling.

Best

Process based SOC modeling
SaaS / tools

Description: Modeling algorithm founded on general scientific understandings of soil processes to estimate SOC.

Benchmarking: Complex approach that requires expert input and high-quality soil and temperature primary data. They are widely used and can deliver low-uncertainty SOC change estimates when well-calibrated. Though scalable across regions and farm types, they demand significant data, time, and parameter calibration.

TQR	Cost effectiveness	Scalability
★★★	★★☆	★★★

Reporting: GHGP-LSRG / SBTi FLAG; CSRD, GRI

Verification: Ground truthing via soil sampling.

Key considerations and gaps

→ Soil carbon sequestration is hard to measure, particularly as soil varies within field and emissions and removals are constantly in flux. More scientific consensus is required on areas such as minimal numbers, timing and spatial distribution for measuring SOC.

→ Soil sampling and portable soil spectrometers for in field use can provide valuable primary data that can feed models and tools.

→ Developing global, comprehensive spectral libraries of SOC will be a key enabler of infrared spectroscopy. Existing partnerships promoting this include Global Soil Partnership and Open Soil Spectral Library.

→ Greater standardization of SOC measurement methods is required to estimate changes in stocks. At present, different MRV protocols (e.g. Verra VM42, Plan Vivo, etc.) have different levels of requirements, which can lead to inconsistent methods and estimations of SOC change, and make it harder in some instances to compare results and credibly report on progress.

Future innovation opportunities:

SOC spectrometers need further calibration to be able to measure SOC content in the soil sample and, therefore, calculate SOC stock change and measure sequestration. This can be achieved through improved technology but also via increased adoption, as the more SOC stock measurements will be done, the more robust repository databases will become. Moreover, R&D could bring down unit costs, which are currently prohibitive for large scale adoption by corporates

Good

Metric: **MT CO_2 eq**

Indicator: **Soil carbon sequestration**

Approach category: **Field survey**

Valid approach for collecting primary data to feed models / tools

Soil sampling

Description	Physical sampling of soil at multiple depths, followed by lab analysis of soil organic carbon (SOC) via dry combustion, oxidation or IR spectroscopy. To measure SOC content, fine earth and coarse earth fraction (rock content) and soil bulk density need to be quantified. Sequestration is measured by the difference of multiple SOC assessments over a defined timeframe. Examples: Agricarbon

Technology and quality readiness ★★★

Operational in multiple regions, trained models exist for many crops and used in government and research.

Cost effectiveness ★☆☆

Quite costly approach due to labor, transport, processing requirements for obtaining an accurate estimation.

However, very useful approach to obtain primary data to feed into models and ground truth remote sensing estimates.

Scalability ★★☆

Vertical: Scalable in regions with established laboratory infrastructure / mature markets.

Horizontal: Suitable for any commodity type.

Farm Archetypes: Suitable for all farm archetypes.

Reporting

GHGP LSRG / SBTi FLAG: Being a primary data collection method, this approach would satisfy GHGP LSRG requirements for reporting carbon removals. Method can align if there is ongoing storage monitoring plan and if uncertainties are disclosed. Also aligned with CSRD; GRI.

Verification

Approach: Third party verification

Description: External professional checking the practices implemented to carry out measurements have been conducted appropriately.

Better

Metric: **MT CO2 eq**

Indicator: **Soil carbon sequestration**

Approach category: **Connected and sensor technologies**

Valid approach for collecting primary data to feed models / tools

Portable soil spectrometer for in-field use

Description	Use of portable near- or mid-infrared spectrometers to analyse SOC in soil samples. SOC concentration is measured through reflectance of light on soil in infrared region - SOC is determined depending on what light wavelength soil organic matter absorbs. This is then compared with a statistical model based on a spectral library to determine soil carbon percentage of the unknown samples. Sequestration is measured by the difference of multiple SOC assessments over a defined timeframe.

Technology and quality readiness ★★☆

Early technology made available commercially recently, still in development.

Accuracy of the results depends on availability of global repositories of spectral SOC analyses, which are currently being developed. Accuracy of models built in spectrometers to calculate sequestration is evolving.

Data generated through this approach can provide high resolution, spatially explicit measurements that can help calibrate and validate models by providing accurate baseline SOC levels and have the potential to capture variability across different soil types and management conditions.

Cost effectiveness ★★☆

Unit costs range from £20-30k, meaning high scaling costs. Future R&D is likely to bring costs of this technology down.

Quicker assessments and less expertise required than laboratory analysis, but still a costly approach.

Scalability ★★★

Well suited to scale horizontally and vertically as well as suitable for any farm archetype but needs to be calibrated depending on commodity and geography.

Reporting

GHGP LSRG/ SBTi FLAG: This is assumed to be a primary data collection method, therefore satisfying GHGP LSRG requirements for reporting carbon removals. Method can align if there is ongoing storage monitoring plan and if uncertainties are disclosed. Also aligned with CSRD; GRI.

Verification

Approach: Soil sampling.

Description: SOC Lab analysis of soil samples to verify results of spectrometer.

Best

Metric: **MT CO2 eq;**

Indicator: **Soil carbon sequestration**

Approach category: **Software as a service & tools**

Process based SOC modeling

Description

Modeling algorithm founded on general scientific understandings of soil processes to estimate SOC. Models can look only at carbon e.g. Roth C or also at other nutrients cycles e.g. DayCent ; DNDC models.

Technology and quality readiness ★★★

Widely operational in many countries.

Can produce estimation of SOC stock change with low uncertainties, depending on the quality of the primary data inputted into the model.

Beyond carbon process-based models simulate the interactions between the different soil processes, providing a more holistic view of soil health than any other approach. This in turn can inform mitigation strategies at farm level. However, their extensive data requirements make them a complex and expensive method.

Cost effectiveness ★★☆

Models require primary data on soil carbon as well as pedoclimatic data. Generally complex models requiring expertise and time for data processing. Beyond carbon models are more complex and therefore more costly.

Scalability ★★★

Vertical: Suitable for point in time, but also country and larger scale monitoring although it would require high data volumes, knowledge, and calibration of fixed model parameters for ecosystem adaptation. Combination with satellite data would enable scaling up quicker.

Horizontal: Suitable for any commodity type.

Farm Archetypes: Suitable for any farm archetype.

Reporting

GHGP LRSG requires whole value chain measurements, meaning tools can align with it if complemented with assessments of whole value chain GHG emissions impact. Compliance with GHGP would make approach compliant with IFRS and CSRD.

Some tools provide outputs which can enable manual separation of FLAG vs non FLAG GHG emissions to be compliant with SBTi FLAG.

Verification

Approach: Third party verification / validation.

Description: Validation of data entered into tools by an independent third party. Farm visits can be conducted by independent auditors.

4.2. Outcome: *increase sequestered carbon*

Indicator: Total carbon sequestration

Metric: MT CO_2 eq

Total carbon sequestration

Read more on this indicator here

Intended as the sum of biomass carbon sequestration and soil carbon sequestration. The approaches below have been identified to estimate biomass carbon sequestration.

Good	Better	Best
Gain loss or stock difference method *SaaS / tools*	**Ground based measurements** *Field survey*	**Active or optical (passive) remote sensing** *Remote sensing*
Description: Conversion of activity data on land area desired to be assessed to biomass carbon content using secondary biomass growth factors associated to and use, climate, ecological zone and land management.	**Description:** Combination of field measurements and destructive sampling techniques to estimate weight and carbon content via elemental analysis.	**Description:** Estimating aboveground soil organic carbon via satellite data obtained through active or optical (passive)remote sensing.
Benchmarking: Widely used, affordable approach with low data needs and moderate expertise. It offers limited accuracy due to reliance on general biomass growth factors.Best suited for large-scale monitoring across all commodities and farm types.	**Benchmarking:** Providing accurate biomass carbon estimates at the field level although involving multiple steps / data. Though scalable geographically, the cost limits practicality for broad deployment.Applicable across all commodities and farm types.	**Benchmarking:** Widely used, cost-effective approach for frequent landscape-scale assessments across all commodities and farm types. Dense vegetation can cause signal saturation and accuracy can be affected by weather or terrain.
TQR ★☆☆ · Cost effectiveness ★★★ · Scalability ★★☆	TQR ★★★ · Cost effectiveness ★☆☆ · Scalability ★★☆	TQR ★★☆ · Cost effectiveness ★★★ · Scalability ★★★
Reporting: GHGP-LSRG / SBTi FLAG; CSRD, GRI	**Reporting:** GHGP-LSRG / SBTi FLAG; CSRD, GRI	**Reporting:** GHGP-LSRG / SBTi FLAG; CSRD, GRI
Verification: Third party verification	**Verification:** Third party verification	**Verification:** Ground based measurements of biomass carbon content.

Good

Metric: **MT CO2 eq**

Indicator: **Total carbon sequestration**

Approach category: **Software as a service / tool**

Gain loss or stock difference method

Description	Conversion of activity data on land area desired to be assessed to biomass carbon content using secondary biomass growth factors associated to and use, climate, ecological zone and land management. Biomass carbon sequestration is measured by the difference of multiple assessments over a defined timeframe. When added to SOC sequestration the output will be Total Carbon Sequestration.

Technology and quality readiness ★★★	Cost effectiveness ★☆☆	Scalability ★★☆
Approach in widespread use. Limited accuracy with biomass growth estimation factors used. Requires repeated inventory plot measurements to have minimum precision e.g. activity-based data on land use stratified by forest type is not sufficient	Low data requirement, medium expertise required and considered an affordable measurement approach.	Vertical: Suitable for country / large landscape level monitoring Horizontal: Suitable for any commodity. Farm Archetypes: Suitable for all.

Reporting	Verification
Not aligned to GHGP LRSG due to use of secondary datasets.	Approach: Third party verification. Description: External professional checking the practices implemented to carry out estimation have been conducted appropriately

Better

Metric: **MT CO2 eq**

Indicator: **Total carbon sequestration**

Approach category: **Field surveys**

Ground based measurements

Description	Combination of field measurements of tree diameter and height - inputted into allometric equations - and destructive sampling techniques for herbaceous and belowground biomass to estimate weight and carbon content via elemental analysis. Biomass carbon sequestration is measured by the difference of multiple assessments over a defined timeframe. When added to SOC sequestration the output will be Total Carbon Sequestration.

Technology and quality readiness ★★★

Widely adopted approach readily available. Provides accurate estimations of biomass carbon content at specific field level.

Cost effectiveness ★☆☆

Time consuming process which requires several steps and data. Costly approach for large scale measurements.

Scalability ★★☆

Vertical: Can be scaled across geographies but unpractical as it would result in being very costly.

Horizontal: Suitable for any commodity.

Farm Archetypes: Suitable for all archetypes.

Reporting

GHGP LSRG / SBTi FLAG: Being a primary data collection method, this approach would satisfy GHGP LSRG requirements for reporting carbon removals. Method can align if there is ongoing storage monitoring plan and if uncertainties are disclosed. Also aligned with CSRD; GRI.

Verification

Approach: Third party verification.

Description: External professional checking the practices implemented to carry out measurements have been conducted appropriately.

Best

Metric: **MT CO2 eq;**

Indicator: **Total carbon sequestration**

Approach category: **Remote sensing**

Future innovation opportunities: P-band sensors are a promising technology to provide accurate biomass carbon stocks. Recently launched ESA Biomass mission aims at proving this.

Active or optical (passive) remote sensing

Description

Estimating aboveground soil organic carbon via satellite data obtained through active or optical (passive) remote sensing. Optical Remote sensing: Remote sensing of vegetation via natural radiation from the sun to estimate aboveground soil organic carbon. Active Remote sensing: Active satellite-based sensors such as light detection and ranging (Lidar) / radio detection and ranging (radar) data. Biomass carbon sequestration is measured by the difference of multiple assessments over a defined timeframe. When added to SOC sequestration the output will be Total Carbon Sequestration.

Technology and quality readiness ★★☆

Commercially available and in widespread use.

In optical sensing the reflectance signal saturates when vegetation thickens, compromising accuracy.

Active remote sensing is able to penetrate through vegetation meaning it provides additional information related to height and structure; but signal can also saturate.

Adverse atmospheric and topographic conditions, limit accuracy of results.

Cost effectiveness ★★★

Generally cost effective solution as it enables measurements with high frequency at minimal cost.

Active remote sensing has greater data requirements / processing than optical remote sensing, but still considered cost effective.

Both require expertise for data processing.

Scalability ★★★

Vertical: Excellent landscape / national scale use for areas of low forest density. Requires local calibration for different geographies.

Horizontal: Suitable for any commodity.

Farm Archetypes: Suitable for all farm archetypes.

This approach is well suited for measuring GHG emissions with no farm traceability, assuming country/region are known.

Reporting

GHGP LSRG / SBTi FLAG: Assuming this to be a primary data collection method, this approach would satisfy GHGP LSRG requirements for reporting carbon removals. Method can align if there is ongoing storage monitoring plan and if uncertainties are disclosed. Also aligned with CSRD; GRI.

Verification

Approach: Ground based measurements of biomass carbon content.

Description: Ground truthing via sampling biomass on the ground to measure carbon content.

Case Study

Olam Food Ingredients (OFI)

Introduction

Since 2022 OFI has been measuring Carbon sequestration in biomass (MT CO2) with the aim of monitoring, reporting and verifying the benefits of agroforestry and tree planting on farms. They have been able to do so through analysing satellite images combining machine learning techniques and carbon sequestration models built within Google Earth Engines.

Benefits

- This approach can be used across geographies, commodities, and for different project sizes.
- This approach allows for estimation of natural carbon sequestration per plot and regions to report removals on yearly bases – enabling evaluation and demonstration of benefits from agroforestry projects.

Measuring

Data is collected through combining Remote sensing and SaaS & Tool measurement approach categories with an in-house algorithm which uses Sentinel 1,2 and Global Ecosystem Dynamics Investigation (GEDI) satellite data in a Carbon Sequestration Monitoring Tool. Aboveground biomass (AGB) – vegetation above soils including stumps, trees and foliage - is monitored in geolocations of production plots (polygons) to estimate how much carbon is present in each plot. In parallel, a carbon sequestration model leveraging on allometric equations obtained from the literature is used to estimate potential carbon sequestration from tree planting. Models are calibrated through primary data which is planned to be collected in the coming months to ground truth estimations.

Reporting

The data is used for meeting CDP, GRI and SBTi corporate reporting requirements as well as for compliance with legislation.

Verification

Currently data is third party audited, validated and certified. The algorithm itself is not verified against a specific standard, but OFI developed a protocol for removal accounting, and this has been successfully audited by SustainCERT.

CONSIDERATIONS

"The data informs the planning, development, and MRV of sustainability programs—both within and beyond OFI.

Beyond OFI supply chains, there is potential to use the tool to quantify carbon stocks and removals across entire production landscapes to provide better data for institutional stakeholders on land use change and carbon removals."

4.3. Outcome: *increase cultivated biodiversity*

Indicator: Crop diversity

Metric: Modification of the Hill-Shannon diversity index

Crop diversity

Read more on this indicator here

Good

Multispectral satellite imagery combined with land cover classification algorithms
Remote sensing

Description: Use high-resolution multispectral satellite imagery combined with land cover classification algorithms (to distinguish between natural/semi-natural vegetation and cultivated areas.

Benchmarking: Widely used and proven across geographies, commodities, and farm types, this solution requires satellite data, GIS software, skilled staff, and mid-level hardware. High accuracy is only reached with high resolution imagery.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★★

Reporting: SBTN Land, TNFD, CSRD

Verification: Cross-validation with high-resolution imagery and field plots

Better

Agricultural census data
SaaS / tools

Description: Analyze farm-reported crop type distributions within defined areas.

Benchmarking: Based on publicly available, low-maintenance data and established national tools with proven accuracy, this approach scales across geographies, commodities, and farm types, though update frequency may vary..

TQR	Cost effectiveness	Scalability
★★☆	★★☆	★★★

Reporting: SBTN Land, TNFD, CSRD

Verification: Administrative dataset triangulation.

Best

Farm input and plot inventories
Field surveys

Description: Use structured farm-level interviews and plot inventories to document crop types and their respective areas within each km² grid.

Benchmarking: Mature, widely used method requiring basic data collection and simple tools, with moderate geographic scalability, limited crop applicability, and lower suitability for large-scale monocultures.

TQR	Cost effectiveness	Scalability
★★★	★★☆	★★☆

Reporting: SBTN Land, TNFD, CSRD

Verification: Survey audit and cross-validation.

Key considerations and gaps

- → For broader implementation and scaling, modeling becomes crucial due to the unavailability or inaccessibility of consistent primary data but needs ground truthing to verify model results.
- → There is a need for MRV tools that are appropriate for different systems (e.g., annual crops vs. perennials or mixed systems like silvopasture), as most tools are currently crop-specific.

Future innovation opportunities:

1. Remote plant species-level classification: Enhanced satellite and UAV imaging combined with machine learning will improve the ability to distinguish between crop types and monitor rotational practices.
2. Crowdsourced ground-truthing: Farmer-facing apps could allow users to submit verified crop data that enhances remote sensing models and reduces ground survey costs.
3. Temporal diversity tracking: Emerging platforms may track not just spatial diversity but crop rotations over time, offering richer data on agroecosystem health

Good

Metric: **Modification of the Hill-Shannon diversity index**

Indicator: **Crop diversity**

Approach category: **Remote sensing**

Multispectral satellite imagery combined with land cover classification algorithms

Description	Apply time-series analysis of the Normalized Difference Vegetation Index (NDVI) or other indices from Sentinel-2 or MODIS data to detect phenological patterns unique to different crop types, then classify them using machine learning. The temporal signatures allow identification and quantification of individual crop types in each grid cell. The modified Hill-Shannon Index is computed using the relative abundance of each crop class, reflecting both richness and evenness of crop diversity.

Technology and quality readiness ★★★

Operational in multiple regions, trained models exist for many crops and used in government and research.

Cost effectiveness ★☆☆

Requires image processing capacity and some software/data subscription costs. Training in remote sensing and hardware for analysis is needed.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Helps monitor landscape-level functional diversity.

SBTN Land: Monitors diversity as a key nature target.

CSRD: Supports disclosure of sustainable farming practices.

Verification

Approach: Cross-validation with high-res imagery and field plots

Description: Crop-specific phenological patterns analyzed and verified with local cropping system data.

Better

Metric: **Modification of the Hill-Shannon diversity index**

Indicator: **Crop diversity**

Approach category: **Software as a service / tool**

Agricultural census data

Description	Analyze farm-reported crop type distributions within defined areas.

Technology and quality readiness ★★☆

Long-standing national tools, proven accuracy in most regions and integrated in reporting cycles. Unclear how frequently updated.

Cost effectiveness ★☆☆

Includes publicly available data and a low data cleaning effort.

Scalability ★★★

Vertical: Applicable in any geography, if data is available.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Helps monitor landscape-level functional diversity.

SBTN Land: Monitors diversity as a key nature target.

CSRD: Supports disclosure of sustainable farming practices.

Verification

Approach: Administrative dataset triangulation.

Description: Uses self-reported or government-reported data; validated through trend analysis and independent reports.

Best

Metric: **Modification of the Hill-Shannon diversity index**

Indicator: **Crop diversity**

Approach category: **Field surveys**

Farm input and plot inventories

Description	Use structured farm-level interviews and plot inventories to document crop types and their respective areas within each km² grid. Enumerators collect data on all cultivated crops, including minor and intercropped species, along with their spatial extent. This information is used to compute a modified Hill-Shannon Index per km², capturing both the number and proportional distribution of crops.

Technology and quality readiness ★★★	**Cost effectiveness** ★★☆	**Scalability** ★★☆
Widely used, mature method, consistent with field practices and no complex tools needed.	Requires only basic data collection and manual or simple digital tools.	Vertical: Moderately scalable across geography (logistics off trained staff). Horizontal: Not suited for broad crop types. Farm Archetypes: Less scalable in large-scale monocultures, where detailed interviews are impractical and crop diversity is low.

Reporting	**Verification**
TNFD: Helps monitor landscape-level functional diversity. SBTN Land: Monitors diversity as a key nature target. CSRD: Supports disclosure of sustainable farming practices	Approach: Survey audit and cross-validation. Description: Enumerators collect detailed crop data, cross-checked against physical farm visits or satellite imagery.

4.4. Outcome: *reduce pesticide risk*

Indicator: Pesticide risk

Metric: EIQ score ecological component x application rate

Pesticide risk

Read more on this indicator here

Good

Farm input surveys
Field surveys

Description: Monitor pesticide types, quantities, and application frequencies directly from farm management systems or farm-level surveys, with a focus on evaluating alignment with Integrated Pest Management (IPM) principles.

Benchmarking: A low-tech, widely adopted method with minimal software needs and proven data standards, it integrates well into farm operations, scales globally and across commodities, but can be labor-intensive at larger scales.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★☆

Reporting: SBTi FLAG, GHG Protocol, CSRD, GRI

Verification: Survey audit and cross-validation.

Better

Lifecycle Assessment models
SaaS / tools

Description: Lifecycle inventory and assessment models are designed to estimate pesticide emissions to various environmental compartments and assess their impact on the environment.

Benchmarking: This method relies on input data and LCA models, with free open LCA options or paid platforms like SimaPro, offering geographic and commodity-wide scalability and comparative assessments.

TQR	Cost effectiveness	Scalability
★★☆	★★☆	★★★

Reporting: SBTi FLAG, GHG Protocol, CSRD, GRI

Verification: Survey audit and cross-validation. Model validation with samples

Best

Farm specific risk assessment
Field surveys

Description: Assess risk locally e.g. based on weather or field characteristics and adjust farmer practices accordingly.

Benchmarking: A high-tech method with data and mechanization needs. Requires standardization via local regulation. However, it considers best real-world environmental risk and how to mitigate it.

TQR	Cost effectiveness	Scalability
★★★	★★★	★★☆

Reporting: SBTi FLAG, GHG Protocol, CSRD, GRI

Verification: Validation with environmental samples.

Key considerations and gaps

→ To quantify pesticide risk, beyond simply recording applied volumes, for broader implementation and scaling, modeling becomes crucial due to the unavailability or inaccessibility of consistent primary data at this point in time and the lack of technology to assess pesticide risk location specific in real time.

→ Models like PestLCI and USEtox® or EIQ are used to model pesticide risk. They produce a comparative scoring which have to be translated into a farmer recommendation how to reduce the pesticide risk. The models vary in terms of their ability to consider technologies to reduce pesticide risk with EIQ being only able to assess the choice of pesticide and the volume and models such as PestLCI and USEtox® being able to consider as well innovative ways to apply pesticides, precision application technology, etc.

→ The environmental impact of pesticide application beyond–farm is difficult to measure, especially for smaller farms who may have lack of infrastructure or awareness of the impact pesticides have beyond their application on farm

Future innovation opportunities:

1. Digital labels: Providing automated and always up to date information on how to apply the pesticide to the farmer and allowing for automated data capture.
2. Digital pesticide logs with QR traceability: Farm-level digital records linked to product traceability could help verify safe use practices across the supply chain.
3. AI-driven farm specific risk modeling: Integrating data from weather, soil, and farm practices to dynamically predict runoff, drift, and ecological impact from pesticide applications. Combined with a digital label and modern application equipment this could enable in-field specific application recommendations in real time.

Good

Metric: **EIQ score ecological component x application rate**

Indicator: **Pesticide risk**

Approach category: **Field surveys**

Farm input surveys

Description

Monitor pesticide types, quantities, and application frequencies directly from farm management systems or farm-level surveys, with a focus on evaluating alignment with Integrated Pest Management (IPM) principles. Surveys should capture information on non-chemical pest control strategies, pest thresholds, and decision-making processes to assess progress toward reduced-risk and sustainable pest management.

Technology and quality readiness ★★☆

Technology is available. Partially off the shelf by market data companies. Global availability and in-country representativeness can be challenging. Data quality can vary. Needs additional leverage to result in EIQ.

Cost effectiveness ★★★

In the absence of digital and centralized record keeping, field level surveys are necessary.

Scalability ★★☆

Vertical: Scalable across countries.

Horizontal: Applicable across crops.

Farm Archetypes: Adaptable by farm size..

Reporting

TCSRD: Supports EU Taxonomy-aligned chemical use disclosures.

GRI: Supports with pesticides fertilizer reduction initiatives data.

SBTi FLAG: Enables field-use pesticide assessments.

GHG Protocol: Tracks agrochemical impact as part of emissions reporting.

Verification

Approach: Survey audit and cross-validation.

Description: Representative depends on sample size and quality of interviews or digital record.

Better

Metric: **EIQ score ecological component x application rate**

Indicator: **Pesticide risk**

Approach category: **Software as a service / tool**

Lifecycle assessment models

Description

Lifecycle inventory and assessment models, like PestLCI 2.0 and USEtox® are designed to estimate pesticide emissions to various environmental compartments and their impact on the environment. Check Bayer AG case study showcasing how this is applied in practice.

Technology and quality readiness ★★☆

Solid foundation through LCA but not recognized for all use cases. Specifically tailored for pesticides impact assessment. LCA assessment can be broader and include other environmental impact categories such as eutrophication, climate. Needs additional leverage to result in EIQ.

Cost effectiveness ★★☆

Requires specific data (application method, climate, soil), while model licensing is free and available for open LCA. If SimaPro or GaBi is used, the costs of the platforms need to be included. LCA expertise is needed but there is the opportunity of shared scenarios among institutions or projects.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

CSRD: Supports EU Taxonomy-aligned chemical use disclosures.

GRI: Supports with pesticides fertilizer reduction initiatives data.

SBTi FLAG: Enables field-use pesticide assessments.

GHG Protocol: Tracks agrochemical impact as part of emissions reporting.

Verification

Approach: Survey audit and cross-validation. Model validation with samples.

Description: Models environmental impacts of pesticides on and around the field based on farm level input data

Best

Metric: **EIQ score ecological component x application rate**

Indicator: **Pesticide risk**

Approach category: **Software as a service / tool**

Farm specific risk assessment

Assess risk locally e.g. based on weather or field characteristics and adjust farmer practices accordingly.

Technology and quality readiness ★★★

Several multi-stakeholder initiatives exist (e.g. AgriGuide) which aim to create the foundational technologies. Real world case studies are available. Results in EIQ

Cost effectiveness ★★★

Requires an established infrastructure and link to local regulatory systems (digital labels, machinery, equipment, digital records)

Scalability ★★☆

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

CSRD: Supports EU Taxonomy-aligned chemical use disclosures.

GRI: Supports with pesticides fertilizer reduction initiatives data.

SBTi FLAG: Enables field-use pesticide assessments.

GHG Protocol: Tracks agrochemical impact as part of emissions reporting.

Verification

Approach: Survey audit and cross-validation.

Description: Collected from farmers and validated using receipts or pesticide container checks.

Case Study

Bayer AG

Introduction

Global Bayer Crop Protection (CP) has set a target to reduce its global crop protection environmental impact per hectare by 30% by 2030 against a baseline of the period 2014-18. The impact is monitored by the **KPI**: "global treated area weighted crop protection environmental impact per hectare", which is assessed with annual frequency through a bespoke methodology developed with the Technical University of Denmark which combines the use of PestLCI and USEtox® models to calculate the Pesticide Impact Score.

Benefits

- Freely available and global applicability through scenario-based assessment. Costs are mainly with data collection and processing
- Actively used and continuously being updated by a scientific consortium: For USEtox®, this comprises the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC); for Pest LCI this is the Technical University of Denmark.
- Ability to consider innovation in the impact assessment, such as modern ways to apply pesticides.

Measuring

As data input, the combination of tools requires:

- **Product:** Active ingredient and applied dose
- **Application:** Method and growth stage
- **Scenario:** Crop, location and field area treated

Pesticide applications as reported by farmers through surveys combined with impact calculations performed by the tools based on publicly available substance data..

Reporting

The metric tracks and reports annual progress, both internally and publicly, toward Bayer's goal of reducing crop protection environmental impact by 30% by 2030, using a 2014–2018 weighted average baseline. The approach contributes to the Global Biodiversity Framework (GBF) Target 7 "Reduce pollution risks".

Verification

The methodology has been verified by an independent expert panel, and Bayer's sustainability reporting is subject to external audit.

DIRECT ADVICE

"Collaborate with academic partners. Be mindful that a pesticide impact assessment needs to be translated into tangible agronomic advice for farmers."

Daniel Glas, Bayer

4.5. Outcome: *improve environmental flows*

Indicator: Blue water

Metric: Blue water withdrawal (m3/ha) split by level of water stress risk

Blue water

Read more on this indicator here

Good

Farm input and water metering systems
Field surveys + connected & sensor technologies

Description: Combine surveys on irrigation practices with field measurements of irrigation equipment and flow meters. Cross-referencing this with local or national maps of water stress risk enables categorization by stress level.

Benchmarking: This requires medium investment per site, is common in irrigation-intensive areas, and scales across geographies, commodities, and farm types

TQR	Cost effectiveness	Scalability
★★★	★★☆	★☆☆

Reporting: SBTN Freshwater, TNFD, CSRD, GRI, IFRS

Verification: Survey audit and validation

Better

Hydrological modeling
SaaS / tools

Description: Use models (WaterGAP) to estimate withdrawals and stress levels by region.

Benchmarking: This globally validated method requires modeling expertise and potential licensing, with calibration data costs, excels at watershed-scale applications, moderately fits various crops, and scales to all farm types.

TQR	Cost effectiveness	Scalability
★☆☆	★★☆	★★★

Reporting: SBTN Freshwater, TNFD, CSRD, GRI, IFRS

Verification: Regional water budget validation.

Best

Combine satellite imagery with water stress data
Remote sensing + SaaS / tools

Description: Integrate satellite-based evapotranspiration estimates. Overlaying this with regional water stress data allows disaggregation of withdrawals by stress level.

Benchmarking: High-resolution remote sensing involves upfront data processing costs but provides a cost-effective, scalable solution with variable subscription fees and free regional water stress data, widely used in scientific global water monitoring.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★★

Reporting: SBTN Freshwater, TNFD, CSRD, GRI, IFRS

Verification: Cross-validation with high-resolution imagery and field plots

Key considerations and gaps

→ There's a need to specify where primary data is sourced from, as it affects the reliability and validity of assessments.

→ For broader implementation and scaling, modeling becomes crucial due to the unavailability or inaccessibility of consistent primary data.

→ Field surveys, while accurate, are impractical, sensitive and cost-prohibitive for many, especially those without agronomic teams. Remote sensing is viewed as a preferable, scalable alternative.

Future innovation opportunities:

1. Improvement of precision irrigation integration: Technologies that link satellite water stress data with irrigation systems for real-time optimization of water use.
2. Groundwater telemetry networks: Low-cost, networked sensors for groundwater level tracking could improve water governance and compliance monitoring.

Good

Metric: **Blue water withdrawal (m3/ha) split by level of water stress risk**

Indicator: **Blue water**

Approach category: **Software as a service / tool**

Hydrological modeling

Description	Use models (WaterGAP) to estimate withdrawals and stress levels by region.

Technology and quality readiness ★☆☆

Widely validated globally, used by institutions (e.g., FAO, USDA) and mostly used in science, not commercially.

Cost effectiveness ★★☆

Needs modeling expertise and may require licensing costs. Data input for calibration can add to costs.

Scalability ★★★

Vertical: Excellent for watershed-scale.

Horizontal: Good crop compatibility.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Identifies water dependencies at field level.

SBTN Freshwater: Aligns with freshwater withdrawal targets.

CSRD: Provides primary data for water use reporting.

GRI: Supports with water consumption & management data.

IFRS: Supports climate-related physical risk assessment tied to water scarcity in agriculture.

Verification

Approach: Regional water budget validation.

Description: Estimates compared with actual basin-level withdrawal data.

Better

Metric: **Blue water withdrawal (m3/ha) split by level of water stress risk**

Indicator: **Blue water**

Approach category: **Field surveys / connected & sensor technologies**

Farm input and water metering systems

Description	Combine farmer surveys on irrigation practices (e.g., frequency, source, volume estimates) with field measurements of irrigation equipment and flow meters when available. Data on water use per crop and field size allow estimation of water withdrawal in m^3/ha. Cross-referencing this with local or national maps of water stress risk (obtained from hydrological surveys or administrative data) enables categorization by stress level.

Technology and quality readiness ★★☆

Common in irrigation-heavy regions, tech is fully operational and accurate and automated. Additional water stress measurements are needed.

Cost effectiveness ★★☆

Device installation is possible per site but includes a medium investment per area and calibration.

Scalability ★☆☆

Vertical: Applicable only in irrigation-heavy geographies.

Horizontal: Works across commodities.

Farm Archetypes: Scales to large-scale farm types mostly..

Reporting

TNFD: Identifies water dependencies at field level.

SBTN Freshwater: Aligns with freshwater withdrawal targets.

CSRD: Provides primary data for water use reporting.

GRI: Supports with water consumption & management data.

IFRS: Supports climate-related physical risk assessment tied to water scarcity in agriculture.

Verification

Approach: Survey audit and cross-validation.

Description: Flow meter readings and survey combining reconciliation self-reports with metered or estimated data.

Best

Metric: **Blue water withdrawal (m3/ha) split by level of water stress risk**

Indicator: **Blue water**

Approach category: **Remote sensing / SaaS / tool**

Combine satellite imagery with water stress data	
Description	Integrate satellite-based evapotranspiration estimates (e.g., from SEBAL models using Landsat and weather data) with crop maps and groundwater/surface data. Remote sensing-derived actual evapotranspiration is used as a proxy for irrigation demand, which is converted to m³/ha. Overlaying this with regional water stress data (e.g., from WRI Aqueduct or SBTN Water) allows disaggregation of withdrawals by stress level.

Technology and quality readiness ★★☆	**Cost effectiveness** ★★★	**Scalability** ★★★
Proven satellite missions, used in global water tracking and mostly used in science, not commercially.	While high-resolution remote sensing may involve upfront costs for data processing and specialized tools, it offers a cost-effective solution at scale. Subscription costs vary by resolution, but free or lower-cost imagery can often meet baseline monitoring needs. Most regional water stress data can be obtained without costs. Costs can be reduced with scale.	Vertical: Applicable in any geography. Horizontal: Works across commodities. Farm Archetypes: Scales to all farm types

Reporting	**Verification**
TNFD: Identifies water dependencies at field level. SBTN Freshwater: Aligns with freshwater withdrawal targets. CSRD: Provides primary data for water use reporting. GRI: Supports with water consumption & management data. IFRS: Supports climate-related physical risk assessment tied to water scarcity in agriculture.	Approach: Cross-validation with high-res imagery and field plots. Description: Combines satellite-derived data with on-the-ground field measurements to validate and enhance accuracy. Field plots, measured using standardized protocols serve as ground-truth references.

4.6. Outcome: *minimize water pollution*

Indicator: Nutrient loss

Metric: Nutrient use efficiency (%)

Nutrient loss

Read more on this indicator [here]

Software as a Services / Tools like Cool Farm Tool or Cornell's Nutrient Management Spearbox support the calculation step, but measurement is not conducted through the digital tools.

Good

Sensor-based fertilizer management
Connected & sensor technologies

Description: Use precision ag tools to assess real-time nutrient efficiency. Sensors can include optical, electrochemical, and electrophoretic devices.

Benchmarking: Precision tools require costly installation, calibration, and trained staff, with expenses rising at scale; currently commercial in high-tech farms, emerging for mid-scale, suited for monocultures, and ideal for single-farm use.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★☆

Reporting: TNFD, GHG Protocol, CSRD, GRI

Verification: Calibration and ground-truth testing.

Better

Nutrient levels assessed via remote sensing
Remote sensing

Description: Use satellite data to compute the Nitrogen nutrition index for the crops Nitrogen status or other nutrients such as phosphorus and sulphur.

Benchmarking: TRequires trained staff and high-resolution imagery but becomes cost-effective at scale through data collection, using proven satellite missions, mainly in scientific contexts, suited for monocultures, and flexible across all farm types.

TQR	Cost effectiveness	Scalability
★★☆	★★☆	★★★

Reporting: SBTN Freshwater, TNFD, CSRD, GRI, IFRS

Verification: Regional water budget validation.

Best

In-field soil & plant testing
Field surveys

Description: Monitor nutrient uptake and availability before and after application and guide farmers to facilitate self-monitoring.

Benchmarking: Low-tech lab tests and field kits, requiring trained personnel and possible shipping costs, are common in precision agriculture with globally validated procedures, applicable across geographies and commodities, and moderately flexible for farm types.

TQR	Cost effectiveness	Scalability
★★★	★★☆	★★★

Reporting: TNFD, GHG Protocol, CSRD, GRI

Verification: Survey audit and cross-validation.

Key considerations and gaps

→ There's a major need for compatibility between various Farm Management Systems (FMS) platforms and enterprise systems to streamline data collection and reporting.

→ SaaS-based tools are effective but face issues like lack of region-specific emission factors, limited granularity, and data integration hurdles. Also, measurement is not conducted through the digital tools like Cool Farm Tool or Cornell's Nutrient Management Spearbox as they only support the calculation. Furthermore, public data access is inconsistent across regions for modeling.

→ Collected primary data, models and calculations tied to Nutrient Use Efficiency and chemical ingredients, must be scientifically validated to be used for changing management practice or for external communication.

→ Effective outcomes are increasingly achieved by integrating software tools with agronomist expertise, particularly for real-time decision-making.

→ There is growing demand for metrics that reflect ecological benefits.

Future innovation opportunities:

1. Real-time nutrient sensors: Deployment of Internet of Things (IoT) devices that provide direct, in-field readings of soil or plant content will enable responsive nutrient management.
2. AI-guided adaptive nutrient plans: Algorithms that adjust fertilizer recommendations based on current weather, crop status, and historical performance.

Good

Metric: **Nutrient use efficiency (%)**

Indicator: **Nutrient loss**

Approach category: **Connected & sensor technologies**

Sensor-based fertilizer management

Description

Use precision ag tools (e.g., N-sensors) such as portable devices and sensors to assess real-time nutrient efficiency. Sensors can include optical, electrochemical, and electrophoretic devices.

Technology and quality readiness ★★★

Commercial in high-tech farms, prototype tools emerging for mid-scale and not yet ubiquitous.

Cost effectiveness ★☆☆

Precision tools are often expensive and come with installation and calibration costs. Furthermore, trained personnel is needed. The costs can increase with scale.

Scalability ★★☆

Vertical: Applicable in any geography.

Horizontal: Suits monocultures.

Farm Archetypes: Best for single-farm use.

Reporting

TNFD: Evaluates nutrient-related nature dependencies.

CSRD: Ensures accurate reporting on fertilizer efficiency.

GRI: Supports with soil health data.

GHG Protocol: Required for farm nutrient balance disclosure.

Verification

Approach: Calibration and ground-truth testing.

Description: Sensors estimate real-time demand; checked with lab data.

Better

Metric: **Nutrient use efficiency (%)**

Indicator: **Nutrient loss**

Approach category: **Remote sensing**

Nutrient levels assessed via remote sensing

Description

Use satellite data (e.g., Sentinel 2, PlanetScope or RapidEye) to compute the Nitrogen nutrition index for the crops Nitrogen status or other nutrients such as phosphorus and sulphur.

Technology and quality readiness ★★☆

Proven satellite missions and mostly used in science, not commercially.

Cost effectiveness ★★☆

Though trained personnel and high-resolution imagery are needed, the approach becomes cost-effective at scale, with hardware and analysis costs offset by broad coverage and repeatable data collection

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Suits monocultures.

Farm Archetypes: Flexibility across all farm types.

Reporting

TNFD: Evaluates nutrient-related nature dependencies.

CSRD: Ensures accurate reporting on fertilizer efficiency.

GRI: Supports with soil health data.

GHG Protocol: Required for farm nutrient balance disclosure.

Verification

Approach: Cross-validation with high-res imagery and field plots.

Description: Satellite-derived biomass validated with field yield data: Assesses N-demand based on remote biomass calculations.

Best

Metric: **Nutrient use efficiency (%)**

Indicator: **Nutrient loss**

Approach category: **Field surveys**

In-field soil & plant testing

Description	Monitor nutrient uptake and availability before and after application and guide farmers to facilitate self-monitoring (e.g. Leaf Color Chart). Soil testing is a widely used method that analyzes samples to determine nutrient levels (e.g., nitrogen, phosphorus, potassium) and pH, guiding fertilizer application. Tissue testing or plant sap analysis involves collecting samples to measure nutrient concentrations directly in the plant, providing real-time insight into.

Technology and quality readiness ★★★	**Cost effectiveness** ★★☆	**Scalability** ★★★
Common in precision ag, used in extension services and validated procedures are available worldwide. Labs can differ in their methodology/ results.	Lab tests and field kits are required but considered as low-tech. Shipping/ transport costs might occur next to costs for trained personnel.	Vertical: Applicable in any geography. Horizontal: Works across commodities. Farm Archetypes: Moderate flexibility in farm types.

Reporting	**Verification**
TNFD: Evaluates nutrient-related nature dependencies. CSRD: Ensures accurate reporting on fertilizer efficiency. GRI: Supports with soil health data. GHG Protocol: Required for farm nutrient balance disclosure.	Approach: Survey audit and cross-validation. Description: Before/after nutrient analysis using lab tests to evaluate nutrient uptake efficiency.

4.6.1. Nitrogen use efficiency (NitUE): *a deeper dive*

Indicator: Nutrient loss

Contextualisation

Nitrogen use efficiency (NitUE) refers specifically to how effectively a plant or cropping system uses applied nitrogen to produce yield, minimizing losses to the environment. In contrast, nutrient use efficiency is a broader term that includes the efficient use of all essential nutrients (e.g., nitrogen, phosphorus, potassium). Important information for contextualisation include the following aspects:

Nitrogen mining vs nitrogen leaking

- Nitrogen mining occurs when more nitrogen is removed from the soil (e.g., through crop harvest) than is added back, leading to long-term soil nutrient depletion.
- Nitrogen leaking happens when excess nitrogen (often from fertilizers) is not taken up by plants and instead escapes into the environment—through leaching into groundwater or as emissions—causing pollution.

The recommended ideal range is a 60%-80%, depending on soil, crop and farming system.

Measuring beyond software

CAP FaST (Common Agricultural Policy – Farm Sustainability Tool for Nutrients) is a digital tool developed by the European Commission to help farmers manage nutrient use more sustainably under the EU's Common Agricultural Policy (CAP).

The tool uses farm-specific data (e.g. soil type, crop type, climate, and satellite data) to generate nutrient management advice

Public databases

International fertilizer association (IFASTAT)

Nutrient use and outcome network (NUOnet)

FAOSTAT reference database

Data collection incentivization

- Visibility of NitUE data can attract investors and stakeholders who prioritize ESG metrics, regenerative agriculture, or climate-smart practices.
- Blockchain-enabled traceability tools and platforms that issue carbon credits for reduced fertilizer use (e.g., Indigo Ag) create financial incentives for accurate NUE tracking.
- Incentives of NitUE approaches are linked to carbon projects.
- MRV approaches that are linked to multiple regen ag outcomes enable higher incentives for practice management that is appropriate to produce the greatest impact.
- Pay-for-outcome programs enhance existing pay-for-practice initiatives by incentivizing the implementation of practices that achieve the greatest environmental benefits.

Accurate data and scientifically rigorous accounting methods are essential for effectively driving incentives at the farm level.

Broader food system relevance

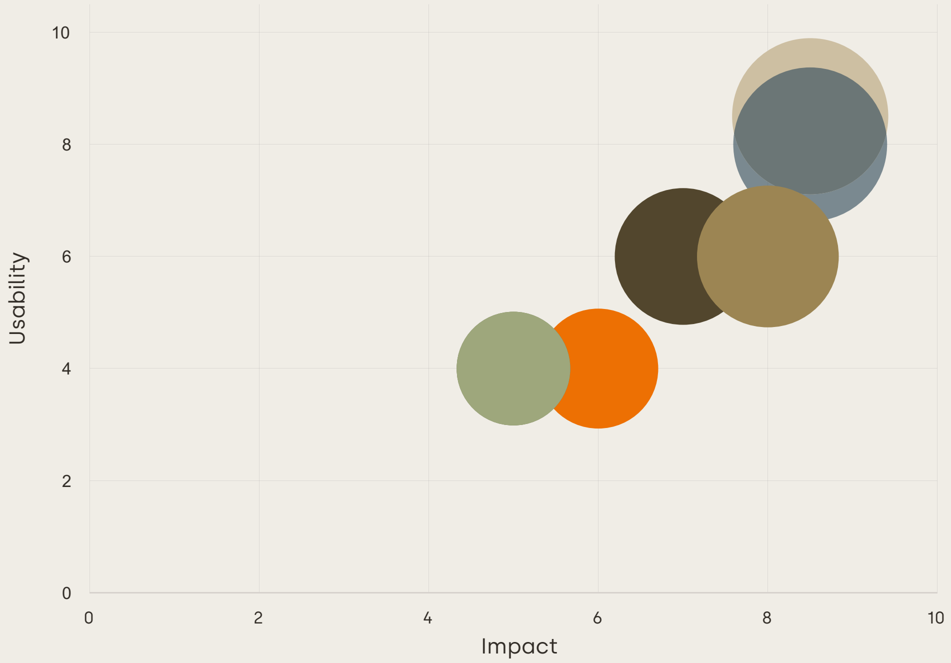
NitUE provides value across the food system:

- **Farmers:** Improves yield per unit of input, reduces fertilizer costs, and enhances soil health in the long term.
- **Agribusinesses:** Input suppliers and agtech firms can tailor precision solutions and demonstrate impact to customers and regulators.
- **Food brands & retailers:** Use NitUE as a proxy for sustainable sourcing, supporting Scope 3 emissions reporting and sustainability certifications.
- **Investors & lenders:** NitUE data supports environmental risk assessments and performance-based financing (e.g., sustainability-linked loans).
- **Policymakers & regulators:** Helps evaluate nitrogen runoff risks, inform subsidies, and assess compliance with agri-environmental schemes.
- **NGOs & consumers:** NitUE contributes to transparency in food production and environmental impact enabling better consumer labelling and advocacy.

NitUE scatter plot

Contributions & applicability of NitUE to other regen agriculture metrics & outcomes

Figure 3: contributions and applicability of NitUE to regenerative agriculture outcomes



Impact: How strongly NitUE contributes to the outcome (0-10)

Usability: How practical or applicable NitUE is for achieving the outcome (0-10)

Overlap (size): Degree to which NitUE shares results or practices with the outcome (average)

Minimize GHG Emissions · Increased sequestered carbon · Increased cultivated biodiversity · Minimized water pollution · Improved environmental flows · Inreased soil health · Increased financial benefits

Nutrient vs nitrogen use efficiency MRV

Table 4. Comparison between nutrient use efficiency (NUE) and nitrogen use efficiency (NitUE) MRV

Comparison	*Nitrogen*	*Nutrient*
Measurement	Tracks N input (kg/ha), N uptake in biomass, losses (e.g., leaching, volatilization).	Measures full nutrient input spectrum and uptake/output for each macro- and micronutrient.
Reporting	N-based indicators like partial factor productivity of N (PFP-N), agronomic efficiency of N (AE-N), recovery efficiency (RE-N).	Same indicators but expanded across nutrients. Requires more data streams and harmonization.
Verification	May use lab analysis (soil, tissue), remote sensing, or yield measurements to verify N performance. Easier to implement.	Requires multivariate lab analysis and often more complex verification (e.g., interactions between nutrients). Harder to standardize.
Complexity	N pathways are well understood and monitored.	More holistic but nutrient interactions and variability increase complexity.
Scalability	Standardized protocols exist for many crops/regions.	More data, regional variation, and fewer standardized benchmarks.
Limitations	Doesn't capture nutrient interactions or broader soil fertility. Risk of narrow optimization.	Data-heavy, complex to standardize across geographies, may be harder to validate at scale.

4.7. Outcome: *increase financial benefits*

Indicator: Farm net income

Metric: Farm net income LCU/ha/year

Farm net income

Read more on this indicator here

Good

Self-reporting of farm economic data
Field survey + SaaS / tools

Description: Self-reporting of farm economic data via mobile phone app hosting survey / questionnaire or via Farm Management Information Systems (FMIS).

Benchmarking: Increasingly viable, especially through mobile apps and FMIS tools, with minimal or no licensing costs.Scalable and usable in remote areas, but data quality depends on farmer input and willingness to report.

TQR	Cost effectiveness	Scalability
★★☆	★★☆	★★☆

Reporting: CSDDD; CSRD

Verification: Third party surveying.

Better

Primary farm economic data collection
Field surveys

Description: Collecting farm economic data via farm / farmer survey through manual or digital data collection methods.

Benchmarking: Accurate but costly method involving on-the-ground teams and extensive processing. Scalable across commodities, geographies, and farm types but difficult to scale due to resource demands and data privacy concerns.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★☆

Reporting: CSDDD; CSRD

Verification: Third party verification.

Best

Secondary databases
SaaS / tools

Description: Estimation of Farm Net Income via secondary / external datasets on country / regional data.

Benchmarking: Most practical and cost-effective method available. Scalable across regions, commodities, and farm types but heavily dependent on the availability and quality of datasets.Accuracy can be improved by integrating primary data where possible.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★★

Reporting: CSDDD; CSRD

Verification: Ground truthing via farm economic data surveys.

Key considerations and gaps

- Approaches leveraging primary data are better suited to tracking the impact of a specific program on farm income.
- Farmer centric approaches may compel future participants in disclosing. Qualitative, directional survey questions (e.g., indicating increases or decreases in productivity or revenue) can avoid sensitivities around economic data.
- **Strategies to overcome challenges for collecting primary data:**
  - Establish trusting relationship amongst involved stakeholders
  - Clarify purpose of data collection
  - Develop, Implement and regularly update data protection policies
  - Use neutral third parties
  - Adopt anonymisation techniques
  - Provide data handling training
  - Offer incentives and support
- Farmers should be provided with the right tools and documents to collect primary data.
- Farmers participating in surveys which feed secondary datasets are not necessarily representative of typical farmer. Datasets would not cover additional income streams generated by farmers.
- Secondary datasets updated more frequently are more likely to provide an accurate, up-to-date estimation of the metric.
- When there is uncertainty around secondary data, on the ground resources (in field staff operators) can supply relevant information.
- Initiatives driving standardisation on socioeconomic indicators are needed to increase focus and promote measurement uptake.
- In mature markets, Farm Management Information Systems can be leveraged at no additional cost for Farm Net Income.

Future innovation opportunities:

Future MRV innovations for farm net income include real-time digital data collection and AI-driven analysis, blockchain for secure and transparent records, and integration of remote sensing to link productivity with income.

Good

Metric: **Farm net income LCU/ha/year**

Indicator: **Farm net income**

Approach category: **Field surveys - Software as a service & tools**

Self-reporting of farm economic data	
Description	Self-reporting of farm economic data via mobile phone app hosting survey / questionnaire or via Farm Management Information Systems (FMIS) (e.g. Bushel Farm, Granular Insights).

Technology and quality readiness ★★☆	**Cost effectiveness** ★★☆	**Scalability** ★★☆
Advancing technology becoming an increasingly viable option for capturing farm economic data among smallholder farmers. FMIS widely used in mature markets. Quality of data outputs depending on farmers inputs.	Mobile based tools can be free or have licensing costs. FMIS information can be leveraged at no additional cost. Operational costs include farmer training and data processing.	Commodity agnostic approach better suited for field/farm level assessments. Mobile apps do not require connectivity for collecting data, meaning they can be used in remote locations. Their use however is dependent on access to mobile phones and willingness to share the data. Mobile app more suitable for smallholder farms / FMIS for more mature, larger scale farms. Approach scalability entirely relies on farmers' willingness of farmers to voluntarily report

Reporting	**Verification**
CSRD: Organizations are required to track compliance with fair wage regulations for farm workers. CSDDD – Companies have a responsibility to adapt their business practices and operations to contribute towards suppliers' living wages and incomes.	Approach: Farm economic data surveying via independent enumerators. Description: Surveying self-reporting farms / farmers to validate results

Better

Metric: **Farm net income LCU/ha/year**

Indicator: **Farm net income**

Approach category: **Field surveys**

Primary farm economic data collection

Description	Collecting farm economic data via farm / farmer survey. These can be collected via manual data collection methods e.g. paper surveys, or through digital methods e.g. via digital apps available via phones and tablets. Data can be collected by in house, company members staff operating on the ground, or via third party enumerators. Data can be collected via rough or advance sampling strategy to cover a representative number of farms.

Technology and quality readiness ★★★

Well established method that produces high accuracy results.

Third party auditors/ enumerators; digital data collection methods and advance sampling strategies will produce the least biased and most accurate data for measurements.

Cost effectiveness ★☆☆

Overall, a costly approach which entails an equipe going on the ground and resources for data processing. Third party surveyors will be more costly.

If digital tools are employed by data collectors, there will be further training required which will be more costly.

Scalability ★★☆

Suitable for any commodity and geography and any farm archetype. Well suited approach for tracking the impact of a specific program on farm income. However, scaling up this approach is considered very unpractical due to resource requirements and sensitivities around data privacy.

To overcome barrier of data privacy, companies are advised to: i. Establish trusting relationship amongst involved stakeholders. ii. Clarify purpose of data collection iii. Develop, Implement and regularly update data protection policies iv. Use neutral third parties. v. Adopt anonymisation techniques. vi. Provide data handling training. vii. Offer incentives and support.

Reporting

CSRD: Organizations are required to track compliance with fair wage regulations for farm workers.

CSDDD – Companies have a responsibility to adapt their business practices and operations to contribute towards suppliers' living wages and incomes.

Verification

Approach: Third party verification.

Description: Independent review of collected data validating logically and ensuring responses fall within established thresholds.

Best

Metric: **Farm net income LCU/ha/year**

Indicator: **Farm net income**

Approach category: **Software as a service / tool**

Secondary databases

Description	Estimation of Farm Net Income via secondary / external datasets on country / regional data.	
Technology and quality readiness ★★☆	**Cost effectiveness** ★★★	**Scalability** ★★★
Established methodology developed by DIASCA / GiZ but entirely dependant on availability and quality of datasets. Databases are compiled from non-representative farms, and secondary sources limit the ability to monitor positive financial changes on farm from specific programmes. The more frequent secondary sources are updated, the more accurate the estimation will be. Primary data can be integrated to increase accuracy.	Currently most practical and cost-effective approach. The more granular the estimate is desired, the higher the cost and the time requirements.	Method scalable across geographies and commodities for any farm archetype. However, its usability entirely depends on the availability of secondary datasets.

Reporting	**Verification**
CSRD: Organizations are required to track compliance with fair wage regulations for farm workers. CSDDD – Companies have a responsibility to adapt their business practices and operations to contribute towards suppliers' living wages and incomes.	Approach: Ground truthing via farm economic data surveys. Description: Surveying sample selection of farms to validate estimation from secondary sources

4.8. Outcome: *improve ecological integrity*

Indicator: Natural/ restored habitat in agricultural landscapes

Metric: Natural/semi-natural habitat(NSH) in agricultural land (% per km^2)

Natural/ restored habitat in agricultural landscapes

Read more on this indicator here

Good

Multispectral satellite imagery combined with land cover classification algorithms
Remote sensing

Description: Use high-resolution multispectral satellite imagery combined with land cover classification algorithms (to distinguish between natural/semi-natural vegetation and cultivated areas.

Benchmarking: Widely used and proven across geographies, commodities, and farm types, this solution requires satellite data, GIS software, skilled staff, and mid-level hardware.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★★

Reporting: TNFD, SBTN Land, CSRD, GRI

Verification: Cross-validation with high-resolution imagery and field plots.

Better

Transect or plot-based surveys
Field survey

Description: Systematic transect or plot-based surveys across agricultural landscapes to identify and map patches of NSH. The total area of NSH is then calculated and expressed as a percentage of the total surveyed km².

Benchmarking: A low-tech, cost-effective, and labor-intensive method with global ecological use. Though scalable geographically, the cost limits practicality for broad deployment. Applicable across all commodities and farm types.

TQR	Cost effectiveness	Scalability
★★★	★☆☆	★★☆

Reporting: TNFD, SBTN Land, CSRD, GRI

Verification: GPS-logged habitat observations and photographic records.

Best

Land cover database
SaaS / tools

Description: Analyze land cover datasets like Sentinel-2 Land Cover Explorer to track changes in NSH over time.

Benchmarking: Utilizing freely available, regularly updated datasets with minimal analysis and training needs, this widely validated method scales across geographies, commodities, and farm types.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★★

Reporting: TNFD, SBTN Land, CSRD, GRI

Verification: Historical comparison and cross-referencing with remote sensing layers.

Key considerations and gaps

- While definitions of natural and semi-natural habitat do exist such as those provided by IPBES, many companies remain unaware of them, leading to continued confusion.
- There is a need to clearly specify the source of primary data on natural and semi-natural habitats within agricultural landscapes, as data origin directly impacts the reliability and ecological validity of habitat assessments.
- Field surveys, while accurate, are cost-prohibitive for many, especially those without agronomic teams. Remote sensing is viewed as a preferable, scalable alternative, but needs regular ground truthing. However, resolution of freely available images is usually not high enough to identify details and models for remote sensing need region-specific training.
- For broader implementation and scaling, modeling becomes crucial due to the unavailability or inaccessibility of consistent primary data. However, ground truthing remains essential to validate model outputs and ensure accuracy.
- Field surveys commodity agnostic in terms of horizontal scalability but depends on the biome the commodity grows in as different expertise is needed for various biomes.
- In mature markets, Farm Management Information Systems can be leveraged at no additional cost for Farm Net Income.

Future innovation opportunities:

1. AI-enabled habitat classification: Advances in AI and hyperspectral imaging will allow for more precise and automated detection of habitat types and degradation patterns across landscapes.
2. Dynamic biodiversity indicators: Innovations such as acoustic monitoring or environmental DNA (eDNA) can enable real-time biodiversity assessment, moving beyond static land cover metrics but result interpretation needs to be verified.
3. Blockchain for land use records: Decentralized technologies could provide secure, tamper-proof documentation of conservation commitments and land-use designations.
4. The absence of robust criteria for nature-related metrics in current frameworks like CSRD/ESRS presents a significant opportunity for innovation in developing clear, science-based guidance to support consistent and regulation-aligned reporting.

Good

Metric: **Natural/semi-natural habitat(NSH) in agricultural land (% per km2)**

Indicator: **Natural/restored habitat in agricultural landscapes**

Approach category: **Remote sensing**

Multispectral satellite imagery combined with land cover classification algorithms

Description

Use high-resolution multispectral satellite imagery (e.g., Sentinel-2 or Landsat) combined with land cover classification algorithms (e.g., Random Forest or Support Vector Machines) to distinguish between natural/semi-natural vegetation and cultivated areas. The Normalized Difference Vegetation Index (NDVI) and other vegetation indices help differentiate managed crops from wild vegetation, enabling the mapping of NSH patches within agricultural landscapes.

Technology and quality readiness ★★★

Widely commercialized (e.g., Sentinel, Landsat), proven in agriculture & conservation and routinely used by governments & NGOs.

Cost effectiveness ★☆☆

Requires large datasets of high-resolution satellite data subscriptions as well as GIS software and skilled staff. Resolution of freely available images is usually not high enough to identify details. Mid-level hardware is needed for the analysis.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types

Reporting

TNFD: Recommends landscape-scale biodiversity risk mapping.

SBTN Land: Recommends habitat extent tracking in target setting.

CSRD: Recommends reporting on ecosystem condition.

GRI: Aligns with biodiversity impact disclosures.

Verification

Approach: Cross-validation with high-res imagery and field plots.

Description: NDVI and other indices differentiate crops from natural vegetation; results are validated using finer-resolution data or field observations.

Better

Metric: **Natural/semi-natural habitat(NSH) in agricultural land (% per km2)**

Indicator: **Natural/restored habitat in agricultural landscapes**

Approach category: **Field surveys**

Transect or plot-based surveys

Description

Conduct systematic transect or plot-based surveys across agricultural landscapes to identify and map patches of NSH such as hedgerows, grasslands, woodlots, or unmanaged field margins. Field teams can record GPS locations, habitat types, and vegetation characteristics within each km² sample area. The total area of NSH is then calculated and expressed as a percentage of the total surveyed km².

Technology and quality readiness ★★★

Fully established method, used in ecological monitoring globally and no technical innovation needed.

Cost effectiveness ★☆☆

Requires only minimal tools (low-tech) and low equipment costs but can be labor-intensive (high OPEX).

Scalability ★★☆

Vertical: Moderately scalable across geography (logistics off trained staff).

Horizontal: Less commodity relevance.

Farm Archetypes: Easily adjusted to farm type.

Reporting

TNFD: Enables landscape-scale biodiversity risk mapping.

SBTN Land: Supports habitat extent tracking in target setting.

CSRD: Facilitates reporting on ecosystem condition.

GRI: Aligns with biodiversity impact disclosures.

Verification

Approach: GPS-logged habitat observations and photographic records.

Description: On-ground mapping of NSH patches, verified by habitat type logs and physical evidence.

Best

Metric: **Farm net income LCU/ha/year**

Indicator: **Farm net income**

Approach category: **Software as a service / tool**

Land cover database

Description: Analyze land cover datasets like Sentinel-2 Land Cover Explorer to track changes in NSH over time.

Technology and quality readiness ★★☆

Used in EU, FAO datasets, etc, regular updates and validation and no prototype dependency. More useful to identify larger areas than smaller landscape features.

Cost effectiveness ★★★

Includes freely available datasets with minimal analysis tools needed and low training burden.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Enables landscape-scale biodiversity risk mapping.

SBTN Land: Supports habitat extent tracking in target setting.

CSRD: Facilitates reporting on ecosystem condition.

GRI: Aligns with biodiversity impact disclosures.

Verification

Approach: Historical comparison and cross-referencing with remote sensing layers.

Description: Tracks land cover changes over time; validation through overlay with independent satellite data.

4.8. Outcome: *improve ecological integrity*

Indicator: Land / freshwater ecosystem use change

Metric: ha or km^2

Land / freshwater ecosystem use change

Read more on this indicator here

Good

Transect or plot-based surveys
Field surveys

Description: Conduct systematic surveys over time to identify use changes. The total area is then calculated and expressed as a percentage of the total surveyed km² or ha.

Benchmarking: : A low-tech, cost-effective method used globally in ecological monitoring, it can be labor-intensive over time, offers moderate geographic scalability, limited commodity relevance, and scales to all farm types.

TQR	Cost effectiveness	Scalability
★★★	★★☆	★★☆

Reporting: TNFD, SBTN Land, IFRS

Verification: GPS-logged habitat observations and photographic records.

Better

Multitemporal satellite-based land cover change detection
Remote sensing

Description: Use satellite imagery from multiple time points to detect changes in land or water cover. Images are classified into land cover types, and changes are quantified spatially.

Benchmarking: Relies on satellite data, analytics expertise, and suitable hardware, with costs rising by resolution, and is widely used in environmental monitoring across geographies, commodities, and farm types.

TQR	Cost effectiveness	Scalability
★★★	★★☆	★★★

Reporting: Cross-validation with high-res imagery and field plots.

Verification: Cross-validation with high-res imagery and field plots.

Best

Historical land/water use databases
SaaS / tools

Description: Access digitized records and spatial datasets of historical land and water use. These databases often integrate administrative, satellite, and survey data sources.

Benchmarking: This plug-and-play, low-expertise approach uses open-source national datasets and validated tools for land use change detection, with global applicability across commodities and farm types.

TQR	Cost effectiveness	Scalability
★★☆	★★★	★★★

Reporting: TNFD, SBTN Land, IFRS

Verification: Cross-check with policy/ land registry data.

Key considerations and gaps for all land / freshwater ecosystem metrics

→ There's a need to specify where primary data is sourced from, as it affects the reliability and validity of assessments.

→ For broader implementation and scaling, modeling becomes crucial due to the unavailability or inaccessibility of consistent primary data.

→ Field surveys, while accurate, are cost-prohibitive for many, especially those without agronomic teams. Remote sensing is viewed as a preferable, scalable alternative.

→ Measuring the conserved area in hectares cannot rely solely on Field surveys, as these are limited to assessing the ecological condition within the area. The actual extent of the conserved area is defined by administrative boundaries, which can only be accurately measured using remote sensing or geospatial databases that include boundary data.

Future innovation opportunities:

1. High-resolution, near-real-time satellite monitoring: Innovations in small satellite constellations will enhance the ability to detect changes in land cover within days rather than months.
2. The absence of robust criteria for nature-related metrics in current frameworks like CSRD/ESRS presents a significant opportunity for innovation in developing clear, science-based guidance to support consistent and regulation-aligned reporting.

Land / freshwater ecosystem use change

1. AI-powered change attribution: Emerging AI tools can distinguish between types of land-use change (e.g., natural vs. anthropogenic) and flag illegal or high-risk activities automatically.
2. Geo-tagged community observations: Participatory MRV via mobile apps can crowdsource land-use change data, improving verification in areas with poor satellite coverage or cloud interference.

Land / freshwater ecosystem restored/conserved

1. Ecological integrity scoring tools: Innovation in scoring systems that go beyond binary "protected/not protected" labels, to reflect habitat quality, connectivity, and pressures.
2. eDNA and acoustic sensors for biodiversity health: Cost-effective biodiversity monitoring using environmental DNA sampling or soundscape analysis allows for non-invasive tracking of species richness.

Good

Metric: **Land / Freshwater ecosystem use change**

Indicator: **Natural/restored habitat in agricultural landscapes**

Approach category: **Field surveys**

Transect or plot-based surveys

Description	Conduct systematic transect or plot-based surveys over time to identify use changes. Field teams can record GPS locations, habitat types, and vegetation characteristics within each km² sample area. The total area of are is then calculated and expressed as a percentage of the total surveyed km² or ha.

Technology and quality readiness ★★★

Fully established method, used in ecological monitoring globally and no technical innovation needed.

Cost effectiveness ★★☆

Can be labor-intensive depending on the time period, but relies on low-tech methods, keeping equipment costs low.

Scalability ★★☆

Vertical: Moderately scalable across geography (logistics off trained staff).

Horizontal: Less commodity relevance as focussed on landscape and not commodity.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Requires disclosure of ecosystem conversion risks, which land/freshwater use change metrics directly support.

SBTN Land: Includes ecosystem conversion as a key pressure metric for setting science-based targets.

IFRS: Uses ecosystem degradation and land-use change as factors contributing to climate transition and physical risks.

GHG LRSG: Land use change needs to be accounted.

Verification

Approach: GPS-logged habitat observations and photographic records.

Description: On-ground mapping, verified by habitat type logs and physical evidence.

Better

Metric: **Land / Freshwater ecosystem use change**

Indicator: **Natural/restored habitat in agricultural landscapes**

Approach category: **Remote sensing**

Multitemporal satellite-based land cover change detection

Description	Use satellite imagery from multiple time points to detect changes in land or water cover. Images are classified into land cover types, and changes are quantified spatially. The extent of change is then aggregated and reported per km² or ha. Examples include USGS EarthExplorer, PlanetScope and RapidEye.

Technology and quality readiness ★★★

Uses mature, widely adopted satellite imagery techniques. The methodology is proven, routinely applied in environmental monitoring, and supported by operational systems like Landsat and Sentinel. It involves standardized image classification and spatial change detection, indicating full system integration and deployment.

Cost effectiveness ★★☆

Requires satellite data access, analytics expertise and hardware for analysis. Costs increase with satellite imagery resolution.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Requires disclosure of ecosystem conversion risks, which land/freshwater use change metrics directly support.

SBTN Land: Includes ecosystem conversion as a key pressure metric for setting science-based targets.

IFRS: Uses ecosystem degradation and land-use change as factors contributing to climate transition and physical risks.

GHG LRSG: Land use change needs to be accounted.

Verification

Approach: Cross-validation with high-res imagery and field plots.

Description: Image differencing + validation with change records: Uses satellite time-series analysis and change detection; checked against local land conversion records.

Best

Metric: **Land / freshwater ecosystem use change**

Indicator: **Natural/restored habitat in agricultural landscapes**

Approach category: **Software as a service / tool**

Historical land/water use databases

Description	Access digitized records and spatial datasets of historical land and water use. These databases often integrate administrative, satellite, and survey data sources. Analysts can query and extract use change metrics over defined areas and timeframes. Examples include Global Forest Watch, MapBiomas or Dynamic World.

Technology and quality readiness ★★☆	**Cost effectiveness** ★★★	**Scalability** ★★★
Pug-and-play approach: the technology, data, and interfaces are already built, validated, and in operational use for land use change detection worldwide. Updates vary with databases.	Existing datasets can be used open source from national databases and only little expertise is needed.	Vertical: Applicable in any geography. Horizontal: Works across commodities. Farm Archetypes: Scales to all farm types

Reporting	**Verification**
TNFD: Requires disclosure of ecosystem conversion risks, which land/freshwater use change metrics directly support. SBTN Land: Includes ecosystem conversion as a key pressure metric for setting science-based targets. IFRS: Uses ecosystem degradation and land-use change as factors contributing to climate transition and physical risks. GHG LRSG: Land use change needs to be accounted.	Approach: Cross-check with policy/land registry data. Description: Tracks ecosystem transitions with long-term harmonized datasets.

4.8. Outcome: *improve ecological integrity*

Indicator: Land / freshwater ecosystem restored

Metric: ha or km^2

Land / freshwater ecosystem restored

Read more on this indicator [here]

Good	Better	Best
Vegetation index time-series *Remote sensing*	**Field ecological surveys of restored sites** *Field surveys*	**Not available**
Description: Analyze vegetation indices such as NDVI or EVI over time using satellite data. Increases in vegetation index values can indicate regrowth or restoration success. **Benchmarking:** This validated method for ecological recovery monitoring uses open satellite data with moderate computational costs, requires analysis hardware and expertise, and scales globally across commodities and farm types.	**Description:** Use satellite imagery from multiple time points to detect changes in land or water cover. Images are classified into land cover types, and changes are quantified spatially. **Benchmarking:** Relies on satellite data, analytics expertise, and suitable hardware, with costs rising by resolution, and is widely used in environmental monitoring across geographies, commodities, and farm types.	**No third approach** is included as there is not tool available to measure the condition of the restored area. Data for analyzing the condition can be derived from crowd-sourced or participatory monitoring via mobile apps and community platform like eBird or iNaturalist but are not validated.
TQR: ★★☆ Cost effectiveness: ★★☆ Scalability: ★★★	TQR: ★★★ Cost effectiveness: ★★☆ Scalability: ★★★	
Reporting: TNFD, SBTN, GRI **Verification:** Cross-validation with high-res imagery and field plots.	**Reporting:** Cross-validation with high-res imagery and field plots. **Verification:** Cross-validation with high-res imagery and field plots.	

Good

Metric: **ha or km²**

Indicator: **Land / freshwater ecosystem restored**

Approach category: **Remote sensing**

Vegetation index time-series

Description

Analyze vegetation indices such as NDVI or EVI over time using satellite data. Increases in vegetation index values can indicate regrowth or restoration success. The extent of restored land is quantified by the area showing consistent vegetative recovery.

Technology and quality readiness ★★★

Uses well-established vegetation indices, widely applied in ecological monitoring and restoration assessment. But it cannot cover all trends within biodiversity such as species richness of others than plants.

Cost effectiveness ★★☆

Includes moderate computational cost and open satellite data can be used. Hardware for analysis as well as expertise is needed and costs increase with satellite image resolution.

Scalability ★★☆

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Emphasizes restoration as part of nature-positive strategies and risk mitigation.

SBTN Land/Freshwater: Includes restoration as a measurable outcome when setting targets for nature recovery.

GRI: Includes metrics for restored ecosystem area and ecological outcomes, supporting transparent sustainability reporting.

Verification

Approach: Cross-validation with high-res imagery and field plots.

Description: Trend analysis validated with restoration site data: Time-series NDVI shows vegetation regrowth; validated with site-based recovery evidence.

Better

Metric: **ha or km²**

Indicator: **Land / freshwater ecosystem restored**

Approach category: **Field surveys**

Field ecological surveys of restored sites

Description	Conduct on-the-ground surveys to assess ecological characteristics of restored sites. Measurements may include species composition, soil quality, and hydrological conditions. Restoration effectiveness is then mapped and quantified by surveyed area.

Technology and quality readiness ★★★

Relies on long-standing, widely adopted Field survey techniques used globally in ecological monitoring and restoration projects. It involves direct measurement of key ecological indicators like with standardized protocols in place. It provides accurate, ground-truthed data essential for mapping and assessing restoration effectiveness.

Cost effectiveness ★★☆

Labor intensive and trained staff is required, but low-tech (high OPEX costs).

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Emphasizes restoration as part of nature-positive strategies and risk mitigation.

SBTN Land/Freshwater: Includes restoration as a measurable outcome when setting targets for nature recovery.

GRI: Includes metrics for restored ecosystem area and ecological outcomes, supporting transparent sustainability reporting.

Verification

Approach: Survey audit and cross-validation.

Description: On-site assessments verify restoration outcomes.

4.8. Outcome: *improve ecological integrity*

Indicator: Land / Freshwater ecosystem conserved

Metric: ha or km^2

Land / freshwater ecosystem conserved

Read more on this indicator here

Good	Better	Best
Monitoring conservation areas via national protected area boundaries *Remote sensing*	**Protected area and conservation registry data** *Remote sensing + SaaS / tools*	**Not available**
Description: Use satellite imagery to monitor land cover within officially designated protected areas based on National databases.	**Description:** Use satellite imagery to monitor land cover within officially designated protected areas based on tools like IBAT.	**No third approach** is included as measuring the conserved area in hectares cannot rely on Field surveys or sensors, as these are limited to assessing the ecological condition within the area. The actual extent of the conserved area is defined by administrative boundaries, which can only be accurately measured using remote sensing or geospatial databases that include boundary data.
Benchmarking: Costs vary with monitoring frequency and scale, requiring satellite data access and analytics expertise, while uses established techniques and standardized datasets for conservation monitoring across geographies, commodities, and farm types.	**Benchmarking:** Data availability varies by quantity, with IBAT licensing costs, requiring remote sensing expertise and hardware, while leveraging well-established data.	
TQR ★★★ / Cost effectiveness ★★★ / Scalability ★★☆	TQR ★★★ / Cost effectiveness ★★☆ / Scalability ★★★	
Reporting: TNFD, SBTN, GRI	**Reporting:** TNFD, SBTN, GRI.	
Verification: Cross-validation with high-res imagery and field plots.	**Verification:** Survey audit and cross-validation.	

Good

Metric: **ha or km²**

Indicator: **Land / freshwater ecosystem restored**

Approach category: **Remote sensing**

Vegetation index time-series

Description

Analyze vegetation indices such as NDVI or EVI over time using satellite data. Increases in vegetation index values can indicate regrowth or restoration success. The extent of restored land is quantified by the area showing consistent vegetative recovery.

Technology and quality readiness ★★★

Uses well-established vegetation indices, widely applied in ecological monitoring and restoration assessment. But it cannot cover all trends within biodiversity such as species richness of others than plants.

Cost effectiveness ★★☆

Includes moderate computational cost and open satellite data can be used. Hardware for analysis as well as expertise is needed and costs increase with satellite image resolution.

Scalability ★★☆

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Emphasizes restoration as part of nature-positive strategies and risk mitigation.

SBTN Land/Freshwater: Includes restoration as a measurable outcome when setting targets for nature recovery.

GRI: Includes metrics for restored ecosystem area and ecological outcomes, supporting transparent sustainability reporting.

Verification

Approach: Cross-validation with high-res imagery and field plots.

Description: Trend analysis validated with restoration site data: Time-series NDVI shows vegetation regrowth; validated with site-based recovery evidence.

Better

Metric: **ha or km²**

Indicator: **Land / freshwater ecosystem conserved**

Approach category: **Remote sensing/ Software as a service / tool**

Protected area and conservation registry data

Description	Retrieve spatial and attribute data from protected area registries (IBAT license). These tools provide boundaries, legal status, and conservation designations. Total conserved area is derived from the sum of registered protected zones within the target geography.

Technology and quality readiness ★★★

Uses well-established protected area registries, which provide standardized, legally recognized spatial and attribute data. It is fully operational, widely used in conservation planning and reporting, and backed by global institutions such as the IUCN and UNEP-WCMC.

Cost effectiveness ★★☆

Data is available but costs depend on quantity, while also requires IBAT license (5,000-35,000 USD). For remote sensing analytical expertise as well as hardware for analysis is needed.

Scalability ★★★

Vertical: Applicable in any geography.

Horizontal: Works across commodities.

Farm Archetypes: Scales to all farm types.

Reporting

TNFD: Prioritizes conservation status as a core indicator of nature-related risk and resilience.

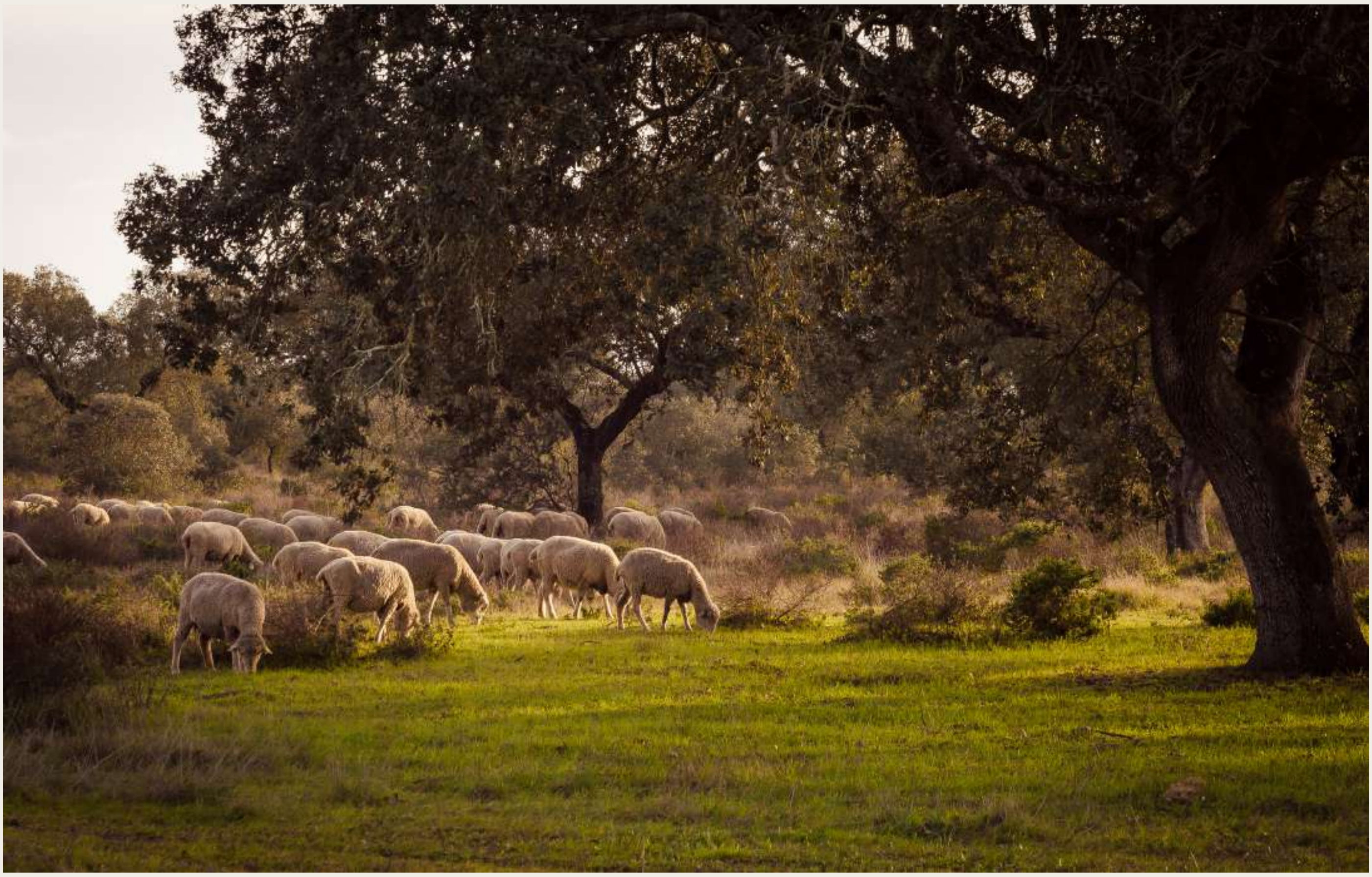
SBTN Land: Uses conservation as a key lever in achieving no net loss or net gain for ecosystems.

IFRS: Supports disclosures on ecosystem conservation when material to long-term environmental and financial outcomes.

Verification

Approach: Legal documentation and registry validation.

Description: Uses standardized national conservation databases to confirm protection status and area extent.



Annex I:
ESG frameworks MRV requirements

1. GHG protocol - corporate standard

Follow the 5 accounting and reporting principles defined by the Greenhouse Gas Protocol: **Relevance, Completeness, Consistency, Transparency and Accuracy**.

Inventory boundary: Reporting entity or company must define organizational and operational boundaries to develop an inventory**.** Organizational boundaries help define what constitutes the company, and these can be determined either via an equity share approach (prioritizing economic interest / risk over legal) or via a control approach, which in turn can be either operational or financial. Operational boundaries define instead the sources of emissions included within a company's operations and GHG inventory, categorizing them either as direct or indirect emissions and classifying them as Scope 1, 2 or 3. Scope 1 covers emissions arising from sources owned or controlled by the company. Scope 2 are indirect emissions from purchased energy (GHG emissions physically occur at facilities where energy is generated). All other indirect emissions fall under Scope 3.

Select base year: 1) Choose and report a base year providing rationale for choosing that year. This can be the basis for target setting and tracking. 2) Develop a significant threshold for base year emission recalculation policy in the case of company restructuring or methodology changes – see various examples guidance of when to re-baseline at p.38-40 here.

Identifying and calculating GHG emissions:
1) Identify emission sources. There are 4 main categories of emission sources: stationary combustion, mobile combustion, process emissions, fugitive emissions. Categorize across scope 1,2,3. 2) Define a calculation approach based on the type and quality of data available (e.g. activity data, spend data). Source-specific emission factors are recommended where possible. Specific sector activity guidances and tools are available for calculation support. 3) Roll out chosen approach at corporate level.

Managing inventory quality: Companies shall develop an Inventory Management Plan and ensure principles of the protocol are followed throughout.

Corporate accounting: GHG emissions reductions are calculated by comparing changes in the company's GHG emission inventory over time relative to base year. It is recommended that calculation of emissions are carried out from bottom up, meaning calculating emissions at individual source and facility and then rolling up to corporate level which allows information reporting at different company scales. Changes in GHG emissions can be caused by acquisitions, site closures, changes in production levels, etc. and ensuring base year recalculation where relevant is key to identifying and tracking actual GHG reductions.

Reporting: Reporting **shall** include 1) description of company and inventory boundary (organizational and operational and reporting period covered) 2) GHG emissions information including: total scope 1, scope 2 and scope 3 emissions reported separately, emissions data covering all 6 GHGs, results in metric tones of CO2 equivalent (CO2e), methodologies to calculate emissions, and any exclusions of sources, facilities or operations. Considerations on reporting: exclude double counting within the corporate boundary and consider use of ratio indicator to provide performance information if relevant for the type of business. Any GHG removals (e.g., biological GHG sequestration) shall not be included in scope 1, 2 or 3, and shall be reported separately.

Verification: Objective assessment of accuracy and completeness of reported GHG information to mitigate risks of material discrepancies in reported data. Need to assess material discrepancies (threshold commonly defined at 5% of total inventory). A number of factors and parameters are used to verify risk. The whole inventory or specific parts can be chosen for verification depending on the goal of the company or of requirements.

GHG protocol - corporate standard - scope 3 requirements

Same MRV requirements as outlined in the previous slide of the Corporate Standard for Scope 1 and 2, plus:

Accounting & inventory boundary:

- Any GHG removals (e.g., biological GHG sequestration) shall not be included in scope 3 and shall be reported separately.
- Companies shall account for emissions from each scope 3 category from this list: 1. Purchased goods and services 2. Capital goods 3. Fuel- and energy-related activities (not included in scope 1 or scope 2) 4. Upstream transportation and distribution 5. Waste generated in operations 6. Business travel 7. Employee commuting 8. Upstream leased assets Downstream scope 3 emissions 9. Downstream transportation and distribution 10. Processing of sold products 11. Use of sold products 12. End-of-life treatment of sold products 13. Downstream leased assets 14. Franchises 15. Investments. Each category has a specific boundary defined in table 5.4 at page 34 of the guidance.

- → Companies shall account for scope 3 emissions of all 6 greenhouse gases CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6, if they are emitted in the value chain. Biogenic CO_2 emissions that occur in the value chain shall not be included in the scope but shall be included and reported separately (See LRSG slide).

Reporting:

- → Companies shall report: Total scope 3 emissions reported separately by each scope 3 category; a list of scope 3 categories and activities included in the inventory; a list of scope 3 categories or activities excluded from the inventory with justification of their exclusion; The methodologies, allocation methods, and assumptions used to calculate emissions from each category; the percentage of emissions calculated using data obtained from suppliers or other value chain partners;
- → For each scope 3 category, companies shall report: total GHG emissions reported in metric tons of CO_2 equivalent, excluding biogenic CO_2 emissions and independent of any GHG trades, such as purchases, sales, or transfers of offsets or allowances; any biogenic CO_2 emissions reported separately; a description of the types and sources of data, including activity data, emission factors and global warming potential (GWP) values used to calculate emissions, and a description of the data quality of reported emissions data.

2. GHG protocol - land sector removal guidance (draft)

Monitoring requirements:

- → This guidance shall be followed if the company has land sector activities in their operations or value chains. To comply with this guidance, entities shall also comply with GHGP corporate and scope 3 standard (see previous slides).
- → Companies shall follow principles of relevance, completeness, consistency, transparency, accuracy, conservativeness (Use conservative assumptions, values, and procedures when uncertainty is high. Conservative values and assumptions are those that are more likely to overestimate GHG emissions and underestimate removal), permanence (Ensure mechanisms are in place to monitor the continued storage of reported removals, account for reversals, and report emissions from associated carbon pools) and comparability (Apply common methodologies, data sources, assumptions, and reporting formats such that the reported GHG inventories from multiple companies can be compared).
- → **Inventory boundary – companies shall:**
  - – Keep organizational boundaries consistent across inventory.
  - – Account for all scope 1,2,3 emissions (the latter following Scope 3 standard and include all categories except exclusions)
  - – Account for emissions from land-based emission sources : Land-use Change and land management (CO_2 and non-CO_2 emissions) from p.71 here.
  - – Accounting Removals is optional. If removals are reported, companies shall account for these separately. They shall report based on the sink process and storage pool. Stock change accounting methods shall be employed to account for scope 1 / scope 3 removals. If a company reports scope 1 and scope 3 removals, then it shall meet also the following requirements: 1) Have an ongoing storage monitoring of carbon pools specified through a monitoring plan; 2) There is full physical traceability through the carbon removal pathway- meaning there needs to be a physical link between removals and purchased commodity 3) Net carbon stock changes are accounted via primary empirical data 4) Uncertainties are quantified and provided; 5) Carbon stock losses shall also be reported (net CO_2 emissions or reversals) 6) Biogenic CO_2 emissions and removals, if applicable, shall be reported separately. For removals from assets owned by multiple companies – removals must be claimed and apportioned in a way that avoids double counting.
- → **Land use change (LUC) accounting – companies shall:**
  - – Account for LUC across all carbon pools: biomass, SOC, dead organic matter.
  - – Account for CO_2, CH_4 and N_2O emissions.
  - – Report direct or statistical LUC for Scope 1,2,3; justifying why one was chosen over the other.
    - – Assessment period shall be always of 20 years or greater.
    - – Linear ("20 year decline") or equal ("20 years constant") discounting approach to distribute emissions in an inventory.
    - – Choose one land tracking metric and report it separately from emissions and removals and apply consistently across inventory. Metrics can be: indirect LUC emissions (carbon stock decrease that takes place outside the landscape in which a product is produced or sourced, induced by change in demand for a product produced or sourced by the company), carbon opportunity cost (total historical amount of carbon lost from plants and soils on lands productively used for agriculture or forestry) or land occupation (amount of land required per year to produce or extract the products produced or sourced by a company).

→ **Land management accounting – companies shall:**

- Account for land management net biogenic CO_2 emissions, land management non-CO_2 emissions (CH_4 and N_2O) separately.
- Land carbon stock changes must be accounted by any company managing land, including changes owing to fires, storms and natural disturbances. Carbon stock measurement method must be resampled at least every 5 years. When estimating net carbon stock change, companies need to account for biomass, dead organic matter and soil carbon stock changes.
- Land management removals can be optionally accounted and reported. If so, they need to follow same principles as above in the land use change section: monitoring, traceability, primary data, uncertainty and reversals.

GHG protocol - land sector removal guidance (DRAFT) cont.

Reporting Requirements:

→ **Inventory boundary :**

Companies shall include: 1) An outline of the organizational boundaries chosen, including the chosen consolidation approach; Scopes, scope 3 categories, gases, sources, and sinks included in the GHG inventory 2) Any scopes, scope 3 categories, accounting categories, gases, sources or sinks excluded from the GHG inventory, with justification for their exclusion 3) The reporting period covered.

→ **Disclosure of GHG emissions:**

- Scope 1,2 emissions disaggregated by land emissions, non-land emissions with biogenic CO_2 emissions reported separately from non biogenic emissions. Reported in individual GHG (CO_2, CH_4, N_2O) in metric tonnes and CO_2 equivalent. The same for Scope 3 emissions, disaggregated by scope 3 category.
- For all of the above, description of methodologies, allocation methods, assumptions used to calculate emissions, description of types and data sources, description of data quality of reported emissions data.
- For scope 3 emissions, % of emissions calculated using data from suppliers and other value chain partners.

→ **Disclosure of GHG removals (if applicable) – companies shall:**

- Report removals separately from emissions, disaggregating by land management, geological pool, product storage biogenic or technological removal (only for scope 3).
- Disclose: 1) Methods and assumptions 2) Systems and procedures in place for long term monitoring 3) Information on physical traceability 4) Description of types and sources of data 5) Uncertainty 6) Reversals.

→ **LUC and land tracking- companies shall disclose:**

- Scope 1, 2 and 3 land tracking metric(s): (Indirect land use change emissions, Carbon opportunity costs, and/or Land occupation – see previous slide for more information).
- Whether direct land use change (dLUC) or statistical land use change (sLUC) was used, with justification for the approach used.
- Whether the shared responsibility approach or product expansion approach was used to calculate sLUC emissions, with justification for the approach used.
- The land use change assessment period and approach used to distribute emissions across the assessment period (linear discounting approach or equal discounting approach), with justification for the approach used.
- Data sources, methods, and assumptions used to quantify Land use change emissions and selected land tracking metric(s).
- Allocation method(s) used for quantifying land use change emissions.
- If companies use certification or chain-of-custody programs, the type of certification programs or chain-of-custody models used.

→ **Land management – companies shall disclose:**

- Approach(es) used to account for anthropogenic emissions and removals due to land management, with justification.
- Description of the definitions and criteria used to distinguish managed and unmanaged lands if a company chooses to separate them.
- Which land uses and carbon pools are included in their analysis of net carbon stock changes, including where they assume no carbon stock changes for a particular carbon pool and land use.
- Data sources, quantification methods, and assumptions used.
- Spatial scale and level of traceability of data used, by product type (e.g., harvested area, land management unit, sourcing region, jurisdiction, global) and the attributable managed lands included in the spatial boundary used to evaluate net carbon stock changes.
- Monitoring approach and frequency used to estimate Land management net CO_2 emissions or removals for each relevant land use and/or activity in scope 1 or scope 3.

- Primary data sampling method(s) used, if applicable.
- Uncertainties of the results, quantitatively (with methodology) or qualitatively (description).
- Allocation method(s) used for land management emissions and removals.

3. SBTi FLAG

Companies must measure and set FLAG targets **if** they either come from one of the following sectors: Forest and Paper Products–Forestry, Timber, Pulp and Paper, Rubber / Food Production; Agricultural Production/ Food Production; Animal Source/ Food and Beverage Processing/ Food and Staples Retailing/Tobacco. **Or** if they have Companies with FLAG related emissions that total 20% or more of total emissions.

→ FLAG emissions

Guidance on accounting for FLAG emissions is provided by GHGP LSRG (currently in draft stage still). In essence, they relate to on-farm and forest activities, and they shall be divided in Land Use Change, Land Management and on farm fossil fuel (although the latter being optional).

→ FLAG Targets:

- FLAG target applied to separate FLAG inventory which covers emissions from the land sector up to farm and forest gate.
- On farm / in forest fossil emissions can be optionally included in FLAG target.
- Require a deforestation commitment.
- Requires FLAG emissions to be properly accounted. Completion of FLAG Annex. This entails that FLAG data ought to be separated from commodity group and sourcing region.
- Land use change emissions, land management and land-based removals ought to be disaggregated in the FLAG inventory.

4. IFRS

Subsumed TCFD and sets out the requirements for assessment and disclosure of climate related risks and opportunities. It seeks to establish a global baseline for voluntary sustainability (S1) and climate (s2) related risk and opportunity disclosure.

TCFD framework structuring information around 4 thematic areas design to reflect how companies operate: **governance**, **strategy**, **risk management**, **metrics and targets.** Superseded by ISSB in 2023 with IFRS, which follows the same pillars of TCFD framework, but do not just focus on climate, but sustainability risks and opportunities also.

Governance: The governance processes, controls and procedures the entity uses to monitor, manage and oversee sustainability/ climate-related risks and opportunities.

Strategy: The approach the entity uses to manage sustainability/ climate-related risks and opportunities.

Risk management: The processes the entity uses to identify, assess, prioritise and monitor sustainability/ climate-related risks and opportunities.

Metrics and targets: The entity's performance in relation to sustainability/ climate-related risks and opportunities, including progress towards any targets the entity has set or is required to meet.

IFRS S1: Metrics used by the entity to measure sustainability risks and opportunities and monitor its performance in relation to the them, including progress towards targets set and required to meet by any law or regulation. The Agricultural Products Sustainability Disclosure Standard requires companies to **measure and report** the following relevant topics and metrics:

→ **GHG emissions:** Global Scope 1 GHG emissions calculated according to GHG Protocol Corporate Standard; Short- and Long-term plans to manage Scope 1 GHG emissions, including reduction targets and performance; Fleet fuel consumption with percentage of renewable in Gigajoules (GJ).

→ **Energy management:** Total operational energy consumed, indicating how much has been supplied from grid electricity and how much was renewable, in Gigajoules (GJ).

→ **Water management:** Total water withdrawn from all water sources in thousands of cubic meters, indicating if significant portions of withdrawals come from non freshwater sources, and indicating the total amount of water consumed in operations (also in thousands of cubic meters); water management risks associated with withdrawals, consumption and discharge; short and long term strategies to mitigate such risks; number of incidents of non compliance related to water quality permits and standards and regulations.

→ **Environmental and social impact:** For agricultural products purchased from Tier 1 suppliers, percentage of agricultural products sourced that are certified to a third-party environmental or social standard, and percentages by standard; suppliers' non conformance rate with social and environmental audit standards (internal or external) and relative corrective action rate for non conformances.

→ **Ingredients sourcing:** Disclose principal crops that are a priority to the business and describe risks and opportunities presented by climate change (water availability , pest, extreme weather); disclose percentage of agricultural products sources from regions with high baseline water stress.

IFRS S2: Climate related targets aligning with GHG Protocol i.e. Scope 1,2,3 emissions, Scope 3 emissions categories, Requirements for target setting etc.

- S2 is similar to S1 but it has an explicit **climate focus** and explicitly requires companies to provide information on climate related risks and opportunities both physical and transitional, that can affect entity's cash flows, access to finance or cost of capital over short, medium or long term. S3 covering nature and biodiversity will be developed in the future.
- In terms of accounting, ISSB / IFRS defers to GHGP accounting requirements so the requirements of GHGP can be followed.
- IFRS S2 is interoperable with EFRAG (ESRS) – See CSRD slide further below in deck.

Metrics required to be measured

GHG emissions, Fuel use, Energy use, Water, Environmental and social impact. Other less relevant metrics, but required: Food Safety, GMO management.

5. Science based targets for nature (SBTN) land

- To align reporting with SBTN Land, organizations must assess and disclose their land-related impacts, dependencies, and risks while setting science-based targets to reduce land conversion and degradation. This involves following SBTN's five-step process—Assess, Interpret & Prioritize, Measure, Set Targets, and Act—to ensure measurable and actionable commitments toward sustainable land use.

MRV is covered by Step 5 in SBTN. **Currently no specific guideline is available for this Step.**

As an interim solution, companies setting targets in 2023 will use an action plan to outline implementation steps and progress monitoring. This plan can be refined after the 2024 validation pilot, ahead of full MRV guidance.

Monitoring and measurement approach depends on targets , scale (site, value chain...) and AR3-T action.

Monitoring & Measuring **CAN** include:

Table 5:Science based targets for nature (SBTN) land

Target scale	*Conversion*	*Target scale*	*Land footprint*	*Target scale*	*Land engagement*
Direct operations	Remediation of converted areas	Absolute	% of reduced land footprinting across upstream and direct operations	No scale	Initiative engaged in and improvements made
Upstream activities	Volumes sourced from conversion-free areas Remediation of converted areas	Intensity	% of reduced land footprinting across upstream and direct operations per unit		

6. Science based targets for nature (SBTN) freshwater

→ To align reporting with SBTN Freshwater, organizations must assess and disclose their freshwater-related impacts, dependencies, and risks while setting science-based targets to reduce freshwater pollution and use. This involves following SBTN's five-step process—Assess, Interpret & Prioritize, Measure, Set Targets, and Act—to ensure measurable and actionable commitments toward sustainable freshwater use.

MRV is covered by Step 5 in SBTN. **Currently no specific guideline is available for this Step.**

As an interim solution, companies setting targets in 2023 will use an action plan to outline implementation steps and progress monitoring. This plan can be refined after the 2024 validation pilot, ahead of full MRV guidance.

Monitoring and measurement approach depends on targets , scale (site, value chain...) and AR3-T action.

Monitoring & Measuring **CAN** include:

Table 6: Science based targets for nature (SBTN) freshwater

Target scale	*Freshwater use*	*Freshwater pollution*
Monthly target	Monthly water withdrawal	Monthly nutrient load (n or p)
Annual target	Annual water withdrawal	Monthly nutrient load (n or p)

7. Taskforce on nature-related financial disclosures (TNFD)

To align with TNFD, organizations must assess and disclose their nature-related risks and opportunities using the LEAP framework (Locate, Evaluate, Assess, and Prepare). They need to integrate nature-related considerations into governance, strategy, risk management, and metrics, similar to TCFD but focused on biodiversity and ecosystems. Alignment involves reporting on dependencies and impacts on nature, identifying material risks, and ensuring transparency in decision-making regarding nature-related financial risks.

Monitor: Aligning metrics with WBCSD's Regenerative Agriculture Vision include: 1) Total rehabilitated/restored area (km²) & Total disturbed area (km²); 2) Extent of land/freshwater/ocean ecosystem use change (km²); 3) Pollutants released to soil (tonnes); 4) Volume of water discharged (m³) & Water withdrawal and consumption (m³)

Reporting across four core pillars with descriptive statements which are encouraged to be supported by relevant DIRO as far as possible. It is aligned to TCFD, GBF and ISSB Standards. The four core pillars are:

a. **Governance:** Addresses the organization's oversight and management of nature-related issues. This includes the tasks: (A) Describe the board's oversight of nature-related dependencies, impacts, risks, and opportunities; (B) Describe management's role in assessing and managing nature-related dependencies, impacts, risks, and opportunities; (C) Describe the organization's human rights policies and engagement activities, and oversight by the board and management, with respect to Indigenous Peoples, Local Communities, affected and other stakeholders, in the organization's assessment of, and response to, nature-related dependencies, impacts, risks, and opportunities.

b. **Strategy:** Focuses on the actual and potential impacts of nature-related dependencies and risks on the organization's business model, strategy, and financial planning. This includes the tasks: (A) Describe the nature-related dependencies, impacts, risks, and opportunities the organization has identified over the short, medium, and long term.; (B) Describe the effect nature-related dependencies, impacts, risks, and opportunities have had on the organization's business model, value chain, strategy, and financial planning, as well as any transition plans or analysis in place. (C) Describe the resilience of the organization's strategy to nature-related risks and opportunities, taking into consideration different scenarios. (D) Disclose the locations of assets and/or activities in the organization's direct operations and, where possible, upstream and downstream value chain(s) that meet the criteria for priority locations.

c. **Risk and impact management:** Details the processes used to identify, assess, and manage nature-related risks and impacts. This includes the tasks: (A) Describe the organization's processes for identifying, assessing, and prioritizing nature-related dependencies, impacts, risks, and opportunities in its direct operations; (B) Describe the organization's processes for identifying, assessing, and prioritizing nature-related dependencies, impacts, risks, and opportunities in its upstream and downstream value chain(s). (C) Describe the organization's processes for managing nature-related dependencies, impacts, risks, and opportunities. (D) Describe how processes for identifying, assessing, prioritizing, and monitoring nature-related risks are integrated into and inform the organization's overall risk management processes.

d. **Metrics and targets:** Involves the metrics and targets used to assess and manage relevant nature-related risks and opportunities. This includes the tasks: (A) Disclose the metrics used by the organization to assess and manage material nature-related risks and opportunities in line with its strategy and risk management process. (B) Disclose the metrics used by the organization to assess and manage dependencies and impacts on nature. (C) Describe the targets and goals used by the organization to manage nature-related dependencies, impacts, risks, and opportunities and its performance against these.

Verify: TNFD recommends to verify secondary data by validating and ground-truthing proxies against location-specific nature-related data.

8. Corporate sustainability reporting directive (CSRD)

To align reporting with the CSRD, organizations must disclose ESG impacts using the European Sustainability Reporting Standards (ESRS). This includes conducting double materiality assessments, reporting on sustainability risks, opportunities, and impacts across the value chain, and ensuring data is assurable and audit-ready. Companies must integrate information into annual reports, following mandatory sector-specific and general disclosure requirements.

Monitor: Companies must track key environmental indicators such as soil carbon sequestration, water retention, biodiversity, pesticide use, and deforestation, aligning with the ESRS. No metrics and related units are prescribed. ESRS Subtopics covered by Regenerative Agriculture include:

- **Climate change adaption & mitigation**: (A) Carbon sequestration practices in soil and vegetation; (B) Greenhouse gas (GHG) emissions reductions from agricultural activities; (C) Adoption of climate-smart agriculture techniques, such as cover cropping and agroforestry and (D) Resilience strategies for extreme weather events.
- **Pollution of water, soil & living organisms and food resources**: (A) Reduction in chemical fertilizer and pesticide usage; (B) Implementation of integrated pest management (IPM) practices; (C) Contamination levels of water and soil due to agricultural runoff and (D) Steps taken to restore soil health through organic matter replenishment.
- **Water consumption & withdrawals**: (A) Total water usage and sources (e.g., groundwater, rainwater harvesting); (B) Water efficiency improvements through drip irrigation and soil moisture conservation; (C) Impact on local water tables and aquatic ecosystems and (D) Measures taken to prevent over-extraction and contamination of water sources.
- **Land use change & land degradation**: (A) Conversion of natural ecosystems into agricultural land; (B) Restoration efforts such as reforestation and habitat conservation; (C) Impact of land-use changes on biodiversity and carbon stocks and (D) Sustainable land management practices adopted.
- **Desertification**: (A) Percentage of land at risk of desertification; (B) Implementation of erosion control measures; (C) Soil restoration initiatives using organic amendments and (D) Use of drought-resistant crop varieties and sustainable grazing practices.
- **Soil sealing:** (A) Amount of agricultural land lost to non-agricultural uses; (B) Measures to mitigate soil sealing effects, such as permeable infrastructure; (C) Compensation efforts through afforestation or land conservation programs and (D) Soil regeneration techniques employed to restore productivity.
- **Adequate wages**: While environmental factors are central to regenerative agriculture, the social and economic dimensions are equally important. ESRS reporting requires organizations to track: (A) Compliance with fair wage regulations for farm workers; (B) Gender equality and inclusion in agricultural employment; (C) Worker safety standards and conditions and (D) Access to healthcare, education, and social benefits for agricultural laborers.

Report: Organizations must disclose regenerative agriculture practices, land-use changes, and nature-related risks in their annual sustainability reports, demonstrating alignment with double materiality (financial and impact materiality).

Verify: Independent third-party assurance ensures the reliability of reported data, with an evolving requirement from limited to reasonable assurance over time, ensuring credibility and accountability. After the Omnibus regulation assurance is expected to be limited only.

9. Corporate sustainability due diligence directive (CSDDD)

Monitoring:

- Integrate due diligence into **policies** & **risk management systems**: risk-based assessment.
- **Identify, assess and prioritize** actual or potential adverse human rights and **environmental impacts** in their operations and chains of activities (as per Omnibus proposed updates, due diligence limited to Tier 1 only, and Tier 2 if the company has information about adverse impacts occurring in tier 2+ suppliers). These will have to be identified through measures a given company chooses to assess compliance with its due diligence policies. **Prevent, mitigate or bring to an end** adverse impacts.

- **Provide remediation** where necessary. Specifically, in Articles 34,46,47,54 the regulation explicitly states the responsibility of companies to contribute to suppliers' living wages and incomes.
- Meaningfully **engage** with stakeholders (as per Omnibus proposed updates, scope of the supplier engagement should be limited to large suppliers i.e. 500 employees or more).
- Implement a robust **notification/complaints** mechanism.
- **Monitor** the effectiveness of measures taken – at least once every 5 years. This used to be yearly, with Omnibus to change to every 5 years minimum or ad hoc as needed.

Reporting:

- **Communicate** publicly on due diligence. Need to describe the company's approach to due diligence.
- Develop and implement a **climate transition plan** (Omnibus introduced 'implementation' to ensure alignment with CSRD).

Verification

- Entities shall obtain contractual assurance that it will ensure compliance with company's code of conduct (policy), AND that it will take appropriate measures to verify compliance.

10. Global reporting initiative (GRI)

- To align reporting with GRI, organizations must disclose sustainability impacts using the GRI Standards, which include universal, sector, and topic-specific standards. This involves identifying material topics, reporting on ESG impacts across the value chain, and ensuring transparency through stakeholder engagement. Companies must provide quantitative and qualitative disclosures on areas such as biodiversity, land use, and climate, ensuring comparability and accountability. Standards are structured in three components: (1) Universal Standards (GRI 1-3): These apply to all organizations and set the foundation for sustainability reporting, including disclosures on material topics and stakeholder engagement; (2) Sector Standards: These are industry-specific standards providing tailored guidelines for different sectors. Agriculture, aquaculture, and fishing industries must follow sector-specific reporting criteria; (3) Topic-Specific Standards: These cover particular sustainability issues, such as GRI 304 (Biodiversity), GRI 301 (Materials), and GRI 13, which specifically targets agriculture.

Monitor: Organizations must track key environmental indicators such as soil health, land conversion, pesticide use, and biodiversity impact, aligning with GRI 304 (Biodiversity) and GRI 301 (Materials). Metrics include (units are not prescribed):

- **Land use changes & restoration efforts (hectares converted/restored):** (A) Hectares of land converted from natural ecosystems to agriculture; (B) Land restoration initiatives, including afforestation and rewilding projects; (C) Sustainable land management practices to prevent deforestation and (D) Policies to protect high-conservation-value areas.
- **Soil health & carbon sequestration:** (A) Levels of soil organic carbon (SOC) as a measure of soil health; (B) Adoption of regenerative agriculture practices such as no-till farming and cover cropping; (C) Reduction in soil erosion and improvement in soil fertility and (D) Contribution to carbon sequestration through sustainable farming methods.
- **Pesticide & fertilizer reduction initiatives:** (A) Amount of synthetic fertilizers and pesticides used per hectare; (B) Implementation of integrated pest management (IPM) strategies; (C) Use of organic and natural soil amendments and (D) Reduction in agricultural runoff and impact on nearby water bodies.
- **Water consumption & management:** (A) Total water withdrawn for agricultural use; (B) Percentage of water recycled and reused; (C) Impact of irrigation practices on local water tables and (D) Measures to improve water efficiency and reduce contamination.

Report: Companies must disclose their impact on land use, soil regeneration, and sustainable farming practices through standardized GRI disclosures and publish in sustainability reports annually. Reporting formats include Standalone GRI Reports, Integrated Reports and GRI-Referenced Reports.

Verify: GRI encourages third-party assurance for sustainability data, but it is not mandatory. This approach helps businesses demonstrate progress in sustainable land management, soil carbon sequestration, and nature-positive farming, aligning with global sustainability goals.

Annex II:
List of all MRV approaches included

MRV approaches can be leveraged to measure impact across multiple indicators

Organizations should consider the opportunity to consolidate approaches across metrics and frameworks with opportunities to reduce data collection burden and avoid duplication of effort and investment.

Table 7: Leveraging MRV approaches across multiple regenerative agriculture and nature positive indicators

Core Indicator	*Field survey*	*SaaS & Tools*	*Connected & sensor technologies*	*Remote sensing*
Agricultural GHG emissions (total & per product)	■	■	■	■
Soil carbon sequestration	■	■	■	■
Total carbon sequestration	■	■		■
Natural/semi – natural habitat in agricultural land	■	■		■
Crop diversity	■	■		■
Pesticide risk	■	■		
Blue water	■	■	■	■
Nutrient loss	■		■	■
Farm net income	■	■		
Land / freshwater ecosystem use change	■	■		■
Land / freshwater ecosystem restored	■			■
Land / freshwater ecosystem conserved		■		■

It is likely a combination of MRV approaches is needed to scale

Organizations should consider a combination of primary and secondary data sources based on the decision (& ambition level) they are trying to make.

Organizations should consider a combination of primary and secondary data sources based on the decision (& ambition level) they are trying to make.

Table 8: Overview of the main and compatible hybrid MRV approaches per core indicator

Core indicator	*Specific approach*	*Field survey*	*Saas & tools*	*Connected & sensor technologies*	*Remote sensing*
Agricultural ghg emissions	Satellite emissions data analysis				
	Beyond carbon process-based models				
	Carbon calculator tools				
Soil carbon sequestration	Soil sampling				
	Portable soil spectrometer for in-field use				
	Process based soc modeling				
Total carbon sequestration	Gain loss or stock difference method				
	Ground based measurements				
	Remote sensing				
Natural/semi-natural habitat	Multispectral satellite imagery combined with land cover classification algorithms				
	Transect or plot-based surveys				
	Land use database				
Crop diversity	Multispectral satellite imagery combined with land cover classification algorithms				
	Agricultural census data				
	Farm input and plot inventories				
Pesticide risk	Farm input				
	Farm specific risk assessment				
	Lca models				
Nutrient loss	In-field soil & plant testing				
	Sensor-based fertilizer management				
	Nutrient levels assessed via rermote sensing				
Blue water	Farm input and water metering systems				
	Hydrological modeling				
	Combine satellite imagery with water stress data				
Farm net income	Primary farm economic data collection				
	Self reporting of farm economic data				
	Secondary databases				

Land / freshwater ecosystem use change	Multitemporal satellite-based land cover change detection				
	Transect or plot-based surveys				
	Historical land/water use databases				
Land / freshwater ecosystem restored	Vegetation index time-series				
	Field ecological surveys of restored sites				
Land / freshwater ecosystem conserved	Monitoring conservation areas via nat. Protected area boundaries				
	Protected area and conservation registry data				

Maximizing one measurement – field surveys

→ Field surveys are commonly used across many core indicators.

Table 9: overview of field survey specific approaches per core indicator

Core indicator	*Field survey specific approach*
Agricultural GHG emissions	Collecting farm activity data
Soil Carbon sequestration	Soil sampling
Total carbon sequestration	Ground based measurements
Natural/semi-natural habitat	Transect or plot-based surveys
Crop diversity	Farm input and plot inventories
Pesticide risk	Farm specific risk assessments
Nutrient loss	In-field soil & plant testing
Blue water	Farm input and water metering systems
Farm net income	Primary farm economic data collection
	Self reporting of farm economic data
Land / freshwater ecosystem use change	Transect or plot-based surveys
Land / freshwater ecosystem restored	Field ecological surveys of restored sites

Maximizing One Measurement – Remote sensing

→ Remote sensing is used in the majority of core indicators.

Table 10: Overview of remote sensing specific approaches per core indicator

Core indicator	*Remote sensing specific approach*
Agricultural GHG emissions	Satellite emissions data analysis
Total carbon sequestration	Optical remote sensing
	Active remote sensing
Natural/semi-natural habitat	Multispectral satellite imagery combined with land cover classification algorithms
Crop diversity	Multispectral satellite imagery combined with land cover classification algorithms
blue water	Combine satellite imagery with water stress data
Land / freshwater ecosystem use change	Multitemporal satellite-based land cover change detection
Land / freshwater ecosystem restored	Vegetation index time-series
Land / freshwater ecosystem conserved	Monitoring conservation areas via nat. Protected area boundaries
	Protected area and conservation registry data

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Any mention, or non mention, of specific models, tools, platforms, case studies in this guidance document is not an endorsement or judgement on specific tools or proprietary technology.

This guidance document has been prepared with the aim of aiding companies in decision-making process. Companies should do further due diligence and consult with experts for assuring they are using the tools and approaches correctly and in the right use cases.

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Throughout the report, a series of case studies are featured. Through these stories, we aim to highlight our members' commitment to advancing the transition to regenerative agricultural practices and the impact they are making.

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