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Banking Targets in Primary Agriculture and Food Production: Financial Strategies for Sustainable Transition

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ABSTRACT

Primary agriculture is central to Europe's sustainability transition yet remains a significant source of biogenic greenhouse gases, biodiversity loss, soil degradation, and water stress. Financial institutions have moved to the forefront of this transition as supervisors, standard setters, and markets increasingly require sector-specific strategies, robust disclosure, and demonstrable real-economy outcomes. This thesis investigates how banks can define and operationalize effective key performance indicators (KPIs) to steer capital toward credible agricultural decarbonization and nature-positive pathways while complying with the European Green Deal, Farm to Fork, the reformed Common Agricultural Policy (CAP), the EU Regulation on deforestation-free products, and the prudential and disclosure framework formed by CRR III/CRD VI, the EBA Guidelines on ESG risks, and the CSRD/ISSB baseline. Building on a comprehensive literature and policy review, the study develops a KPI architecture that integrates exposure and governance measures, transition-input and capex indicators, and outcome metrics covering financed emissions with explicit methane treatment, soil health and water productivity, biodiversity, and deforestation-free verification. An empirical benchmarking of Intesa Sanpaolo, Crédit Agricole, and BNP Paribas assesses current agricultural strategies and disclosed metrics against this architecture, with particular emphasis on short-term (three- to five-year) implementability, alignment with SBTi FLAG, TPT/ACT transition-plan elements, and inclusion mechanisms that stabilize farmer incomes and avoid smallholder exclusion under supply-chain regulation. The thesis contributes conceptually by bridging agricultural policy, prudential supervision, and standards into a single governance spine for banks; empirically by identifying critical gaps in current practice; and practically by proposing implementable KPIs and product features that can be embedded in risk appetite, underwriting, and pricing. The findings offer a pathway for financial institutions to align portfolio steering with climate-nature objectives while enhancing the resilience and competitiveness of Europe's primary farming systems.

Table of Contents

ABBREVIATION

3-NOP: 3-Nitrooxypropanol

ACT: Assessing Low-Carbon Transition (ADEME)

ADEME: Agence de la transition écologique (French Environment & Energy Agency)

AD: Anaerobic Digestion

APCNF: Andhra Pradesh Community-managed Natural Farming

CAP: Common Agricultural Policy

CBI: Climate Bonds Initiative

CH_4: Methane

CO_2: Carbon Dioxide

CRD VI: Capital Requirements Directive VI

CRR III: Capital Requirements Regulation III

CSRD: Corporate Sustainability Reporting Directive

EBA: European Banking Authority

EGD: European Green Deal

ESG: Environmental, Social and Governance

ESRS: European Sustainability Reporting Standards

EUDR: EU Deforestation Regulation

F2F: Farm to Fork Strategy

FAO: Food and Agriculture Organization of the United Nations

FLAG: Forest, Land and Agriculture (SBTi)

GAEC: Good Agricultural and Environmental Conditions

GHG: Greenhouse Gases

GHG Protocol: Greenhouse Gas Protocol

ICAAP: Internal Capital Adequacy Assessment Process

IFRS S1/S2: International Financial Reporting Standards (Sustainability/Climate) by ISSB

IoT: Internet of Things

ISSB: International Sustainability Standards Board

KPI: Key Performance Indicator

LEAP: Locate, Evaluate, Assess, Prepare (TNFD)

MRV: Monitoring, Reporting and Verification

N_2O: Nitrous Oxide

NBS: Nature-based Solutions

NZBA: Net-Zero Banking Alliance

PCAF: Partnership for Carbon Accounting Financials

SBTi: Science-Based Targets initiative

SLL: Sustainability-Linked Loan

SOC: Soil Organic Carbon

TCFD: Task Force on Climate-related Financial Disclosures

TNFD: Taskforce on Nature-related Financial Disclosures

TPT: UK Transition Plan Taskforce

WBA: World Benchmarking Alliance

WBCSD: World Business Council for Sustainable Development

WFD: Water Framework Directive

ZBNF: Zero-Budget Natural Farming

INTRODUCTION

Primary agriculture—comprising crop cultivation and livestock rearing for food, fibre, and bio-based raw materials—sits at the fulcrum of the sustainability transition. It is both a vital source of livelihoods and food security and a major locus of environmental pressure, from biogenic greenhouse gases and land-use change to biodiversity loss, soil degradation, and water stress. Over the past decade, finance has moved from the periphery to the centre of this transition. Banks now face converging expectations to decarbonise portfolios, manage nature-related risks, and demonstrate real-economy impact, even as their clients in farming and agri-food navigate volatile markets, tightening regulation, and uneven data and monitoring capacity. This thesis examines how financial institutions can design and implement decision-useful key performance indicators (KPIs) that steer capital toward credible agricultural transition pathways while meeting emerging supervisory, disclosure, and market standards.

The research context is shaped by three dynamics. First, the decarbonisation of primary farming has become integral to corporate transition plans and bank portfolio strategies because agricultural emissions are dominated by non-CO_2 gases and land-use change, which require sector-specific levers rather than energy-sector analogies. Second, the European Union has assembled a dense policy architecture—centred on the European Green Deal and the Farm to Fork Strategy and operationalised through the reformed Common Agricultural Policy (CAP)—that links farm income support to environmental outcomes and strengthens expectations on biodiversity, soil health, and water stewardship. Trade-and-environment instruments, most notably the EU Regulation on deforestation-free products (EUDR), extend accountability upstream by requiring due diligence and geolocation-anchored traceability for key commodities. Third, the prudential and disclosure landscape for banks has matured: the Capital Requirements Regulation (CRR III) and Directive (CRD VI), the European Banking Authority's Guidelines on ESG risks, and the Corporate Sustainability Reporting Directive (CSRD) collectively push institutions to integrate climate and environmental risks into governance and risk management, and to disclose progress with a double-materiality lens. Voluntary and market standards complement these frameworks. The Science-Based Targets initiative's FLAG guidance mandates land-sector-specific target-setting and no-deforestation commitments; the ISSB provides a global baseline for climate disclosure; the Transition Plan Taskforce (TPT) and ADEME's ACT framework define the elements of credible transition plans and forward-looking alignment; TNFD supplies a location-based approach to nature-related risk and opportunity; and the Climate Bonds Initiative clarifies criteria for agriculture and forestry instruments. Together, these developments elevate the role of banks from passive capital providers to active transition enablers.

Against this backdrop, the thesis asks a central research question: how can financial institutions define and implement effective KPIs—embedded in their transition governance—that support the climate and environmental transition of the primary farming sector while aligning with sustainability regulation, the CAP, and innovation in agribiotech and the wider bioeconomy? The underlying premise is that credible KPIs for agriculture must be sector-specific, operational in the near term, and capable of linking client-level practice change to portfolio-level risk management and target-setting. They should combine backward-looking measures that validate performance trends with forward-looking indicators that test plan credibility and capital-expenditure alignment. They must also extend beyond carbon to include nature outcomes—biodiversity, soils, water—and supply-chain integrity, including deforestation-free verification.

The objectives flow directly from this question. First, the thesis identifies a coherent set of KPIs that can support net-zero and broader environmental transitions in primary farming, with particular attention to methane management, land-use change, soil health, water productivity, and biodiversity. Second, it analyses how agricultural policy instruments, especially the CAP's conditionality and eco-schemes, can be integrated with EU financial regulation and supervisory guidance so that banking products and covenants reinforce policy goals rather than merely report on them. Third, it assesses the contribution of agribiotech and the bioeconomy—encompassing improved breeding, biological inputs, digital MRV, and circular resource use—to decoupling productivity from environmental pressure and considers the implications for bankable transition levers. Finally, it evaluates how KPIs can illuminate risk drivers for EU financial institutions by improving the identification, measurement, and management of both transition and physical risks in agricultural portfolios, including collateral sensitivity to soil and water conditions and counterparty exposure to supply-chain regulation such as the EUDR.

The contribution of the thesis is threefold. Conceptually, it bridges agriculture policy, prudential supervision, and standard-setting to specify what "good" looks like for bank KPIs in a land-based sector, explicitly addressing methane, land-use change, biodiversity, water, and soils alongside carbon. Empirically, it provides a comparative assessment of leading European banks' agriculture strategies and metrics, identifying where practices align with the literature and policy signal and where critical gaps persist, for example in FLAG integration, nature outcomes, soil and water considerations in collateral and underwriting, and just-transition mechanisms that stabilise farmer incomes during adoption. Practically, it translates these insights into an implementable KPI set and associated governance, engagement, and product features that can be adopted within three to five years and progressively tightened as data quality and policy clarity improve. The approach emphasises feasibility and verifiability—using conditionality linked to CAP eco-schemes, time-bound milestones for geolocation-based traceability, ring-fenced credit for practice adoption such as manure management, precision nutrient management, cover crops, agroforestry, and peatland rewetting, and measurable soil and water indicators—while aligning with supervisory expectations and disclosure standards.

The thesis is organised as follows. Chapter 1 develops the theoretical framework and literature review, defining primary farming and situating it within EU policy, trade-and-environment measures, and the innovation agenda, before turning to financial-sector governance and the standards ecosystem that underpins credible transition plans and metrics. Chapter 2 analyses the drivers and issues that shape KPI design, covering climate and environmental performance, nature and deforestation, and the social dimensions of a just transition, including farmer income stability and the enabling roles of agribiotech, the bioeconomy, and nature-based solutions. Chapter 3 presents the empirical analysis, reviewing the literature on agricultural KPIs, assessing the targets and metrics disclosed by the three banks, and proposing a sector-specific KPI architecture that balances backward-looking, point-in-time, and forward-looking indicators with an emphasis on short-term implementability in the EU context. Chapter 4 conducts a gap analysis that compares banking frameworks with agricultural sector needs, identifies discrepancies and risk drivers, and offers policy and managerial recommendations to improve banks' strategies for the sector. The conclusion reflects on implications for supervisors, policymakers, and industry practitioners and outlines avenues for future research, including the integration of emerging soil-monitoring data, biodiversity and water metrics into credit processes, and the scaling of inclusive traceability to meet EUDR obligations without excluding smallholders.

In conclusion, by integrating agricultural science, EU policy, prudential supervision, and market standards into a single analytic frame, the thesis develops a practical, standards-aligned KPI system that can help financial institutions steer capital to credible, inclusive pathways for decarbonising and restoring Europe's primary farming systems.

METHODOLOGY

This thesis adopts a staged, mixed-methods design that moves from problem definition to comparative evidence and, finally, to an operational framework for banks. The analytical focus is the EU context and a pragmatic time horizon of three to five years, reflecting the implementation cadence of CSRD/ESRS, CRR III/CRD VI, EUDR and CAP eco-schemes.

The study begins with a structured literature review to define the sectoral boundaries of primary agriculture—crop and livestock production at farm level and the immediate interfaces that are financeable by banks (on-farm capex, working capital, input efficiency, manure and nutrient management, and practice changes such as cover crops, agroforestry and peatland rewetting). Within this scope, the review consolidates the climate and environmental drivers that are material for European banking: biogenic greenhouse gases (carbon dioxide from land-use change, methane from enteric fermentation and manure, nitrous oxide from soils), deforestation and conversion risks, water stress and nutrient loss, biodiversity decline, and soil health (including soil organic carbon and erosion). The output of this stage is a clear mapping of "real-economy levers" that banks can finance and monitor.

Next, a regulatory and policy review situates these drivers within the EU governance architecture. The analysis covers the European Green Deal and Farm to Fork Strategy, the reformed Common Agricultural Policy (conditionality/GAEC and eco-schemes), the EU Regulation on deforestation-free products, and emerging soil and biodiversity frameworks. On the financial side, it examines CRR III/CRD VI, the EBA Guidelines on ESG risks, CSRD/ESRS and the ISSB baseline, together with transition and nature standards used in practice (SBTi FLAG, TPT, TNFD, Climate Bonds Initiative). This stage distils compliance baselines and credibility tests that any banking KPI system must meet, ensuring that subsequent recommendations are standards-coherent and supervisor-relevant.

The empirical core is a comparative sector analysis of three European banking groups with material agriculture exposure—HSBC, Rabobank and BNP Paribas. Public documents are collected for the 2021–2025 reporting window: annual and sustainability reports, climate and transition-plan disclosures, NZBA/SBTi updates, nature/TNFD pilots where available, sector policies (e.g., deforestation/soft commodities), product frameworks and second-party opinions for labelled instruments. Independent sources such as BankTrack profiles and topic briefs are used to triangulate claims. Disclosures are coded against a common rubric aligned to the literature and standards across four evidence families: (i) exposure and governance (coverage of client transition plans, sector-specific risk appetite, board oversight and escalation pathways); (ii) transition inputs and capex (lending or investment explicitly tied to practice levers and capex alignment tests); (iii) performance (backward-looking and trend metrics for financed emissions with explicit methane treatment, nature outcomes—including hectares under verified practices, soil organic carbon change and water-productivity proxies—and deforestation-free verification/geo-traceability); and (iv) policy/standard alignment (use of SBTi FLAG, TPT/ACT plan elements, TNFD-consistent nature governance, and integration of CAP/EUDR requirements into eligibility, covenants and pricing). Each item is graded on an ordinal credibility scale: absent; narrative only; process evidence; quantitative targets; assured/externally verified.

Building on the literature, policy baselines and benchmarking evidence, the thesis then identifies a bankable KPI architecture for primary agriculture. KPIs are formulated to link farm-level practice change to portfolio steering and are grouped—without bulleting in the main text—into exposure/governance indicators, transition-input/capex indicators, and outcome indicators for climate and nature, complemented by alignment tests to recognised standards. Selection prioritises short-term implementability with today's data systems: for example, proportion of exposure with TPT-consistent client plans; share of new/renewed lending ring-fenced to named practice levers (manure treatment/AD, precision nutrient management, methane-reduction technologies, cover crops, agroforestry, peatland rewetting); coverage of EUDR-ready geo-traceability for exposed commodities; and backward-looking validation via financed-emissions trends (with methane breakout), verified hectares under practices, soil organic carbon change where measured, and water-productivity proxies in stressed basins.

In parallel, sectoral solutions are catalogued and linked to financeable instruments. Agritech solutions (digital MRV, precision fertigation, controlled-manure systems, feed additives, improved genetics) and nature-based solutions (agroforestry, riparian buffers, peatland rewetting, cover crops, habitat features) are translated into loan purposes, eligibility conditions and covenantable performance tests. For each solution, feasible verification routes (certifications, remote sensing, supplier systems, third-party assurance) are identified so that KPIs can be evidenced without imposing impractical data burdens on smaller clients.

The relevance of KPIs and solutions for banks' strategies and risk drivers is then assessed by mapping each indicator to risk appetite, underwriting and pricing levers. This includes credit-policy hooks (eligibility/conditionality tied to CAP eco-schemes, GAEC and EUDR compliance), product design (transition loans and sustainability-linked loans with KPI ratchets), portfolio steering (targets by subsector and geography) and disclosure (CSRD/ESRS and ISSB readiness). Particular attention is paid to risk channels that are often under-recognised in agriculture: income volatility during practice adoption, collateral sensitivity to soil and water risks, and legal/market risks from deforestation-free requirements.

Finally, a gap analysis compares observed bank practice with the proposed KPI frontier and with sector needs. Gaps are classified as standards gaps (e.g., incomplete FLAG or TNFD treatment), data/MRV gaps (e.g., reliance on generic factors rather than verified practice data), product/governance gaps (e.g., weak conditionality or escalation pathways), and inclusion gaps (e.g., insufficient blended-finance for smallholders and co-operatives). The chapter concludes with recommendations that are immediately actionable within the three-to-five-year horizon: priority KPIs to adopt, verification routes to use, product tweaks to embed (eligibility, ratchets, grace periods and risk-sharing), and data partnerships to close the MRV gap. Limitations—chiefly the reliance on public disclosures and portfolio-level proxies where farm-level data are unavailable—are made explicit to bound interpretation and to indicate where supervisory or industry collaboration is needed to advance measurement.

LITERATURE REVIEW

Primary Farming, Sustainability Pressures, and Evolving EU Policy

Primary farming—defined as the cultivation of crops and the rearing of livestock for food, fibre, and bio-based raw materials—sits at the heart of Europe's agri-food systems. It underpins rural livelihoods and food security but also contributes disproportionately to climate forcing and environmental degradation. Emissions from enteric fermentation, manure, and nitrogen fertiliser use, together with land-use change, position agriculture as a key driver of methane, nitrous oxide, and biogenic carbon fluxes. At the same time, biodiversity loss, soil degradation, and water stress linked to intensive production systems have placed agriculture at the centre of debates on transgressed planetary boundaries.

Over the past decade, EU policy has moved progressively toward this reconciliation. The European Green Deal and the Farm to Fork Strategy establish the overarching direction of travel—reduced chemical inputs, greater resilience of food systems, and climate neutrality by 2050. The Common Agricultural Policy reform operationalises this through conditionality, eco-schemes, and performance-based rural development measures, tying income support to soil cover, nutrient balance, biodiversity features, and water protection. Complementary frameworks—the Biodiversity Strategy for 2030, the Water Framework and Nitrates Directives, and the emerging EU Soil Monitoring Law—reinforce this shift by setting measurable environmental obligations and monitoring standards. These policies effectively define the environmental baselines that financial institutions must now incorporate into their credit policies, collateral valuation, and risk management.

Trade and market regulations add a global dimension. The EU Deforestation Regulation requires operators and traders to demonstrate geolocation-based traceability for high-risk commodities and their derivatives, covering both legal and illegal deforestation after the 2020 cut-off. For financial institutions, this translates into heightened due-diligence expectations for supply-chain exposures. Traceability and compliance costs, if left unfinanced, risk excluding smallholders; conversely, banks that mobilise credit for inclusive traceability and landscape partnerships can reduce portfolio risk while supporting policy alignment. Similarly, the EU's soil policy agenda now equips lenders with comparable indicators of soil condition, erosion risk, and restoration liabilities, which can be integrated into collateral and underwriting, reinforcing the case for soil-organic-carbon and erosion-related KPIs in agricultural finance.

The innovation agenda supplies a further lever. The EU bioeconomy strategy highlights agribiotech, biological inputs, and circular resource use as instruments for lowering input dependence and emissions intensity, while nature-based solutions—agroforestry, peatland rewetting, cover crops, and riparian buffers—are recognised for their multi-functional benefits across carbon, water, and biodiversity. Digitalisation through remote sensing, telemetry, and farm management platforms is positioned as the backbone of monitoring, reporting, and verification, underpinning both policy compliance and performance-based finance.

Financial Institutions as Transition Enablers

For banks, these policy shifts intersect directly with prudential regulation and disclosure requirements. The CRR III/CRD VI package strengthens the expectation that environmental risks are integrated into governance, ICAAP, and strategy. The EBA's Guidelines on the Management of ESG Risks formalise supervisory demands for climate- and nature-related risk integration across short-, medium-, and long-term horizons, requiring banks to evidence resilience through credible transition plans. The ECB's Climate and Nature Plan further highlights agriculture as a sector where both transition and physical risks are material, pushing supervisors to test whether banks can provide measurable, sector-specific evidence of resilience.

Disclosure obligations reinforce this trajectory. The CSRD and European Sustainability Reporting Standards embed double materiality into reporting, mandating disclosure of both financial risks and environmental impacts across emissions, biodiversity, soils, and water. At the international level, the ISSB's IFRS S1 and S2 standards set a global baseline for climate- and sustainability-related disclosure. For agriculture, these requirements imply that banks cannot rely on generic financed-emissions metrics but must integrate practice-level KPIs into credit processes in order to populate portfolio disclosures. Voluntary alliances amplify this: the Net-Zero Banking Alliance requires members to set sectoral decarbonisation pathways, with agriculture singled out for its methane and land-use profile.

Together, these frameworks reposition banks as transition enablers. They are expected not only to avoid financing harmful practices but to actively steer capital toward climate- and nature-aligned farming systems. This expectation makes the operational integration of KPIs into origination, underwriting, monitoring, and disclosure a supervisory and strategic priority.

From Standards to Bankable KPIs

Standards have matured rapidly to provide methodological clarity for land-based sectors. The SBTi's FLAG guidance requires dedicated agricultural targets covering methane, land-use change, and soil carbon, together with no-deforestation commitments. The GHG Protocol's Land Sector and Removals Guidance, moving through finalisation, adds accounting clarity for soils, biomass, and carbon removals. The Transition Plan Taskforce provides an interoperable template for credible transition plans, emphasising governance, capital alignment, and milestones. The Taskforce on Nature-related Financial Disclosures introduces a location-based LEAP framework that integrates biodiversity and water, aligning with the Kunming–Montreal Global Biodiversity Framework. Finally, the Climate Bonds Initiative and sectoral taxonomies clarify eligibility thresholds for agricultural and forestry finance, establishing MRV expectations for sustainability-linked products.

These standards collectively argue for KPI systems that are sector-specific, empirically tractable, and forward-looking. Leading indicators—such as the proportion of clients with compliant transition plans, exposure under CAP-linked conditionality, or capex aligned to practice adoption—signal near-term feasibility. Lagging indicators—such as methane intensity, hectares under regenerative practices, soil-carbon change, water productivity, and deforestation-free verification—provide outcome tests that anchor disclosures. Embedding both climate and nature outcomes avoids single-metric "carbonism" and aligns financial practice with the integrated logic of EU policy.

Synthesis

The convergence of policy, supervision, disclosure, and voluntary standards now provides banks with both the mandate and the tools to embed sector-specific KPIs into their agricultural portfolios. EU policy defines what must change on farms; prudential regulation and disclosure rules define how banks must evidence risk management and alignment; and international standards supply methodologies for making these elements interoperable. The practical implication is clear: banks must move from headline commitments to KPI-anchored credit lifecycles that synchronise repayment with biological rhythms, link covenants to measurable practice adoption, and aggregate results into supervisor-ready disclosures.

The next empirical chapters test this proposition by benchmarking leading European banks against these requirements, assessing whether the KPIs they deploy capture the levers—methane reduction, soil health, water stewardship, biodiversity, and deforestation-free traceability—that agronomy and policy identify as decisive for a credible agricultural transition.

CHAPTER 1 – THEORETICAL FRAMEWORK AND LITERATURE REVIEW

1.1. Agriculture-Related Policy and REFERENCE Frameworks

The sustainability of modern agriculture represents a complex intersection of environmental, social, and economic challenges, demanding coordinated policy responses and evidence-based governance frameworks. This chapter explores the theoretical foundations and key literature surrounding agricultural sustainability, with a focus on the European Union's regulatory landscape, strategic initiatives, and policy instruments. Section 1.1 examines agriculture-related policy frameworks, ranging from the European Green Deal and the Farm to Fork Strategy to biodiversity, soil, and water management policies, highlighting how these measures aim to reconcile productivity with ecological stewardship and climate resilience. By situating these policies within a broader literature review, this section provides the necessary context for understanding the interplay between regulatory frameworks, innovation, and sustainable practices in the agricultural sector.

1.1.2 The European Green Deal and the Farm to Fork Strategy

The European Green Deal (EGD), unveiled by the European Commission in 2019, represents the cornerstone of the European Union's long-term vision for a sustainable, climate-neutral economy by 2050. As an overarching policy framework, the EGD integrates climate action, environmental protection, and economic growth, framing them as interdependent objectives in the transition towards sustainability (European Commission, 2019)[1]. At the heart of this agenda lies the recognition that food systems—responsible for significant greenhouse gas emissions, biodiversity loss, and resource depletion—must undergo profound transformation to align with climate and environmental goals.

Within this broader context, the Farm to Fork Strategy (F2F), launched in 2020, serves as the EU's dedicated roadmap for achieving a sustainable and resilient agri-food system. It seeks to address the entire food value chain, from production to consumption, by setting forth ambitious targets aimed at reducing environmental pressures and enhancing public health outcomes. Among its key objectives are a 50% reduction in the overall use of chemical pesticides, a 20% decrease in fertilizer application, and an expansion of organic

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[1] European Commission. (2019). *The European Green Deal*. COM(2019) 640 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640

farming practices to cover at least 25% of the EU's agricultural land by 2030 (European Commission, 2020)[2]. Furthermore, the strategy emphasizes the need for improved animal welfare standards, reduced food waste, and strengthened sustainability labelling to empower consumers in making informed choices.

However, the F2F Strategy has been subject to critical scrutiny regarding its feasibility, socio-economic consequences, and global ramifications. Concerns have emerged among stakeholders in the agricultural sector, policymakers, and scholars about the potential trade-offs between environmental ambitions and agricultural productivity. A key criticism is that strict input reduction targets may adversely impact crop yields, particularly in intensive farming systems, thereby increasing the EU's dependency on food imports from countries with potentially lower environmental standards (Benton et al., 2021)[3]. Such an outcome, often referred to as "leakage," risks externalizing environmental degradation rather than mitigating it within the EU's borders.

Moreover, the voluntary nature of some of the strategy's components and the absence of binding national targets have raised questions about the consistency and effectiveness of its implementation across member states. The heterogeneity of agricultural systems within the EU—ranging from highly industrialized farms to small-scale family agriculture—further complicates the uniform adoption of the strategy's guidelines. Scholars have argued that without clear enforcement mechanisms and supportive economic incentives, the transformative potential of the F2F Strategy may remain unrealized (Pe'er et al., 2020)[4].

Despite these challenges, the Farm to Fork Strategy is widely acknowledged as a significant policy innovation in the realm of sustainability governance. By embedding its objectives within the broader commitments of the European Green Deal, the strategy contributes directly to the realization of several United Nations Sustainable Development Goals (SDGs), notably SDG 2: Zero Hunger and SDG 12:

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[2] European Commission. (2020). *The Just Transition Mechanism: Making sure no one is left behind*. Brussels. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en

[3] Benton, T. G., Bailey, R., Froggatt, A., King, R., Lee, B., & Wellesley, L. (2021). *Food system impacts on biodiversity loss*. Chatham House - The Royal Institute of International Affairs. https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss

[4] Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., … & Lakner, S. (2020). A greener path for the EU Common Agricultural Policy. *Science*, 365(6452), 449-451. https://doi.org/10.1126/science.aax3146

Responsible Consumption and Production (United Nations, 2015)[5]. Its integrated approach underscores the interlinkages between food security, environmental sustainability, and public health—an essential perspective in global efforts to promote sustainable development.

In conclusion, the Farm to Fork Strategy represents a cornerstone of the EU's efforts to transition toward a sustainable and resilient agri-food system, balancing environmental objectives, food security, and socio-economic equity. By promoting reductions in chemical inputs, expanding organic farming, and fostering sustainable production and consumption patterns, the strategy directly addresses key pressures on European ecosystems. However, its success is closely tied to biodiversity outcomes, as sustainable food production cannot be achieved without preserving the ecological integrity of agricultural landscapes. The EU Biodiversity Strategy for 2030 complements the Farm to Fork approach by embedding nature-positive practices—such as crop diversification, habitat restoration, and Ecological Focus Areas—into farm management. Together, these strategies underscore that achieving a truly sustainable and climate-resilient food system requires the integration of production efficiency with biodiversity protection, ensuring that agricultural intensification does not come at the expense of ecosystem health.

1.1.4 Biodiversity Conservation in Agricultural Landscapes

Biodiversity loss is a defining challenge of the Anthropocene, with profound implications for ecosystem resilience, food security, and human well-being. Among the multitude of anthropogenic drivers, agricultural expansion stands out as the single most significant cause of biodiversity decline globally. It is estimated that agriculture accounts for nearly 80% of global deforestation, contributing directly to habitat destruction, ecosystem fragmentation, and species extinction (IPBES, 2019)[6]. The intensification of agricultural practices—often characterized by monocultures, high chemical inputs, and mechanized operations—has further exacerbated pressures on biodiversity, reducing landscape heterogeneity and undermining ecosystem services critical for sustainable food production.

In response to these mounting challenges, the EU Biodiversity Strategy for 2030 was adopted as a key component of the European Green Deal. The strategy envisions a transformative shift towards nature-

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[5] United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. UN General Assembly Resolution A/RES/70/1. https://sdgs.un.org/2030agenda

[6] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. IPBES Secretariat. https://ipbes.net/global-assessment

positive agriculture, emphasizing agroecological practices aimed at restoring ecological balance within farmed landscapes (European Commission, 2021)[7]. Among the measures promoted are crop diversification, the restoration of hedgerows and buffer strips, and the establishment of Ecological Focus Areas (EFAs)—designated portions of farmland set aside for conservation purposes. These interventions are designed to enhance habitat connectivity, support pollinator populations, and strengthen the resilience of agro-ecosystems in the face of climate change.

However, the success of biodiversity-oriented agricultural policies hinges upon navigating the long-standing and often polarized debate between land sparing and land sharing paradigms. The land sparing approach advocates for maximizing agricultural yields on existing farmland through intensification, thereby reducing the pressure to convert natural habitats for agricultural use. Proponents argue that sparing large tracts of land for conservation purposes is the most effective way to protect biodiversity in high-biodiversity regions (Fischer et al., 2014)[8]. Conversely, the land sharing model promotes the integration of biodiversity conservation within productive agricultural landscapes, favouring low-intensity, wildlife-friendly farming systems that aim to maintain both agricultural output and ecological integrity (Tscharntke et al., 2021)[9].

Empirical research reveals that neither paradigm offers a universally applicable solution. Instead, context-specific strategies appear essential, as the ecological effectiveness of land sparing versus land sharing varies according to factors such as local biodiversity richness, land-use history, agricultural practices, and socio-economic conditions (Phalan et al., 2011)[10]. For instance, in regions with high biodiversity and limited land availability, land sparing may provide superior conservation outcomes, whereas in multifunctional landscapes or areas with smallholder-dominated agriculture, land sharing approaches may offer more viable pathways to sustainability.

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[7] European Commission. (2021). *EU Biodiversity Strategy for 2030 (COM(2020) 380 final).* https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

[8] Fischer, J., Abson, D. J., Butsic, V., Chappell, M. J., Ekroos, J., Hanspach, J., … von Wehrden, H. (2014). Land sparing versus land sharing: Moving forward. *Conservation Letters, 7*(3), 149–157. https://doi.org/10.1111/conl.12084

[9] Tscharntke, T., Clough, Y., Wanger, T. C., et al. (2012). Global food security, biodiversity conservation and agricultural intensification. *Biological Conservation, 151*(1), 53–59. https://www.sciencedirect.com/science/article/abs/pii/S0006320712000821

[10] Phalan, B., Onial, M., Balmford, A., & Green, R. E. (2011). Land sharing vs. land sparing. *Science, 333*(6047), 1289–1291. https://doi.org/10.1126/science.1208742

The recognition of this complexity is increasingly reflected in EU policy discourse, which emphasizes adaptive management, stakeholder engagement, and the tailoring of interventions to local contexts. Furthermore, the integration of biodiversity objectives into the Common Agricultural Policy (CAP)—particularly through eco-schemes and agri-environmental measures—represents an attempt to reconcile agricultural production with conservation goals. Nevertheless, the effective implementation of these measures requires robust monitoring frameworks, adequate financial incentives for farmers, and coherent policy alignment at both EU and national levels.

In conclusion, biodiversity conservation in agricultural landscapes is both an ecological necessity and a policy challenge. Agriculture remains the primary driver of biodiversity loss, yet it also holds significant potential to serve as a vehicle for ecological restoration when managed through nature-positive and context-specific approaches. The EU Biodiversity Strategy for 2030, together with CAP reforms, represents a crucial step toward embedding biodiversity goals into agricultural policy. However, realizing these ambitions requires reconciling competing land-use paradigms, ensuring adequate support for farmers, and fostering adaptive governance that aligns local practices with broader sustainability objectives. Importantly, the protection of biodiversity cannot be pursued in isolation: it is intrinsically linked to the sustainable management of natural resources such as water. Agricultural practices that degrade biodiversity often exacerbate water scarcity and pollution, while nature-positive farming can enhance water retention, soil health, and ecosystem resilience. This interdependence underscores the need to view biodiversity and water resource management as complementary pillars of sustainable agriculture—a theme further explored in the next section.

1.1.5 Water Resource Management in Agriculture

Water is an indispensable input in agricultural production, serving critical roles in irrigation, livestock management, and crop processing. Globally, the agricultural sector accounts for approximately 70% of total freshwater withdrawals, making it the largest water-consuming sector (WWAP, 2021)[11]. This high demand poses significant sustainability challenges, particularly in regions facing water scarcity, competition among sectors, and the adverse effects of climate change. The over-extraction of water for irrigation contributes not only to the depletion of surface and groundwater resources but also to ecological degradation, including soil salinization, habitat loss, and reduced water quality.

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[11] World Water Assessment Programme (WWAP). (2021). *The UN World Water Development Report 2021: Valuing water.* UNESCO.https://www.unesco.org/reports/wwdr/2021/en

In recognition of these challenges, the European Union Water Framework Directive (WFD)—Directive 2000/60/EC—was adopted to establish a comprehensive framework for sustainable water management within the EU. The WFD aims to achieve "good status" for all water bodies through integrated river basin management, emphasizing pollution control, water efficiency, and stakeholder participation (European Parliament & Council, 2000)[12]. Key provisions relevant to agriculture include the regulation of diffuse nitrate pollution under the Nitrates Directive and the promotion of sustainable irrigation practices designed to reduce water abstraction pressures (Pahl-Wostl, 2015)[13]. These regulatory mechanisms are complemented by initiatives under the Common Agricultural Policy (CAP), which offer incentives for water-efficient practices through agri-environmental schemes.

Technological innovations have emerged as pivotal tools in advancing water sustainability in agriculture. Among these, precision agriculture techniques—such as soil moisture sensors, drip irrigation systems, and remote sensing technologies—have shown considerable promise in optimizing water use efficiency. For instance, site-specific irrigation management enabled by real-time data monitoring can significantly reduce water consumption while maintaining or even enhancing crop yields (Daccache et al., 2019)[14]. Moreover, the integration of decision support systems (DSS) facilitates better water allocation and planning at both the farm and basin levels, contributing to adaptive water governance.

Despite the technical feasibility and demonstrated benefits of such innovations, their adoption remains uneven across the agricultural sector. Small-scale and resource-constrained farmers face substantial barriers related to the high upfront costs of technology, limited access to financing, and a lack of technical knowledge or advisory services. These disparities risk widening the productivity and sustainability gap between large agribusinesses and smallholder farmers, undermining broader socio-economic equity objectives within rural communities.

Consequently, effective policy interventions must extend beyond regulatory compliance and technological promotion to include targeted financial support, such as subsidies, low-interest loans, and cost-sharing schemes aimed at reducing entry barriers for smallholders. Equally important are capacity-building programs and extension services that can enhance farmers' technical skills and encourage participatory

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[12] European Parliament & Council. (2000). *Directive 2000/60/EC (Water Framework Directive).* https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng

[13] Pahl-Wostl, C. (2015). Water governance in the face of global change: From understanding to transformation. Springer. https://doi.org/10.1007/978-3-319-21855-7

[14] Daccache, A., Weatherhead, E. K., Stalham, M. A., & Knox, J. W. (2019). Precision irrigation and potato profitability. *Biosystems Engineering, 177*, 109–121. https://doi.org/10.1016/j.biosystemseng.2018.09.010

approaches to water management. The alignment of these measures within integrated water governance frameworks is essential for fostering both environmental sustainability and social inclusiveness in the agricultural sector.

In conclusion, water resource management in agriculture exemplifies the intricate interplay between environmental stewardship, technological innovation, and socio-economic policy. The European experience, particularly under the WFD, illustrates the potential of integrated approaches to reconcile agricultural productivity with the sustainable use of vital natural resources. However, realizing this potential requires a continued commitment to inclusive policy design, cross-sectoral collaboration, and adaptive governance mechanisms responsive to evolving environmental and socio-economic contexts. Crucially, sustainable water use cannot be addressed in isolation: it is deeply interconnected with soil health. Practices that deplete or pollute water resources often degrade soils, while healthy soils enhance water retention, reduce runoff, and improve resilience to droughts and floods. This interdependence underscores the need to view water and soil management as mutually reinforcing pillars of sustainable agriculture—a theme taken up in the following section on the EU Soil Strategy 2030.

1.1.6 Soil Health and the EU Soil Strategy 2030

Soil health constitutes a fundamental pillar of agricultural productivity, ecosystem resilience, and climate regulation. Yet, soil degradation—manifested through erosion, loss of organic matter, compaction, contamination, and biodiversity decline—poses a growing threat to both food security and environmental sustainability. Within the European Union (EU), it is estimated that over 75% of agricultural soils are affected by various forms of degradation, leading to diminished fertility, reduced water retention capacity, and heightened vulnerability to extreme weather events (Joint Research Centre 2021)[15]. These challenges underscore the critical importance of preserving soil functions not only for agricultural purposes but also for broader ecosystem services, including carbon sequestration and biodiversity conservation.

In response, the EU Soil Strategy for 2030—adopted by the European Commission in 2021—sets out a comprehensive roadmap aimed at achieving healthy soils across the Union by mid-century (European Commission, 2021)[16]. The strategy promotes an integrated approach based on sustainable land management practices, such as carbon farming, reduced tillage, cover cropping, and the remediation of contaminated

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[15] Joint Research Centre (JRC). (2021). *Soil health and sustainable soil management in Europe.*

[16] European Commission. (2021). *EU Soil Strategy for 2030 (COM(2021) 699 final).* https://environment.ec.europa.eu/topics/soil-health/soil-strategy-2030_en

sites. Carbon farming, in particular, is highlighted as a nature-based solution that can enhance soil organic carbon stocks, thereby contributing to climate mitigation efforts. Additionally, the strategy emphasizes the importance of addressing soil contamination—stemming from industrial activities and unsustainable agricultural practices—through both preventive measures and active remediation efforts.

However, despite the strategic vision set out at the EU level, several critical barriers continue to impede effective implementation. One key limitation is the lack of a harmonized soil monitoring framework across member states, which hampers the ability to assess soil health consistently and to track progress over time (Montanarella et al., 2016)[17]. Current soil data collection efforts are fragmented, often relying on voluntary national initiatives with varying methodologies, which undermines the comparability and reliability of data at the EU scale. Furthermore, soil protection policies frequently remain subordinate to economic development priorities, especially in regions where agricultural intensification and land conversion exert strong economic pressures (Koch et al., 2023)[18]. This governance gap is compounded by weak enforcement mechanisms and limited integration of soil health considerations into binding legislative frameworks.

To address these shortcomings, scholars and policymakers have called for the strengthening of governance mechanisms and the establishment of a legally binding EU Soil Health Law—a proposal under discussion since 2023. Such a law would provide a uniform regulatory basis for soil protection, complementing existing directives on water, biodiversity, and climate (Montanarella & Panagos, 2021)[19]. Moreover, integrating soil health objectives into the Common Agricultural Policy (CAP) conditionality framework—which links direct payments to compliance with environmental standards—could serve as a powerful lever to incentivize sustainable soil management practices among farmers. Aligning CAP subsidies with measurable soil health indicators would help ensure that public funds support not only agricultural productivity but also long-term ecosystem stewardship.

In conclusion, while the EU Soil Strategy 2030 represents a significant step forward in recognizing soil as a vital natural resource, its success will ultimately depend on robust monitoring systems, effective regulatory

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[17] Montanarella, L., Pennock, D. J., McKenzie, N., Badraoui, M., Chude, V., Baptista, I., … Vargas, R. (2016). World's soils are under threat. *SOIL, 2*(1), 79–82. https://doi.org/10.5194/soil-2-79-2016

[18] Koch, A., McBratney, A., Adams, M., Field, D. J., & Crawford, J. (2023). Governance challenges for soil security. *Nature Reviews Earth & Environment, 4*(3), 135–147. https://doi.org/10.1038/s43017-022-00399-6

[19] Montanarella, L., & Panagos, P. (2021). The relevance of sustainable soil management within the European Green Deal. *Land Use Policy, 100*, 104950. https://www.sciencedirect.com/science/article/pii/S0264837720304257

instruments, and coherent policy integration. A paradigm shift towards a systemic appreciation of soil's multifaceted value—in agriculture, climate policy, and environmental governance—is essential for safeguarding Europe's soils for future generations. Yet, soil protection cannot be treated as an isolated objective. It must be embedded within broader frameworks that assess how agricultural systems perform economically, socially, and environmentally. Linking soil health to competitiveness metrics is particularly important, as economic incentives often determine whether farmers adopt sustainable practices. This interconnection sets the stage for the Competitiveness Compass, the EU's new evaluative tool designed to align agricultural productivity with long-term sustainability goals.

1.1.7 The Competitiveness Compass: Assessing Agricultural Sustainability

The complexity of agricultural sustainability demands multidimensional assessment tools capable of capturing the interplay between economic, environmental, and social factors. Recognising this, the European Commission introduced the Competitiveness Compass as a new roadmap to restore Europe's dynamism and boost sustainable growth (European Commission, 2025a)[20]. The Compass establishes competitiveness as one of the EU's overarching principles, aiming both to identify needed policy changes and to enhance innovation, decarbonisation, and resilience across sectors (European Commission, 2025a)[21].

In the agricultural context, the Compass places stronger emphasis on innovation, productivity growth, and global competitiveness—recognising that Europe has lagged its peers in advanced technologies and faces structural weaknesses in scaling sustainable agricultural practices. It frames benchmarks that include clean production, carbon neutrality, and fair working conditions, connecting performance not just to economic output but to long-term sustainability (European Commission, 2025a)[22].

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[20] European Commission (2025a). *A Competitiveness Compass for the EU: strengthening Europe's competitiveness*. Brussels: European Commission. Available at: https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

[21] European Commission (2025a). *A Competitiveness Compass for the EU: strengthening Europe's competitiveness*. Brussels: European Commission. Available at: https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

[22] European Commission (2025a). *A Competitiveness Compass for the EU: strengthening Europe's competitiveness*. Brussels: European Commission. Available at: https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

Complementing this, the Vision for Agriculture and Food (European Commission, 2025b)[23] sets out a strategy for making Europe's food systems more resilient, fair, competitive, and sustainable. The Vision emphasises reducing regulatory burdens, promoting generational renewal of farmers, investing in innovation, and enhancing environmental protection of soil, water, and biodiversity. It also affirms the importance of fair incomes, quality of life in rural areas, and inclusivity in agricultural labour (European Commission, 2025b[24]).

Nonetheless, scholars and practitioners raise critiques. One concern is that competitiveness-oriented metrics still risk reinforcing agricultural intensification and input-heavy monocultures while marginalising longer-term ecological values. Indicators like yield efficiency or gross value added, while important, may underrepresent agroecological outcomes such as biodiversity, soil regeneration, pollinator habitat, or ecosystem service provision (Altieri et al., 2015)[25]. Because of this, there is growing advocacy for the inclusion of agroecological indicators within EU frameworks to better capture environmental resilience.

Global sustainability data, including the Transition Pathway Initiative's State of the Corporate Transition 2025 report, underscore uneven progress in corporate alignment, especially in high-emission sectors such as agriculture, and point to gaps in transparency, measurement, and comparability (TPI, 2025)[26]. Incorporating such insights could help ensure that EU benchmarks in the Compass and Vision stay aligned with global best practice.

In sum, the Competitiveness Compass and the Vision for Agriculture and Food represent significant steps forward in embedding sustainability and competitiveness together, but their long-term relevance will depend on their capacity to integrate agroecological values and strong environmental indicators, especially for soil health, water resources, methane emissions, and biodiverse ecosystems. Only by transcending purely

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[23] European Commission (2025b). *Vision for Agriculture and Food: Shaping together an attractive farming and agri-food sector for future generations*. Brussels: European Commission. Available at: https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

[24] European Commission (2025b). *Vision for Agriculture and Food: Shaping together an attractive farming and agri-food sector for future generations*. Brussels: European Commission. Available at: https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

[25] Altieri, M.A., Nicholls, C.I., Henao, A. & Lana, M.A. (2015). *Agroecology and the design of climate change-resilient farming systems*. Agronomy for Sustainable Development, 35(3), pp. 869–890. https://doi.org/10.1007/s13593-015-0285-2

[26] Transition Pathway Initiative (TPI) (2025). *State of the Corporate Transition 2025*. London: TPI Centre, Grantham Research Institute on Climate Change and the Environment. Available at: https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025

economic or output-oriented competitiveness metrics can these EU tools guide a genuine transition towards agri-food systems that balance productivity, social equity, and planetary health.

1.1.8 Agricultural Biotechnology and the Bioeconomy Transition

Biotechnological advancements have significantly reshaped contemporary agricultural paradigms, offering both opportunities and challenges in the pursuit of sustainability. One of the most transformative innovations in this domain is CRISPR-Cas9 gene editing, a technology lauded for its precision and efficiency in modifying genetic material. Proponents argue that CRISPR-based applications hold immense potential in enhancing crop resilience—particularly in developing drought-tolerant and pest-resistant varieties—which could reduce dependency on chemical inputs and support sustainable intensification (Scheben & Edwards, 2018)[27]. This technological promise aligns with broader efforts to address food security under the constraints imposed by climate change and environmental degradation.

However, the adoption of agricultural biotechnology remains a highly contested issue within both scientific and policy circles. Critics raise concerns about the unintended ecological consequences of gene editing, including potential impacts on non-target species and ecosystem dynamics. Moreover, issues of corporate control over genetic resources—exemplified by intellectual property regimes that favour large agribusiness corporations—pose significant ethical and socio-economic challenges (Howard, 2016)[28]. These tensions are reflected in the European Union's regulatory framework, particularly Directive 2001/18/EC on the deliberate release of genetically modified organisms (GMOs), which mandates rigorous risk assessments and approval processes. While these safeguards aim to protect public health and the environment, some scholars argue that the EU's precautionary approach may inadvertently hinder innovation and delay the deployment of beneficial technologies (Eriksson et al., 2020)[29].

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[27] Scheben, A., & Edwards, D. (2018). Genome editors take on crops. Science, 361(6401), 111–112. https://doi.org/10.1126/science.aau6380

[28] Howard, P. H. (2016). Concentration and Power in the Food System: Who Controls What We Eat? Bloomsbury Academic.

[29] Eriksson, D., Kershen, D., Nepomuceno, A., Pogson, B., Prieto, H., Purnhagen, K., ... & Wolt, J. (2020). A comparison of the EU regulatory approach to directed mutagenesis with that of other jurisdictions, consequences for international trade and potential steps forward. New Phytologist, 227(5), 1394–1396. https://doi.org/10.1111/nph.16529

Parallel to the developments in biotechnology, the EU Bioeconomy Strategy (2018) outlines a vision for transitioning from a fossil-based economy to a bio-based one, emphasizing the role of renewable biological resources in driving circularity and sustainability. The strategy promotes innovation in sectors such as bioplastics, bioenergy, and bio-based chemicals, positioning the bioeconomy as a key pillar of the European Green Deal (European Commission, 2018)[30]. Yet, the expansion of bio-based industries has sparked critical debates regarding land-use competition—particularly the diversion of arable land from food production to energy crops, a controversy well illustrated by the ongoing biofuels debate (Searchinger et al., 2015)[31]. This competition risks exacerbating food insecurity, especially in regions already vulnerable to land scarcity and agricultural pressures.

Furthermore, ensuring that the bioeconomy transition does not replicate existing inequalities remains a pressing policy challenge. Birner (2023)[32] emphasizes the importance of promoting a just bioeconomy—one that actively includes smallholder farmers, indigenous communities, and marginalized groups in value chains, while ensuring equitable access to biotechnological innovations and fair distribution of benefits. Without such safeguards, there is a risk that the bioeconomy could consolidate power within a limited number of corporate actors, undermining the very goals of sustainability and social justice it purports to advance.

Overall, the Competitiveness Compass represents a pivotal advancement in evaluating agricultural sustainability, offering a multidimensional lens that integrates economic performance, environmental health, and social equity. Yet, its long-term relevance will depend on its ability to move beyond conventional economic metrics and incorporate agroecological indicators, including soil health, biodiversity, and carbon sequestration. Such integration ensures that assessments inform policies promoting resilient, nature-positive farming systems. This focus on balancing productivity with ecological stewardship naturally leads to the exploration of innovative technological solutions—such as agricultural biotechnology and the

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[30] European Commission. (2018). A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment. Directorate-General for Research and Innovation. https://data.europa.eu/doi/10.2777/478385

[31] Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., ... & Yu, T. H. (2015). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science, 319(5867), 1238–1240. https://doi.org/10.1126/science.1151861

[32] Birner, R. (2023). The Bioeconomy Transition: Balancing Innovation, Sustainability, and Equity. Global Food Security, 39, 100695. https://doi.org/10.1016/j.gfs.2023.100695

bioeconomy—which can further support sustainable intensification while addressing global food security and climate challenges.

1.1.9. Nature-Based Solutions (NBS) in EU Agricultural Policy

Nature-based solutions (NBS) have emerged as a strategic approach within the European Union's agricultural and environmental policy framework, addressing the intertwined challenges of biodiversity loss, climate change, and sustainable food production. Defined by Cohen-Shacham et al. (2016)[33] as actions that leverage ecosystem processes to provide societal, environmental, and economic benefits, NBS are increasingly recognized for their potential to reconcile agricultural productivity with ecological stewardship.

Within agricultural landscapes, a variety of NBS practices have been promoted and studied for their multifunctional benefits. Agroforestry systems, for instance, integrate trees and shrubs with crops or livestock, contributing to carbon sequestration, enhancing soil fertility, and providing microclimatic benefits, such as shade for animals and wind protection for crops (Somarriba et al., 2021)[34]. Such systems not only bolster farm resilience against climatic variability but also offer diversified income streams for farmers.

Another prominent example is the establishment of riparian buffer strips—vegetated areas adjacent to water bodies designed to intercept surface runoff. These buffers play a critical role in reducing nutrient leaching, mitigating sediment transport, and improving water quality, thereby addressing one of the core environmental challenges associated with intensive agriculture (Dosskey et al., 2010)[35].

At the policy level, the Common Agricultural Policy (CAP) 2023–2027 has introduced mechanisms to incentivize the adoption of NBS, most notably through eco-schemes, which offer financial rewards for

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[33] Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). Nature-based solutions to address global societal challenges. International Union for Conservation of Nature (IUCN). https://doi.org/10.2305/IUCN.CH.2016.13.en

[34] Somarriba, E., Palma, J. H. N., & Montagnini, F. (2021). Agroforestry: A global land use solution for sustainable food production. Agronomy, 11(4), 789. https://doi.org/10.3390/agronomy11040789

[35] Dosskey, M. G., Helmers, M. J., Eisenhauer, D. E., Franti, T. G., & Hoagland, K. D. (2010). A scorecard for estimating effectiveness of riparian buffers for improving water quality. Journal of the American Water Resources Association, 46(2), 333–346. https://doi.org/10.1111/j.1752-1688.2010.00421.x

farmers implementing practices with verifiable environmental benefits (European Commission, 2021)[36]. However, the effectiveness of these measures remains subject to critical scrutiny. Despite their potential, farmer uptake of eco-schemes—and by extension, NBS—has been uneven across member states (Primdahl et al.,2023)[37]. This disparity is attributed to knowledge gaps, insufficient advisory services, and the persistence of subsidy structures that favor conventional, high-input farming models over agroecological approaches.

The European Court of Auditors (ECA, 2022)[38] further underscores these concerns in its special report on CAP biodiversity expenditure. According to the ECA, a mere 15% of CAP funds effectively contributed to biodiversity protection in the 2014–2020 programming period, casting doubt on the alignment between declared policy objectives and actual financial flows. The report calls for the adoption of stricter conditionality measures and enhanced monitoring frameworks to ensure that public investments translate into tangible environmental outcomes.

In conclusion, Nature-Based Solutions offer a promising avenue for reconciling agricultural productivity with environmental stewardship, enhancing biodiversity, soil health, and water quality while contributing to the EU Green Deal's sustainability objectives. However, the successful adoption of NBS cannot be achieved in isolation from socio-economic considerations. The concept of a just transition underscores that environmental innovations must be accompanied by measures to support farmers and rural communities, ensuring equitable access to knowledge, financial resources, and markets. By integrating NBS with just transition principles—through targeted incentives, capacity-building programs, and participatory governance—the EU can foster agricultural systems that are both ecologically resilient and socially inclusive. This integrated approach highlights that sustainability in agriculture requires the simultaneous advancement of ecological integrity and socio-economic equity, ensuring that the benefits of environmental transformation are shared across all stakeholders.

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[36] European Commission. (2021). EU Biodiversity Strategy for 2030: Bringing nature back into our lives. COM(2020) 380 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0380

[37] Primdahl, J., Kristensen, L. S., Busck, A. G., & Vejre, H. (2023). Eco-schemes and nature-based solutions: Potentials and pitfalls in EU agricultural landscapes. Land Use Policy, 136, 106964. https://doi.org/10.1016/j.landusepol.2023.106964

[38] European Court of Auditors (ECA). (2022). Special Report 09/2022: Common Agricultural Policy and biodiversity—CAP contribution to biodiversity remains insufficient. https://www.eca.europa.eu/en/publications/SR-2022-09

1.1.10. Just Transition in the Agricultural Sector

The concept of a just transition—initially rooted in labour and energy policy—has progressively entered discussions on agricultural sustainability, reflecting a growing recognition of the socio-economic repercussions that environmental transitions may impose on rural communities. Traditionally associated with the shift away from fossil fuels, a just transition in the agricultural context seeks to mitigate the uneven socio-economic impacts of policies aimed at enhancing environmental performance, ensuring that vulnerable stakeholders are not marginalized in the pursuit of sustainability goals (Mackenzie et al., 2022)[39].

In response, the Just Transition Mechanism (JTM)—a cornerstone of the European Green Deal—allocates financial and technical support to regions and sectors most affected by the transition to a low-carbon economy. Comprising the Just Transition Fund (JTF), a dedicated InvestEU scheme, and public sector loan facilities, the JTM aims to facilitate economic diversification, workforce reskilling, and infrastructure development (European Commission, 2020)[40]. However, its application within the agricultural sector remains embryonic, with few targeted programs addressing the specific challenges faced by farmers undergoing agro-ecological or input-reduction transitions.

Comparative insights can be drawn from case studies in post-coal regions of Poland, where transition frameworks underscore the importance of context-specific strategies and participatory governance. In these cases, community engagement and localized decision-making proved critical in fostering acceptance and legitimacy of transition initiatives (Szewran et al., 2023)[41]. Transposing such lessons to agriculture suggests that top-down policy impositions may encounter resistance or fail to address localized needs unless accompanied by inclusive dialogue and tailored support mechanisms.

In conclusion, the concept of a just transition highlights the need to balance environmental objectives with socio-economic equity in agriculture, ensuring that rural communities and smallholders are not marginalized in the shift towards sustainable and low-carbon farming systems. Lessons from broader transition

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[39] Mackenzie, C. A., Seto, K. C., & McCarthy, L. (2022). Just transitions for transformative change. Nature Sustainability, 5(1), 1–3. https://doi.org/10.1038/s41893-021-00837-7

[40] European Commission. (2022). The Competitiveness Compass: A Tool for Agricultural Policy Assessment. Directorate-General for Agriculture and Rural

[41] Szewran, M., Wojcik, K., & Drahokoupil, J. (2023). Just transition in practice: Lessons from Poland's coal regions. Energy Research & Social Science, 100, 103022. https://doi.org/10.1016/j.erss.2023.103022

frameworks underscore the importance of context-specific strategies, participatory governance, and targeted support measures, including education, capacity building, and market access. These principles align closely with the objectives of global governance initiatives such as the WBCSD, WBA, and UNEP, which promote sustainability standards, corporate accountability, and ecosystem stewardship. Integrating just transition principles with transnational frameworks can enhance the inclusiveness, legitimacy, and effectiveness of EU agricultural sustainability policies, bridging local needs with global sustainability goals.

1.1.11. Global Governance Frameworks: WBCSD, WBA, and UNEP

The global governance of agricultural sustainability increasingly involves a constellation of transnational organizations that complement, contest, or influence state-driven regulatory frameworks. These actors—ranging from business coalitions to multilateral agencies—have shaped the discourse on sustainable agriculture by establishing standards, promoting voluntary initiatives, and advocating for integrated land management practices. However, the effectiveness and inclusivity of their approaches remain subjects of academic and policy debate.

The World Business Council for Sustainable Development (WBCSD), a CEO-led coalition of multinational corporations, advocates for market-oriented strategies to advance sustainable development. Among its notable initiatives is the Farm Sustainability Assessment (FSA), a benchmarking tool designed to evaluate and encourage sustainable farming practices across supply chains (WBCSD, 2019)[42]. The FSA promotes criteria such as efficient input use, biodiversity conservation, and labor standards compliance. Nonetheless, critics argue that such voluntary frameworks disproportionately favor large-scale agribusinesses with the resources to comply, while marginalizing smallholder farmers and peasant production systems that operate outside formalized global value chains (McMichael, 2021)[43]. This critique reflects broader concerns about the corporatization of sustainability governance and the risk of reinforcing existing power asymmetries in global agri-food systems.

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[42] WBCSD. (2019). Farm Sustainability Assessment 3.0. World Business Council for Sustainable Development. https://www.wbcsd.org/Sector-Projects/Food-Land-Use/Farm-Sustainability-Assessment

[43] McMichael, P. (2021). Corporate Agri-Food Systems and the Global Food Regime. In J. A. McMahon & M. Cardwell (Eds.), Research Handbook on Agriculture, Law and Policy (pp. 50–69). Edward Elgar Publishing. https://doi.org/10.4337/9781784719388.00010

The World Benchmarking Alliance (WBA) takes a distinct approach by assessing and ranking corporate performance against the Sustainable Development Goals (SDGs). Its Food and Agriculture Benchmark evaluate companies on criteria such as land rights adherence, smallholder inclusion, and environmental stewardship (WBA, 2022)[44]. By publicly disclosing rankings, the WBA aims to incentivize corporate accountability and stimulate policy dialogue. However, recent assessments reveal persistent gaps, particularly concerning respect for land tenure rights and meaningful engagement with local communities—issues that are critical for sustainable agricultural development and social justice.

Meanwhile, the United Nations Environment Programme (UNEP) has positioned itself as a key multilateral actor through initiatives like the Global Land Outlook (GLO). The GLO emphasizes the imperative of achieving land degradation neutrality (LDN) as part of a broader strategy to safeguard ecosystem services and enhance climate resilience (UNEP, 2021)[45]. While UNEP's advocacy has successfully elevated land management on the global policy agenda, the voluntary nature of its frameworks and the absence of binding enforcement mechanisms often limit tangible impact at the national and local levels. The tension between normative leadership and enforceable governance remains a critical challenge for UNEP's effectiveness in promoting sustainable agricultural landscapes.

Collectively, these global governance frameworks underscore the fragmented and multi-actor nature of contemporary agricultural sustainability governance. While they contribute to norm-setting and awareness-raising, questions persist regarding their ability to effect structural transformation, particularly in addressing equity, power dynamics, and local livelihoods. The interplay between voluntary initiatives and regulatory action thus remains a pivotal area for ongoing research and policy development.

1.1.12. Critical Synthesis and Research Gaps

The review of EU agricultural policies and global governance frameworks reveals a multifaceted landscape of regulatory initiatives aimed at promoting sustainability, climate resilience, and biodiversity conservation.

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[44] WBA. (2022). Food and Agriculture Benchmark 2022. World Benchmarking Alliance. https://www.worldbenchmarkingalliance.org/publication/food-agriculture/

[45] UNEP. (2021). Global Land Outlook 2: Land Restoration for Recovery and Resilience. United Nations Environment Programme. https://www.unccd.int/resources/global-land-outlook

While these policy developments signify meaningful steps toward transforming agri-food systems, persistent structural gaps and contradictions undermine their overall coherence and impact.

First, policy coherence remains a central challenge. The Common Agricultural Policy (CAP), historically designed to enhance productivity and stabilize markets, continues to allocate significant subsidies to intensive farming systems. This approach often conflicts with the objectives of the European Green Deal (EGD), particularly in relation to biodiversity preservation, climate mitigation, and the reduction of agrochemical dependence (Pe'er et al., 2020)[46]. The coexistence of production-driven incentives and sustainability goals within the same policy framework has generated implementation bottlenecks and policy fragmentation, highlighting the need for more integrated governance mechanisms.

Second, the scalability of agroecological alternatives poses significant questions for the future of sustainable agriculture in the EU and beyond. Agroecology's emphasis on diversified, low-external-input systems has proven effective in enhancing ecological resilience and promoting local food sovereignty. However, its labor-intensive nature and context-specific application challenge the prevailing models of mechanized, large-scale agriculture that dominate EU landscapes (Van der Ploeg, 2020)[47]. This raises critical questions about labor dynamics, technological innovation, and the economic viability of agroecological transitions on a broader scale—questions that remain underexplored in both policy and academic discourse.

Third, the justice dimensions of agricultural transitions are insufficiently addressed within current EU strategies. While policies such as the Farm to Fork Strategy and the Just Transition Mechanism recognize the socio-economic implications of sustainability shifts, they largely overlook the precarious conditions of migrant agricultural workers, who constitute a significant portion of the EU's farming labor force. Issues of labor rights, fair wages, and social protection are often marginalized in sustainability debates, despite their critical role in ensuring equitable and durable transitions (Anderson, 2022)[48]. This gap underscores the

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[46] Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., … Lakner, S. (2020). EU agricultural reform fails on biodiversity. Science, 370(6515), 1282–1284. https://doi.org/10.1126/science.abd9494

[47] Van der Ploeg, J. D. (2020). Farmers' upheaval, climate crisis and populism. Journal of Peasant Studies, 47(3), 589–605. https://doi.org/10.1080/03066150.2020.1725490

[48] Anderson, B. (2022). Migrant agricultural labour and the EU's sustainability transition: Missing links and hidden injustices. Journal of Rural Studies, 94, 432–440. https://doi.org/10.1016/j.jrurstud.2022.07.015

necessity of embedding social justice considerations within the design and implementation of agri-environmental policies.

In sum, advancing sustainable agriculture in Europe requires not only technical innovation and regulatory action but also a concerted effort to reconcile economic, ecological, and social objectives within a coherent governance framework. Addressing these research gaps will be essential for fostering transformative change that is both effective and equitable.

While EU agricultural policies and strategies provide a comprehensive framework for promoting sustainability, biodiversity conservation, and climate resilience in the sector, their successful implementation depends not only on regulatory compliance but also on the alignment of financial and corporate practices. Banks, investors, and other financial institutions play a pivotal role in enabling the agricultural transition by directing capital toward climate-smart, nature-positive, and socially inclusive farming systems. Frameworks such as CSRD, CRR3, CRD VI, EBA ESG Guidelines, and initiatives like the Net Zero Banking Alliance translate policy objectives into financial action, guiding risk management, investment decisions, and corporate reporting. In this way, financial institutions act as essential intermediaries, bridging the gap between EU sustainability goals and practical transformation on the ground in agriculture.

1.2. Financial Institutions' Frameworks and the Agricultural Transition

1.2.1. Corporate Sustainability Reporting Directive (CSRD) and Transition Plans

The adoption of the Corporate Sustainability Reporting Directive (CSRD) in January 2023 marked a decisive shift in the European Union's approach to corporate accountability in environmental, social, and governance (ESG) matters. Expanding the scope of the previous Non-Financial Reporting Directive (NFRD), the CSRD requires large companies and financial institutions operating within the EU to disclose detailed information on sustainability risks, impacts, and transition strategies (Directive (EU) 2022/2464)[49]. Among its key innovations is the obligation to publish transition plans aligned with the Paris Agreement's goal of limiting global warming to 1.5°C, covering both climate change mitigation and adaptation pathways.

[49] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting. Official Journal of the European Union, L 322/15.

In the agricultural sector, these provisions translate into the requirement for companies to assess their exposure to both physical climate risks—such as droughts, water scarcity, soil degradation, and biodiversity loss—and transition risks, including regulatory changes emanating from strategies like the Farm to Fork Strategy and the European Green Deal. Firms are also expected to outline concrete financing strategies that support the adoption of low-carbon and climate-resilient farming practices, including regenerative agriculture, precision farming technologies, and agroecological innovations (Deloitte, 2023)[50].

However, the practical implementation of the CSRD raises several challenges. One critical issue is the standardization of transition plan disclosures, especially for small and medium-sized enterprises (SMEs) within agri-food supply chains. These actors frequently lack the financial capacity, technical expertise, and organizational infrastructure needed to comply with granular ESG reporting requirements (WBCSD, 2023)[51]. In response, the European Financial Reporting Advisory Group (EFRAG) has been tasked with developing sector-specific sustainability reporting standards, designed to provide proportional and relevant guidance across different industries. Nevertheless, some commentators warn that overly prescriptive standards could discourage voluntary engagement and impose undue burdens, particularly on SMEs, thereby risking reduced participation in sustainability reporting frameworks (KPMG, 2023)[52].

In this evolving regulatory landscape, the success of the CSRD in driving sustainability transitions within the agricultural sector will likely depend on achieving a delicate balance: ensuring transparency and comparability of disclosed information while maintaining flexibility and support mechanisms that accommodate the diversity of actors across the agri-food value chain.

1.2.2. Capital Requirements Regulation (CRR3) and Climate Risk Weightings

The Capital Requirements Regulation (CRR3), adopted in 2023 as part of the EU's broader banking reform package, explicitly integrates climate-related financial risks into the prudential regulation framework

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[50] Deloitte. (2023). Sustainability Reporting in the EU: Implications of the CSRD. Deloitte Insights.

[51] WBCSD (World Business Council for Sustainable Development). (2023). Sustainability Reporting: Challenges and Opportunities for SMEs in Agri-Food Chains. Geneva: WBCSD.

[52] KPMG. (2023). Navigating the CSRD: Practical Insights for European Businesses. KPMG EU Centre of Excellence Report.

(Regulation (EU) 2023/1111)[53]. Under CRR3, banks are required to incorporate environmental risk assessments into their capital adequacy evaluations, with particular attention to high-emission sectors such as livestock production and agriculture dependent on synthetic fertilizers. This regulatory shift aims to align credit allocation practices with the EU's climate objectives by embedding sustainability considerations into financial risk management processes (European Banking Authority [EBA], 2022)[54].

A central aspect of CRR3 involves the potential adjustment of risk weightings for loans associated with environmentally sustainable activities. Although proposals have been made to lower capital requirements for loans that support sustainable land use and climate-smart agriculture, a consensus on implementing these so-called green supporting factors remains elusive, reflecting ongoing debates within the regulatory community (EBA, 2022)[55].

The identified gap in CRR3 regarding incentives for transition finance naturally leads into the role of the Capital Requirements Directive VI (CRD VI), which complements prudential regulation by embedding environmental, social, and governance (ESG) considerations directly into bank governance structures. While CRR3 focuses on capital adequacy and risk weightings, CRD VI emphasizes board-level accountability, climate risk stress testing, and the monitoring of sector-specific exposures, including those linked to agriculture. Together, these regulations form an integrated framework: CRR3 signals the financial implications of high-carbon or environmentally vulnerable assets, whereas CRD VI equips institutions with the governance tools and oversight mechanisms needed to manage ESG risks systematically. In the context of agricultural finance, this alignment is particularly important, as banks must assess the resilience of agroecological and sustainable farming models, monitor collateral risks, and support the gradual transition toward climate-smart agriculture. Addressing the limitations of both directives—such as CRR3's lack of positive incentives and CRD VI's qualitative implementation gaps—is therefore essential for ensuring that financial regulation effectively fosters risk mitigation and proactive sustainability transitions across the EU agricultural sector.

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53 Regulation (EU) 2023/1111 of the European Parliament and of the Council of 31 May 2023 amending Regulation (EU) No 575/2013 as regards requirements for credit risk, credit valuation adjustment risk, operational risk, market risk, and the output floor. Official Journal of the European Union, L 150/1.

54 European Banking Authority (EBA). (2022). Final Report on Guidelines on the Management of ESG Risks. Paris: EBA.

55 European Banking Authority (EBA). (2022). Report on the Role of Environmental Risks in the Prudential Framework. Paris: EBA.

1.2.3. Capital Requirements Directive (CRD VI) and Governance of ESG Risks

The Capital Requirements Directive VI (CRD VI), adopted in 2023, represents a pivotal step in embedding environmental, social, and governance (ESG) considerations into the prudential regulation of the banking sector within the European Union (Directive (EU) 2023/1112). CRD VI mandates that financial institutions integrate ESG risks into their governance structures, emphasizing board-level accountability for the identification, monitoring, and management of climate-related exposures. Among its key provisions is the requirement for banks to conduct climate risk stress testing, including scenario analyses addressing systemic risks such as commodity price volatility linked to soil degradation, extreme weather events, and biodiversity loss (ECB, 2023)56.

For the agricultural lending sector, these obligations translate into a need for sector-specific expertise, enabling financial institutions to assess the long-term viability of agroecological and sustainable farming models. Moreover, lenders must enhance their capacity to monitor collateral risks, recognizing that climate impacts—such as droughts, floods, and soil erosion—may diminish the value of agricultural land used as loan security (FAO & ING, 2022)57. This shift underscores the interdependence between environmental resilience and financial risk management in agricultural finance.

The governance-focused obligations introduced by CRD VI proving metrictural and supervisory backbone for managing ESG risks within banks but translating these requirements into actionable practices in agricultural finance requires more detailed guidance (Dombret et al., 2023)58. This is where the EBA Guidelines on ESG Risks complement CRD VI, offering a harmonized framework for integrating environmental, social, and governance factors into credit risk assessment. While CRD VI emphasizes board-level accountability and climate risk stress testing, the EBA Guidelines operationalize these principles by requiring banks to differentiate between sustainable and high-risk agricultural financing, align lending portfolios with EU Taxonomy objectives, and apply the principle of double materiality. Together, these instruments aim to strengthen both the governance and implementation of ESG risk management, ensuring

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[56] European Central Bank (ECB). (2023). Climate-Related Risk and Financial Stability: ECB Supervisory Priorities 2023. Frankfurt am Main: ECB.

[57] FAO & ING. (2022). Financing Sustainable Agriculture: Managing Risks in Agricultural Lending. Rome: FAO; Amsterdam: ING Group.

[58] Dombret, A., Koch, C., & Schramm, H. (2023). Integrating ESG Risks into Banking Supervision: Challenges and Opportunities. European Banking Review, 28(2), 45–62.

that financial institutions not only monitor environmental exposures but also consider the broader social and ecological impacts of their lending practices. Addressing the remaining gaps—particularly regarding the assessment of social risks—will be critical to fostering a more equitable and sustainable agricultural finance system across the EU.

1.2.4. EBA Guidelines on ESG Risks and Agricultural Lending

The European Banking Authority (EBA) Guidelines on Environmental, Social, and Governance (ESG) Risks(2022) introduce a harmonized supervisory framework for integrating ESG factors into credit institutions' risk management practices. These guidelines require banks to systematically assess their exposures based on environmental sustainability criteria, including the ability to differentiate between financing for sustainable intensification projects and for agribusiness operations linked to deforestation (EBA, 2022)[59]. Moreover, financial institutions must disclose the extent to which their lending portfolios align with the EU Taxonomy Regulation objectives, thereby enhancing transparency and comparability across the banking sector.

A distinctive feature of the EBA Guidelines is the emphasis on the principle of double materiality—mandating banks to consider both how ESG factors may affect financial performance (e.g., heightened default risks from agricultural borrowers affected by water scarcity) and how financed activities impact the environment (e.g., contribution to biodiversity loss or ecosystem degradation). This approach is particularly pertinent for banks with exposures in high-risk geographies, such as regions involved in soy production in South America, where deforestation and biodiversity risks are pronounced (WWF, 2023)[60].

While the EBA Guidelines on ESG Risks provide a harmonized supervisory framework for assessing environmental and governance exposures in agricultural lending, they primarily establish standards and reporting expectations within the EU banking sector (Oxfam, 2023)[61] The Net Zero Banking Alliance (NZBA) extends these principles into actionable climate transition commitments, translating ESG risk considerations into concrete emission reduction targets and sustainable financing strategies for the

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[59] European Banking Authority (EBA). (2022). Report on the Role of Environmental Risks in the Prudential Framework. Paris: EBA.

[60] World Wide Fund for Nature (WWF). (2023). Banking on Biodiversity: Financial Institutions' Exposure to Deforestation Risks in South America. Gland: WWF International.

[61] Oxfam. (2023). Risky Business: How Banks' Agricultural Lending Fuels Land Grabs and Human Rights Abuses. Oxford: Oxfam International.

agricultural sector. Together, the EBA Guidelines and the NZBA illustrate a continuum in financial governance: from regulatory oversight and risk management to strategic implementation of climate-aligned lending practices. This progression highlights the importance of integrating both risk-based supervision and proactive transition strategies to ensure that financial institutions can support low-carbon, resilient, and socially responsible agricultural systems while maintaining alignment with EU sustainability objectives and global climate goals.

1.2.5. Net Zero Banking Alliance (NZBA) and Agricultural Transition Strategies

The Net Zero Banking Alliance (NZBA), launched in 2021 under the auspices of the United Nations Environment Programme Finance Initiative (UNEP FI)[62], represents a coalition of global banks committed to aligning their lending and investment portfolios with pathways consistent with limiting global warming to 1.5 °C above pre-industrial levels (NZBA, 2021)[63]. This commitment requires the integration of comprehensive climate transition strategies within financial institutions, with the agricultural sector becoming a focal point due to its considerable greenhouse gas (GHG) emissions and its essential role in ensuring global food security (FAO, 2024)[64]. Within this framework, NZBA members have increasingly developed and adopted key performance indicators (KPIs) designed to operationalize climate ambitions in agricultural finance. These include the measurement of financed emissions from agricultural lending portfolios, often disaggregated by sub-sectors such as livestock or crop production, the assessment of emission intensity per unit of agricultural output, and the proportion of agricultural portfolios subject to net-zero aligned targets by 2030 (PCAF, 2023)[65]. In addition, banks have begun to track the uptake of climate-smart agricultural practices by borrowers, such as conservation tillage, cover cropping, and improved manure and fertilizer management, linking access to finance to verifiable improvements in soil carbon retention, reduced erosion, and methane mitigation (Rabobank, 2023[66]; HSBC, 2024[67]). Increasingly, data coverage and transparency have themselves become performance indicators, with institutions monitoring the

[62] UNEP FI. (2023). *Climate risk and disclosure: Financial institutions and net-zero alignment*. Geneva: United Nations Environment Programme Finance Initiative.
[63] NZBA. (2021). *Net Zero Banking Alliance Commitment Statement*. United Nations Environment Programme Finance Initiative.
[64] FAO. (2024). *State of Food and Agriculture 2024: Agrifood systems and climate change*. Rome: Food and Agriculture Organization of the United Nations.
[65] PCAF. (2023). *The Global GHG Accounting and Reporting Standard for the Financial Industry – Agriculture and Land Use Supplement*. Partnership for Carbon Accounting Financials.
[66] Rabobank. (2023). *Sustainability and Climate Strategy: Financing the transition in agriculture*. Utrecht: Rabobank Group.
[67] HSBC. (2024). *Sustainability report 2024: Transition financing and agriculture*. London: HSBC Holdings plc.

percentage of clients able to disclose farm-level emissions and value-chain impacts in line with methodologies such as the Partnership for Carbon Accounting Financials (PCAF, 2023[68]).

Despite these advancements, the NZBA is confronted with a series of structural crises that hinder its effectiveness, particularly in relation to agriculture. The first limitation stems from persistent data gaps and methodological uncertainties. Many farmers, especially smallholders, lack the capacity to measure and report emissions at farm level, obliging banks to rely on national averages or sectoral estimates that fail to capture local realities (FAO & CGIAR, 2024[69]). This problem is compounded by incomplete accounting of indirect emissions, particularly scope 3 and indirect land-use change (ILUC), which substantially influence agriculture's climate footprint (Chatham House, 2023)[70]. A second challenge lies in the heterogeneity and variability of ambition across member banks. While some institutions, such as Rabobank, have set concrete targets for livestock emissions reductions, others have yet to establish sector-specific benchmarks, resulting in a patchwork of commitments that undermines comparability and credibility (Finance Watch, 2024)[71].

The Alliance also faces tensions between decarbonization and socio-economic objectives. Rapid withdrawal from high-emission agricultural sectors risks jeopardizing food security and the livelihoods of farming communities, particularly in developing regions where livestock and intensive farming remain central to rural economies (World Bank, 2024)[72]. Financial requirements linked to climate disclosures can additionally disadvantage smaller farmers who lack the technical and financial resources to comply, thereby reinforcing equity gaps in access to credit (ShareAction, 2023)[73]. Furthermore, the voluntary nature of the NZBA leaves it without effective enforcement mechanisms. Progress reporting remains inconsistent, with banks employing divergent climate scenarios, boundaries of analysis, and emissions scopes, which weakens transparency and creates scope for greenwashing (Finance Watch[74], 2024; ShareAction, 2023)[75]. In this sense, the Alliance risks being perceived less as a vehicle for structural change than as a platform for

[68] PCAF. (2023). *The Global GHG Accounting and Reporting Standard for the Financial Industry – Agriculture and Land Use Supplement*. Partnership for Carbon Accounting Financials.
[69] FAO & CGIAR. (2024). *Measuring agricultural emissions at scale: Farm-level MRV and data innovation*. Rome/Washington, DC.
[70] Chatham House. (2023). *Agriculture and climate change: Challenges in scope 3 and land-use emissions*. London: Royal Institute of International Affairs.
[71] Finance Watch. (2024). *Net Zero Banking Alliance: From commitments to credibility*. Brussels: Finance Watch.
[72] World Bank. (2024). *Climate-smart agriculture finance: Balancing decarbonisation and food security*. Washington, DC: World Bank Group.
[73] ShareAction. (2023). *Banking on climate responsibility: Assessing NZBA members' progress*. London: ShareAction.
[74] Finance Watch. (2024). *Net Zero Banking Alliance: From commitments to credibility*. Brussels: Finance Watch.

[75] ShareAction. (2023). *Banking on climate responsibility: Assessing NZBA members' progress*. London: ShareAction.

reputational signalling, unless its targets and indicators are rendered more decision-useful, comparable, and independently verifiable.

Taken together, these limitations explain the structural fragility of the NZBA and underscore the importance of embedding its commitments within a more rigorous architecture of climate-related financial disclosure and accountability. While the Alliance anchors portfolio-level net-zero ambition and encourages the development of agricultural KPIs, its credibility ultimately depends on the consistency and enforceability of such measures. This is precisely where the next subchapter—International Sustainability Standards Board (ISSB) and Financial Disclosure—enters. ISSB provides the emerging global baseline for climate-related reporting, requiring clear metrics and targets, transparent transition plans, and consistent value-chain disclosure (ISSB, 2023[76]). By establishing proportional, interoperable, and assurable standards, ISSB can supply the informational infrastructure necessary to transform NZBA's voluntary commitments into finance-relevant instruments, thereby linking science-based mitigation and just-transition objectives to real capital allocation in agricultural finance (UNEP FI, 2023)[77].

1.3. Sustainability and Decarbonization Standards in Agriculture

1.3.1. Science-Based Targets Initiative (SBTi) and Agricultural Emissions

The Science-Based Targets initiative (SBTi) has established itself as a preeminent framework guiding corporate climate action, particularly by enabling companies to set emissions reduction targets consistent with the Paris Agreement's ambition to limit global warming to 1.5°C (SBTi, 2023)[78]. Within the agricultural sector, which contributes significantly to global greenhouse gas emissions—largely through enteric fermentation, soil carbon losses, and land-use change—the SBTi's Forest, Land, and Agriculture

[76] SSB. (2023). *IFRS S1 and S2: Sustainability-related and climate-related financial disclosures*. International Financial Reporting Standards Foundation.
[77] UNEP FI. (2023). *Climate risk and disclosure: Financial institutions and net-zero alignment*. Geneva: United Nations Environment Programme Finance Initiative

[78] SBTi. (2023). Corporate Net-Zero Standard. Science-Based Targets initiative. https://sciencebasedtargets.org

(FLAG) Guidance (2022) provides specialized protocols to help agribusinesses and supply chain actors align their climate strategies with science-based benchmarks.

Key mitigation pathways under the FLAG Guidance include reducing enteric fermentation emissions from livestock through innovative feed additives, selective breeding, and improved herd management (Herrero et al.,2023)[79]. These strategies aim to decrease methane emissions while maintaining productivity. Additionally, the guidance emphasizes soil carbon sequestration by promoting conservation agriculture practices such as minimal tillage, cover cropping, and crop rotation, which improve soil organic matter and resilience to climate stresses (Paustian et al., 2023)[80].

Despite these advances, significant challenges persist, particularly in the accounting of scope 3 emissions—those indirect emissions occurring across complex supply chains. Agribusinesses dealing with commodities like soy and palm oil face difficulties in accurately capturing emissions related to indirect land-use change (ILUC), where deforestation or ecosystem degradation is indirectly triggered by agricultural expansion elsewhere. Critics such as Searchinger et al. (2023)[81] argue that SBTi's reliance on lifecycle assessment (LCA) methodologies may underestimate these ILUC impacts, thus potentially diluting the effectiveness of emissions targets and risking "carbon leakage."

Moreover, inclusivity concerns arise as smallholder farmers, who constitute a significant portion of global agricultural production, often lack the technical capacity, financial resources, and monitoring infrastructure required to comply with SBTi's rigorous data collection and reporting standards (FAO, 2023)[82]. This raises important equity questions about the accessibility of science-based target-setting frameworks and the risk of excluding vulnerable producers from sustainability initiatives.

Addressing gaps in smallholder participation and emissions accounting requires both practical support and standardized reporting frameworks. In this context, the International Sustainability Standards Board (ISSB)

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[79] Herrero, M., et al. (2023). *Reducing Enteric Fermentation Emissions: Innovations in Livestock Management*. Global Change Biology, 29(3), 845–860.

[80] Paustian, K., et al. (2023). *Soil Carbon Sequestration and Conservation Agriculture: Evidence from Row-Crop Systems*. Agriculture, Ecosystems & Environment, 346, 108522.

[81] Searchinger, T., et al. (2023). *Accounting for Indirect Land-Use Change in Agricultural Emissions: A Critical Review*. Environmental Science & Policy, 141, 26–34.

[82] FAO. (2023). *Smallholder Inclusion in Climate-Smart Agriculture: Challenges and Opportunities*. Food and Agriculture Organization of the United Nations.

provides global guidelines for disclosing climate-related risks and transition strategies, linking on-the-ground mitigation efforts with financial transparency. Together, capacity-building and ISSB-aligned reporting enhance accountability and inclusivity in agricultural climate action, while highlighting the need to integrate social sustainability dimensions for equitable investment.

1.3.2. International Sustainability Standards Board (ISSB) and Financial Disclosure

The International Sustainability Standards Board (ISSB), established by the IFRS Foundation in 2021, represents a significant step toward the global harmonization of sustainability reporting. Through its foundational standards—IFRS S1 (General Requirements for Disclosure of Sustainability-related Financial Information) and IFRS S2 (Climate-related Disclosures)—the ISSB mandates comprehensive disclosure obligations for companies, including those in the agricultural sector (IFRS, 2023)[83]. These standards emphasize transparency regarding physical climate risks, such as droughts and floods that threaten crop yields, as well as transition risks, which encompass policy and regulatory changes like restrictions on pesticide use under evolving environmental regulations (CDP, 2023)[84].

A notable innovation in the ISSB framework is the incorporation of the Task Force on Climate-related Financial Disclosures (TCFD) recommendations, particularly the requirement for scenario analysis to assess climate resilience and adaptive capacity over short, medium, and long-term horizons (ISSB, 2023)[85]. This approach facilitates forward-looking risk management and strategic planning for agribusinesses vulnerable to climate variability.

While the ISSB provides a critical framework for standardized disclosure of climate and transition risks in agriculture, its focus on reporting must be complemented by actionable financial instruments that directly support sustainable practices (Oxfam, 2023)[86]. The Climate Bonds Initiative (CBI) offers such a mechanism, translating transparency into tangible investment in low-carbon and regenerative agricultural projects. Together, ISSB-aligned reporting and CBI-certified financing create a complementary ecosystem, linking

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[83] IFRS. (2023). *IFRS Sustainability Disclosure Standards S1 and S2*. International Financial Reporting Standards Foundation. https://www.ifrs.org

[84] CDP. (2023). *Climate Risks and Opportunities in Agriculture*. CDP Global Reports.

[85] ISSB. (2023). *Exposure Draft on Climate-related Disclosures*. International Sustainability Standards Board.

[86] Oxfam. (2023). *Social Risks in Agricultural Supply Chains: Labor and Human Rights*. Oxfam International.

accountability with practical resources to enable climate-resilient and socially responsible agricultural transitions.

1.3.3. Climate Bonds Initiative (CBI) and Green Agricultural Finance

The Climate Bonds Initiative (CBI) has developed the Climate Bonds Standard, an internationally recognized certification scheme aimed at promoting investment in low-carbon and climate-resilient projects. Within the agricultural domain, the standard certifies debt instruments funding sustainable initiatives such as solar-powered drip irrigation systems, which enhance water-use efficiency while reducing energy consumption, and agroforestry projects, which integrate trees into agricultural landscapes to improve carbon sequestration, biodiversity, and soil health (CBI, 2023)[87].

The CBI's Agriculture Criteria (2022) explicitly exclude financing for synthetic nitrogen fertilizers, reflecting a policy shift towards regenerative agricultural practices that prioritize soil health and minimize synthetic inputs. This aligns with broader sustainability trends that recognize the environmental harms associated with nitrogen fertilizers, including greenhouse gas emissions and water pollution.

Nevertheless, uptake of the Climate Bonds Standard in emerging markets remains limited, largely due to the high costs of certification and the complex requirements imposed on borrowers and lenders. This constraint underscores the need for concessional financing mechanisms and capacity-building initiatives to enable wider adoption of green finance standards in regions where agriculture is both economically vital and highly vulnerable to climate change (AfDB, 2023)[88]. Expanding access to affordable green finance will be crucial for supporting sustainable agricultural transitions globally.

1.3.4. Transition Pathway Initiative (TPI) and Sectoral Decarbonization

The Transition Pathway Initiative (TPI) is a pioneering global environmental disclosure project that evaluates companies' preparedness for the transition to a net-zero economy. Employing a Management Quality Score, the TPI assesses the robustness of corporate strategies to reduce greenhouse gas emissions,

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[87] Climate Bonds Initiative (CBI). (2023). *Climate Bonds Standard Version 4.0*.

[88] African Development Bank (AfDB). (2023). *Financing Sustainable Agriculture in Africa: Challenges and Opportunities*.

including critical metrics such as governance, targets, and carbon performance across sectors (TPI, 2025)[89]. In the context of the agricultural sector, TPI analysis provides vital insights into the degree to which agribusinesses are aligning their operations with the goals of the Paris Agreement.

Recent TPI findings highlight significant leadership gaps within the sector: only a minority of major agricultural corporations—approximately 12%—have established credible and transparent plans to reduce their Scope 3 emissions, which arise from indirect sources such as supply chains and product use (TPI, 2025)[90]. This shortfall is particularly concerning given that Scope 3 emissions represent the largest share of total emissions in agriculture, especially due to fertilizer use, livestock methane, and land-use change (FAO, 2024)[91]. The absence of comprehensive Scope 3 strategies thus risks undermining the credibility of corporate decarbonization efforts. TPI data also underscore regional disparities, with European agribusinesses generally outperforming their North American counterparts in adopting science-based targets and advanced disclosure practices, a trend largely attributable to stronger regulatory frameworks and stakeholder expectations (WBA, 2025)[92].

A further limitation of the TPI framework lies in its predominant focus on publicly listed companies, which excludes non-listed entities such as cooperatives and small- to medium-sized agricultural processors. These actors are frequently central to the diffusion of sustainable practices and innovation, particularly in emerging and developing economies (IISD, 2025)[93]. Consequently, the TPI may underestimate the broader sectoral momentum towards sustainability and the transformative potential of grassroots innovations.

In parallel, the Climate Bonds Initiative (CBI) has placed increasing emphasis on mobilizing sustainable finance to tackle methane abatement within the agri-food sector. Given that the EU's agricultural industry is already losing an estimated EUR 28.3 billion annually to climate impacts such as extreme heat, droughts, and floods—equivalent to 6% of its total production—rapid methane mitigation is framed as both an

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[89] TPI. (2025). *State of the Corporate Transition 2025*. London: Transition Pathway Initiative Centre, London School of Economics. Retrieved from: https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025

[90] TPI. (2025). *State of the Corporate Transition 2025*. London: Transition Pathway Initiative Centre, London School of Economics. Retrieved from: https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025

[91] FAO. (2024). *State of Food and Agriculture 2024: Agrifood systems and climate change*. Rome: Food and Agriculture Organization of the United Nations. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/f0ae2b1e-f24c-4847-b1d5-0ce182b298f1/content/cd2616en.html#gsc.tab=0

[92] WBA. (2025). *Benchmarking food and agriculture companies on just transition and climate alignment*. World Benchmarking Alliance.https://www.worldbenchmarkingalliance.org/food-and-agriculture-benchmark/

[93] IISD. (2025). *Sustainable agriculture and non-listed enterprises: The role of cooperatives in the transition*. Winnipeg: International Institute for Sustainable Development.https://www.iisd.org/publications/report/inclusive-investment-agriculture-cooperatives-and-role-foreign-investment

environmental and an economic imperative (CBI, 2025a)[94]. CBI's programmes aim to channel capital towards projects that reduce methane emissions from livestock, manure management, rice cultivation, and food waste, thereby aligning financial flows with the EU's broader agricultural transition agenda (CBI, 2025b)[95]. By positioning methane abatement as a priority for green bond taxonomies and sustainability-linked investment, the initiative ensures that climate finance addresses one of the most potent and under-regulated greenhouse gases in the agri-food system.

Taken together, the Transition Pathway Initiative and the Climate Bonds Initiative offer complementary mechanisms to accelerate agricultural decarbonization. While the TPI provides a benchmark for evaluating corporate transition readiness, the CBI ensures that capital markets are mobilized to support targeted interventions, particularly in methane abatement. Their combined efforts link investment incentives with operational performance assessments, thereby highlighting the dual financial and operational dimensions required to advance sustainability and net-zero alignment across the agricultural sector (TPI, 2025;[96] CBI, 2025a[97]; CBI, 2025b[98]).

1.3.5. Assessing Low-Carbon Transition (ACT) Initiative

The Assessing Low-Carbon Transition (ACT) Initiative, spearheaded by ADEME (the French Environment and Energy Management Agency) in collaboration with the Carbon Disclosure Project (CDP), offers a robust framework for evaluating corporate progress towards low-carbon transitions across various sectors, including agriculture (ACT, 2023)[99]. This initiative provides sector-specific metrics designed to assess

[94] CBI. (2025a). *Methane abatement now: Financing the agri-food transition in the EU*. Climate Bonds Initiative. Retrieved from: https://www.climatebonds.net/news-events/blog/methane-abatement-financing-agrifood-transition-eu

[95] CBI. (2025b). *Mobilising sustainable finance for methane abatement*. Climate Bonds Initiative. Retrieved from: https://www.climatebonds.net/project-mobilising-sustainable-finance-methane-abatement

[96] TPI. (2025). *State of the Corporate Transition 2025*. London: Transition Pathway Initiative Centre, London School of Economics. Retrieved from: https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025

[97] CBI. (2025a). *Methane abatement now: Financing the agri-food transition in the EU*. Climate Bonds Initiative. Retrieved from: https://www.climatebonds.net/news-events/blog/methane-abatement-financing-agrifood-transition-eu

[98] CBI. (2025b). *Mobilising sustainable finance for methane abatement*. Climate Bonds Initiative. Retrieved from: https://www.climatebonds.net/project-mobilising-sustainable-finance-methane-abatement

[99] Assessing Low-Carbon Transition (ACT) Initiative. (2023). *Sectoral Methodology Guidelines*. https://www.actinitiative.org

companies' climate performance, emphasizing quantitative indicators that capture both efficiency and emission reduction efforts.

Within the agricultural context, the ACT Initiative employs metrics such as land-use efficiency, which evaluates crop yield per hectare in relation to emissions intensity, providing insight into how effectively agricultural outputs are generated per unit of greenhouse gases emitted. This metric encourages practices that optimize productivity while minimizing environmental footprints, aligning with the EU's broader climate goals. Additionally, the adoption of renewable energy technologies in processing and manufacturing facilities forms a critical component of the ACT assessment, recognizing the energy-intensive nature of agri-food supply chains and the potential for decarbonization through clean energy transitions (ACT, 2023)[100].

A notable application of ACT's approach is visible in the dairy farming sector, where the metric "Carbon Intensity per Liter of Milk" has catalyzed investments in innovative technologies such as anaerobic digesters. These systems capture methane emissions from manure, converting waste into biogas and thereby significantly reducing the carbon footprint of milk production (FAO, 2023)[101]. Such targeted metrics allow stakeholders to pinpoint emissions hotspots and incentivize technological adoption that contributes to measurable carbon reductions.

However, despite these strengths, the ACT Initiative faces criticism for its relatively narrow operational focus, concentrating primarily on direct emissions within company boundaries. This approach often overlooks broader landscape-level impacts critical to sustainable agriculture, including biodiversity loss, soil degradation, and water resource depletion (IPBES, 2023)[102]. For example, agricultural intensification driven by efficiency metrics may inadvertently exacerbate habitat fragmentation and ecosystem decline, challenges that require more holistic assessment frameworks.

In conclusion, the ACT Initiative illustrates how sector-specific, operational metrics can guide agricultural companies toward measurable emissions reductions and efficiency improvements. However, achieving a systemic low-carbon transition requires extending this accountability beyond individual firms to the

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[100] Assessing Low-Carbon Transition (ACT) Initiative. (2023). *Sectoral Methodology Guidelines*. https://www.actinitiative.org

[101] Food and Agriculture Organization (FAO). (2023). *Innovations in Methane Mitigation for Dairy Farming*. https://www.fao.org

[102] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2023). *Global Assessment Report on Biodiversity and Ecosystem Services*. https://www.ipbes.net

financial actors that enable agricultural production. The WBCSD's Net-Zero Banking Guidance responds to this need by providing banks with tools to integrate financed emissions into their climate strategies, linking corporate climate performance with investment decisions and fostering coordinated, sector-wide progress toward sustainable agriculture.

1.3.6. WBCSD's Guidance for Banks on Farm-Based Emissions

The World Business Council for Sustainable Development published its Net-Zero Banking Guidance in 2023 to address the often-overlooked issue of financed emissions stemming from agricultural lending (WBCSD, 2023)[103]. Recognizing agriculture's substantial contribution to global greenhouse gas emissions, the guidance emphasizes the need for banks to integrate Scope 3 emissions—those indirectly caused by financed activities—into their climate strategies.

A key recommendation involves setting sector-specific targets for agricultural portfolios, with the Global Dairy Sector Framework serving as a prominent example. This framework supports banks in quantifying emissions within complex agricultural value chains and establishing measurable reduction commitments. Moreover, the guidance advocates for engagement strategies that actively support farmers in adopting climate-smart practices, such as the use of methane-reducing feed additives, which have shown significant potential to lower enteric fermentation emissions in livestock (Rabobank, 2023)[104].

In summary, the WBCSD's Net-Zero Banking Guidance highlights the pivotal role of financial institutions in driving decarbonization across agricultural value chains. By integrating Scope 3 financed emissions into risk management and setting sector-specific targets, banks can actively support farmers in adopting climate-smart practices. Yet, persistent challenges around data availability and granularity underscore the limits of financial interventions when considered in isolation, pointing to the need for complementary mechanisms that ensure broader accountability and sustainability.

Building on this perspective, the World Benchmarking Alliance (WBA) extends the lens of responsibility from financial actors to corporate behavior, evaluating agribusinesses' adherence to environmental and social standards. This progression underscores that effective agricultural transformation relies not only on

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[103] WBCSD (World Business Council for Sustainable Development). (2023). Sustainability Reporting: Challenges and Opportunities for SMEs in Agri-Food Chains. Geneva: WBCSD.

[104] Rabobank. (2023). Innovations in Methane Reduction in Livestock. https://www.rabobank.com

sustainable finance but also on robust corporate accountability frameworks that safeguard land rights, promote inclusive governance, and drive systemic change throughout supply chains.

1.3.7. World Benchmarking Alliance (WBA) and Corporate Accountability

The World Benchmarking Alliance plays a critical role in enhancing corporate accountability within the food and agriculture sectors through its Food and Agriculture Benchmark, which evaluates 350 companies based on their sustainability performance (WBA, 2023)[105]. This benchmark assesses companies across several dimensions, including:

- Implementation of deforestation-free supply chains, critical for curbing biodiversity loss and mitigating climate change.
- Provision of a living wage for agricultural workers, an essential factor for social sustainability and just transitions.

The 2023 benchmark report revealed alarming gaps, notably that 83% of companies lack explicit policies protecting land rights, a fundamental issue linked to the social justice dimension of sustainable agricultural transitions (WBA, 2023)[106]. The absence of robust land rights protections undermines efforts to ensure equitable benefits for smallholders and indigenous communities, exacerbating inequalities and potentially fuelling conflict.

This finding underscores the urgent need for stronger regulatory frameworks and corporate commitments to safeguard land tenure and promote inclusive governance, which are vital components of a just and sustainable agricultural transition.

This chapter has examined the evolving policy and financial frameworks shaping the transition towards sustainable agriculture in the EU and globally. The analysis reveals that while significant progress has been made through initiatives like the European Green Deal and Farm to Fork Strategy, fundamental tensions persist between productivity-focused models and ecological approaches. Financial regulations and market-

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[105] World Benchmarking Alliance (WBA). (2023). Food and Agriculture Benchmark Report 2023. https://www.worldbenchmarkingalliance.org

[106] World Benchmarking Alliance (WBA). (2023). Food and Agriculture Benchmark Report 2023. https://www.worldbenchmarkingalliance.org

based mechanisms are increasingly steering agricultural investments towards sustainability, yet challenges remain in ensuring equitable access for smallholders and addressing systemic socio-economic disparities.

Global sustainability standards demonstrate growing corporate accountability, but critical gaps in emissions accounting, land rights protections, and supply chain transparency limit their effectiveness. The findings underscore that successful agricultural transformation requires more integrated governance approaches that reconcile environmental objectives with social equity and economic viability. Future research should focus on developing coherent policy frameworks that bridge these dimensions to enable truly sustainable food systems.

CHAPTER 2 – DRIVERS AND ISSUES UNDERLYING IDENTIFICATION OF KPIS

2.1 Drivers and Issues

2.1.1 Climate Drivers

Addressing climate change necessitates a comprehensive approach to greenhouse gas (GHG) reduction, with a specific focus on carbon and methane, and the implementation of effective strategies to reduce agricultural emissions, while overcoming significant challenges and sectoral barriers. Agriculture represents both a major contributor to climate change and one of the sectors most vulnerable to its impacts, making emission reduction a critical driver for the identification of sustainability-related KPIs (FAO, 2021)[107].

2.1.1.1 Greenhouse Gas (GHG) Reduction: Carbon and Methane

Methane (CH_4) is identified as the second most important anthropogenic greenhouse gas after carbon dioxide (CO_2) and is a potent contributor to global warming. It possesses a global warming potential approximately 28 times higher than CO_2 over a 100-year horizon, and 80 times higher over a 20-year horizon (IPCC, 2021)[108]. Its relatively short atmospheric lifetime of around nine years makes it a crucial target for short-term mitigation. Anthropogenic CH_4 emissions have already contributed about 0.5°C to current global warming, and their atmospheric concentrations are now 2.6 times higher than pre-industrial levels (UNEP & CCAC, 2021)[109]. Current trajectories align with the most pessimistic IPCC scenarios, projecting global mean temperatures exceeding 3°C by the end of the century. Importantly, there are no known technologies capable of directly removing methane from the atmosphere, unlike CO_2, further emphasizing the urgency of reduction at the source (Shindell et al., 2012)[110].

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[107] FAO. (2021). The State of the World’s Land and Water Resources for Food and Agriculture – Systems at Breaking Point. Rome: FAO.

[108] IPCC. (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.

[109] UNEP & CCAC. (2021). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: UN Environment Programme and Climate & Clean Air Coalition.

[110] Shindell, D., Kuylenstierna, J.C., Vignati, E., et al. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. Science, 335(6065), 183–189.

Although CO_2 emissions from ruminant respiration are generally regarded as less problematic, since they are derived from recently generated biomass, industrial agriculture significantly exacerbates climate change through practices that undermine soil health and promote excessive fertilizer use (Smith et al., 2019)[111]. For this reason, enhancing soil carbon sequestration is considered indispensable for meeting climate objectives. Agricultural soils in the EU, for example, hold a substantial portion of total soil organic carbon stocks, representing an important mitigation potential if managed sustainably (Lugato et al., 2014)[112].

2.1.1.2 Reducing Agricultural Emissions: Strategies, Challenges, and Sectoral Barriers

Agricultural emissions, encompassing both direct production and land-use change, represent a significant share of global GHG emissions. Without targeted mitigation, emissions from agricultural production alone could increase by 58% by 2050 under a business-as-usual scenario, potentially consuming 70% or more of the world's remaining "carbon budget" (IPCC, 2021)[113].

Key Strategies for Emission Reduction:

Agriculture remains one of the most significant contributors to global greenhouse gas (GHG) emissions, yet it also holds some of the most promising opportunities for mitigation. Achieving emission reductions in this sector requires a multi-pronged strategy that addresses production systems, land use, energy integration, and consumption patterns. Each strategy is interconnected, creating pathways not only for emission reduction but also for enhancing resilience, improving efficiency, and advancing sustainability transitions in food systems.

A central area of intervention is livestock management, given that methane emissions from ruminant enteric fermentation and manure represent the largest single source of agricultural GHG emissions worldwide (FAO, 2013)[114]. Mitigation approaches in this domain focus on both animal productivity and waste

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111 Smith, P., Calvin, K., Nkem, J., et al. (2019). Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation? Global Change Biology.

112 Lugato, E., Bampa, F., Panagos, P., Montanarella, L., & Jones, A. (2014). Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices. Global Change Biology.

113 IPCC. (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.

114 FAO. (2013). Tackling Climate Change through Livestock. Rome: Food and Agriculture Organization of the United Nations.

management. Improving animal health and feed conversion efficiency reduces methane per unit of output, while dietary supplements and feed adjustments can lower methane generation directly (Hristov et al., 2013)[115]. Selective breeding programs targeting low-methane traits further demonstrate the potential for long-term systemic change in emission intensity (Pickering et al., 2015)[116]. Equally important are innovations in manure management, such as the adoption of biogas digesters and covered storage systems, which not only reduce methane emissions but also generate renewable energy as a co-benefit (Mottet et al., 2017)[117].

Parallel to livestock interventions, crop management provides a second major avenue for emission reduction. Sustainable intensification practices—such as optimizing fertilizer application with nitrification inhibitors, improving water management in rice cultivation, and adopting reduced tillage—enhance soil carbon sequestration while minimizing nitrous oxide and methane emissions (Yan et al., 2009[118]; Lal, 2020[119]). The incorporation of cover crops and the avoidance of crop residue burning add further benefits by improving soil structure, recycling nutrients, and reducing air pollution (Altieri et al., 2015)[120]. Organic and agroecological practices also contribute to emission reductions while advancing ecological integrity, demonstrating the dual climate and environmental benefits of such approaches.

At the broader landscape scale, land management strategies are pivotal in preserving and enhancing terrestrial carbon stocks. Preventing deforestation and land conversion remains the most immediate and

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[115] Hristov, A.N., Oh, J., Firkins, J.L., et al. (2013). Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. Journal of Animal Science.

[116] Pickering, N.K., Oddy, V.H., Basarab, J., et al. (2015). Animal board invited review: genetic possibilities to reduce enteric methane emissions from ruminants.

[117] Mottet, A., Henderson, B., Opio, C., et al. (2017). Climate change and livestock: Impacts, adaptation, and mitigation.

[118] Yan, X., Yagi, K., Akiyama, H., & Akimoto, H. (2005). Statistical analysis of the major variables controlling methane emission from rice fields.

[119] Lal, R. (2020). Managing soils for negative feedback to climate change and positive impact on food and nutritional security. Soil Science and Plant Nutrition.

[120] Altieri, M.A., Nicholls, C.I., Henao, A., & Lana, M.A. (2015). Agroecology and the design of climate change-resilient farming systems.

effective measure, given the massive emissions released by clearing forests and grasslands (IPCC, 2019)[121]. Complementary strategies include the rewetting and restoration of peatlands, which represent dense carbon reservoirs whose degradation results in disproportionate emissions (Leifeld & Menichetti, 2018)[122]. Expansion of agroforestry systems—integrating trees within croplands and pastures—not only increases carbon storage but also improves biodiversity, water retention, and farmer resilience to climate shocks (Mbow et al., 2014)[123]. These interventions highlight the synergies between climate mitigation and ecosystem restoration.

Another promising area lies in energy integration, where decarbonizing farm operations through renewable energy plays a growing role. Incorporating solar, wind, and bioenergy into agricultural systems reduces dependence on fossil fuels while providing additional income streams for farmers (IRENA, 2022)[124]. Agrophotovoltaics (APV) illustrate the multifunctionality of such systems by allowing dual land use for food production and solar energy generation, thereby maximizing resource efficiency (Dupraz et al., 2011)[125]. These innovations demonstrate how agricultural landscapes can become hubs for renewable energy, linking climate mitigation with rural development and energy access.

Finally, supply-side measures must be complemented by changes in consumption patterns. In high-income contexts, reducing the demand for emissions-intensive products such as beef and dairy can substantially decrease agricultural GHG footprints (Poore & Nemecek, 2018)[126]. Dietary shifts toward plant-based foods, alongside efforts to curb food loss and waste across supply chains, are critical for aligning consumption with

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[121] IPCC. (2019). Climate Change and Land: Special Report. Intergovernmental Panel on Climate Change.

[122] Leifeld, J., & Menichetti, L. (2018). The underappreciated potential of peatlands in global climate change mitigation. Nature Communications.

[123] Mbow, C., Smith, P., Skole, D., et al. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices. Current Opinion in Environmental Sustainability.

[124] IRENA. (2022). Renewable Energy in Agri-food Systems. Abu Dhabi: International Renewable Energy Agency.

[125] Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A., & Ferard, Y. (2011). Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. Renewable Energy.

[126] Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers.

planetary boundaries (FAO, 2019)[127]. By influencing demand, these strategies reduce pressure on land and resources, amplify the effectiveness of production-side mitigation, and contribute to healthier and more sustainable diets.

Taken together, these strategies underscore the need for a systemic approach to agricultural emission reduction. Livestock and crop management provide direct mitigation opportunities within production systems; land management secures long-term carbon stocks; renewable energy integration links agriculture with broader decarbonization goals; and consumption shifts address demand-side drivers of emissions. By combining these levers, the agricultural sector can move toward climate neutrality while simultaneously strengthening food security, ecosystem resilience, and rural livelihoods.

Challenges and Sectoral Barriers:

Despite the growing recognition of agricultural mitigation strategies and their potential to significantly reduce greenhouse gas (GHG) emissions, their adoption remains uneven across regions and farming systems. This uneven uptake is not simply the result of technological limitations but is instead shaped by a complex set of structural, financial, institutional, and cultural barriers that constrain systemic transformation. Understanding these barriers is crucial for designing governance and policy frameworks that can enable effective implementation and long-term sustainability of agricultural mitigation measures.

Institutional barriers represent one of the most persistent challenges. Fragmented policy frameworks and insufficient inter-ministerial coordination frequently undermine the capacity of governments to implement coherent climate strategies in agriculture (Fellmann et al., 2018)[128]. Policies are often designed in a top-down manner, with limited engagement of farmers and rural communities, which restricts their adaptability to local contexts. Moreover, weak political will, sometimes driven by competing economic interests such as export-oriented agriculture or fossil fuel subsidies, prevents climate-smart agriculture from being prioritized within national agendas. Without stronger institutional alignment, mitigation strategies risk being implemented inconsistently or not at all.

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[127] FAO. (2019). The State of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction. Rome: FAO.

[128] Fellmann, T., Witzke, P., Weiss, F., van Doorslaer, B., Drabik, D., Huck, I., Salputra, G., Jansson, T., & Leip, A. (2018). Major challenges of integrating agriculture into climate change mitigation policy framework

A second critical challenge lies in informational barriers. Effective mitigation depends on timely and transparent access to reliable data, yet the agricultural sector often suffers from weak knowledge brokerage systems and unclear governance roles across agencies (Howells et al., 2013)[129]. The absence of open data sharing prevents farmers, policymakers, and investors from accessing the information required to evaluate the costs and benefits of interventions. This lack of clarity not only delays adoption but also reduces accountability and the effectiveness of decision-making.

In parallel, financial barriers continue to limit the scalability of mitigation technologies. Many practices, such as biogas digesters, advanced manure management, or precision agriculture, require high upfront investments that are unaffordable for smallholders and resource-constrained farmers (FAO, 2021)[130]. Access to credit and insurance remains restricted, particularly in low- and middle-income countries, where financial institutions may view climate-smart technologies as risky or unprofitable. While Public-Private Partnerships (PPPs) have been proposed as mechanisms to mobilize private finance, their deployment remains insufficient, and large-scale reliance on external donor funding creates vulnerabilities in sustaining long-term adoption (OECD, 2020)[131].

Beyond financial constraints, behavioural and cultural barriers further impede systemic change. Farmers often perceive climate mitigation practices as risky, fearing potential negative impacts on productivity or profitability (Rickards et al., 2014)[132]. Cultural preferences, such as dietary traditions emphasizing livestock products, and political tendencies toward short-term electoral priorities also reduce the willingness to embrace long-term sustainability measures. These dynamics highlight the importance of social acceptance and trust-building in the success of climate-smart interventions.

Technical barriers remain equally pressing. Many regions lack the necessary technical expertise, institutional capacity, and robust monitoring systems to implement and evaluate mitigation strategies effectively (FAO,

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[129] Howells, M., Hermann, S., Welsch, M., et al. (2013). Integrated analysis of climate change, land-use, energy and water strategies.

[130] Food and Agriculture Organization of the United Nations (FAO) (2021). The State of Food and Agriculture 2021: Making agri-food systems more resilient to shocks and stresses. Rome: FAO.

[131] Organisation for Economic Co-operation and Development (OECD) (2020). Building resilience in agriculture: The role of income diversification. Paris: OECD Publishing.

[132] Rickards, L., Wiseman, J., Edwards, T., & Biggs, C. (2014). The problem of fit: scenario planning and climate change adaptation in the public sector. Environment and Planning C: Government and Policy.

2018)[133]. The absence of technical support and advisory services hinders farmers' ability to adopt new practices, while weak research-extension linkages mean that innovative practices do not reach rural communities in a timely manner. This gap between scientific knowledge and practice contributes to slow diffusion of climate-smart technologies.

Closely linked to technical weaknesses are enforcement and verification challenges, particularly around Measurement, Reporting, and Verification (MRV) systems. Weak MRV frameworks undermine accountability, making it difficult to track progress and ensure compliance with climate targets (UNFCCC, 2015)[134]. This problem is especially acute in low- and middle-income countries, where monitoring capacity is limited and reliance on donor-driven reporting creates asymmetries in data ownership. Without reliable MRV, agricultural mitigation strategies risk being undervalued in national climate plans and in carbon markets.

Finally, the risk of maladaptation underscores the importance of careful design and contextualization of mitigation policies. Poorly conceived adaptation or mitigation measures can inadvertently increase emissions or reduce resilience. For instance, certain dairy feeding strategies that improve productivity may simultaneously increase methane intensity, undermining broader climate objectives (Herrero et al., 2016)[135]. Similarly, large-scale bioenergy projects may displace food production, intensify land-use conflicts, or erode biodiversity. These examples illustrate the need for integrated approaches that avoid trade-offs and ensure that mitigation strategies contribute to long-term climate resilience.

In conclusion, reducing agricultural emissions is less a question of identifying new technologies than of executing a coherent transition that can be priced, monitored, and verified. The most effective way to convert strategy into delivered outcomes is to anchor the sector's mitigation levers—livestock, crops and soils, landscapes, energy integration, and, where relevant, demand—within a compact, finance-relevant KPI architecture. Outcome indicators should make biospheric change explicit, for example methane and nitrous-oxide intensity per unit of output, the annual change in soil organic carbon (t C/ha/yr), verified deforestation-free volumes, water-use efficiency, energy-related emissions intensity, and land-degradation neutrality

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133 FAO. (2018). *Sustainable food systems: Concept and framework.* https://openknowledge.fao.org/server/api/core/bitstreams/b620989c-407b-4caf-a152-f790f55fec71/content

134 UNFCCC. (2015). Paris Agreement. United Nations Framework Convention on Climate Change.

135 Herrero, M., Henderson, B., Havlík, P., et al. (2016). Greenhouse gas mitigation potentials in the livestock sector. Nature Climate Change.

metrics. Process indicators should reveal whether practices are actually shifting on the ground, such as the share of herds using methane-reducing feed additives, the proportion of manure under covered storage or anaerobic digestion, the extent of reduced tillage, cover cropping and alternate wetting and drying in rice systems, the spread of agroforestry, and the degree of traceability to farm polygons. Enabler indicators then test whether the system can scale and endure: the portion of agricultural lending financing climate-smart capex, insurance and guarantee penetration, extension capacity per thousand farmers, MRV coverage with tightening uncertainty bands, and the availability of open, regularly updated datasets.

Setting baselines and 2030 waypoints aligned with NZBA sectoral targets and SBTi/FLAG pathways turns these metrics into transition commitments that lenders can price and supervisors can oversee—for example, a 15–30% reduction in financed methane intensity for livestock portfolios, a 0.2–0.4 t C/ha/yr increase in soil organic carbon on enrolled cropland, or at least half of financed rice area under alternate water management. Disaggregating performance by farm size, region, and gender helps ensure inclusion, while maladaptation sentinels—blue-water footprints, simple habitat indices, yield stability, and grievance tracking—guard against unintended trade-offs. Reported consistently under an ISSB-aligned disclosure, and tied to sustainability-linked covenants, pricing grids, and credit policies, this KPI stack closes the gap between ambition and implementation: it renders agricultural decarbonization measurable, comparable, and bankable, even amid institutional fragmentation, finance constraints, and data limitations.

2.1.2 Environmental Drivers

Environmental drivers—including biodiversity loss, unsustainable land and water resource use, and deforestation—represent some of the most critical pressures shaping global agricultural systems. These drivers are interdependent: land-use change reduces biodiversity, biodiversity loss weakens ecosystem services, and deforestation contributes both to climate instability and to declining land productivity. Their integration into sustainability assessments and KPI frameworks is essential, as they determine the long-term ecological viability of food production and the resilience of agricultural systems to climate shocks.

2.1.2.1 Biodiversity

Biodiversity, encompassing genetic, species, and ecosystem diversity, underpins agricultural productivity through essential ecosystem services. Pollination, nutrient cycling, pest regulation, soil fertility, and water purification all depend on diverse ecological networks. For instance, insect pollinators contribute to the production of 75% of leading global food crops, a service valued at approximately USD 235–577 billion annually (IPBES, 2019)[136]. Declines in pollinator species, largely due to pesticide use, land-use change, and climate variability, directly reduce yields and increase reliance on artificial inputs.

The scale of biodiversity loss is unprecedented: extinction rates are now 100 to 1,000 times higher than the natural baseline, with an estimated 1 million species at risk of extinction within decades (IPBES, 2019)[137]. Forest ecosystems alone host about 80% of amphibians, 75% of birds, and 68% of mammals, yet these habitats are rapidly disappearing. Alarmingly, some studies estimate that 150 species go extinct daily due to deforestation (Pearce, F. (2015)[138]. Such trends undermine food security by destabilizing ecosystems upon which agriculture itself depends.

From a KPI perspective, biodiversity indicators must move beyond simplistic counts of species to incorporate measures of ecosystem functionality, such as pollination sufficiency, soil microbial diversity, and the preservation of genetic resources for crops and livestock. The Kunming-Montreal Global Biodiversity Framework (2022) calls for integrating biodiversity safeguards into agricultural monitoring, reinforcing the need for sector-specific performance metrics.

2.1.2.2 Land and Water Resource Use

Agriculture is the largest user of terrestrial resources, occupying approximately 50% of habitable land and accounting for 70% of freshwater withdrawals (FAO, 2025)[139]. The sector is also the primary driver of land-use change, which threatens 85% of species at risk globally (IPBES, 2019)[140]. Between 1990 and 2020,

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[136] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Global Assessment Report on Biodiversity and Ecosystem Services. IPBES Secretariat. https://ipbes.net/global-assessment

[137] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Global Assessment Report on Biodiversity and Ecosystem Services. IPBES Secretariat. https://ipbes.net/global-assessment

[138] Pearce, F. (2015). Global extinction rates: Why do estimates vary so wildly? Yale Environment 360. Yale School of the Environment.

[139] Food and Agriculture Organization of the United Nations (FAO). (2025). Water and One Health. In One Health: Areas of work. FAO. Retrieved from https://www.fao.org/one-health/areas-of-work/water/en

[140] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Global Assessment Report on Biodiversity and Ecosystem Services. IPBES Secretariat. https://ipbes.net/global-assessment

about 420 million hectares of forest were converted to agricultural and urban uses (FAO, 2020)[141]. Such conversion not only causes direct habitat loss but also fragments landscapes, reducing ecosystem connectivity and resilience.

Land degradation is a particularly acute outcome of unsustainable practices. Approximately 34% of global agricultural land is degraded, suffering from soil erosion, nutrient depletion, and salinization (Ferreira, et al 2022)[142]. For example, deforested soils lose their nutrient-rich top layer at a much faster rate, increasing vulnerability to floods and droughts. Erosion can reduce crop yields by up to 50% over several decades if not addressed through conservation practices (FAO, 2025).[143]

Water stress presents another critical dimension. Agriculture consumes vast amounts of freshwater, with irrigation efficiency often below 40% due to losses from evaporation and seepage. Over-abstraction of aquifers, particularly in South Asia and the Middle East, threatens long-term water availability, while climate change alters precipitation patterns, intensifying droughts and floods. More than 2.4 billion people already live in water-stressed countries, and unsustainable irrigation is a central driver (UN, 2023)[144].

In KPI frameworks, indicators such as water-use efficiency, soil organic carbon content, irrigation sustainability, and land degradation neutrality serve as direct measures of agricultural sustainability. Monitoring these variables enables both governments and producers to track the trade-offs between productivity and resource depletion.

2.1.2.3 Deforestation

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[141] Food and Agriculture Organization of the United Nations (FAO). (2020). The State of the World's Forests 2020. FAO. Retrieved from https://www.fao.org/state-of-forests/en/

[142] Ferreira, C. S. S., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., & Kalantari, Z. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. Science of The Total Environment, 805, Article 150106. https://doi.org/10.1016/j.scitotenv.2021.150106

[143] Food and Agriculture Organization of the United Nations (FAO). (2025). Key messages | Global Symposium on Soil Erosion. FAO. Retrieved from https://www.fao.org/about/meetings/soil-erosion-symposium/key-messages/en/

[144] United Nations. (2023). Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all. In The Sustainable Development Goals Report 2023. United Nations Statistics Division. Retrieved from https://unstats.un.org/sdgs/report/2023/goal-06/

Deforestation, defined as the permanent conversion of forest to non-forest land, continues to be overwhelmingly driven by agricultural expansion. Commodity production—particularly beef, soy, and palm oil—accounts for approximately 60 percent of tropical forest loss (Curtis et al., 2018)[145]. In Brazil, beef production alone is responsible for nearly three-quarters of deforestation, while 75 percent of global soy production is used as livestock feed, reinforcing the indirect relationship between rising meat demand and forest clearance (FAO, 2020)[146]. Globally, forests still cover an estimated 4.06 billion hectares, yet around 10 million hectares are lost every year, with Brazil and Indonesia jointly responsible for about 45 percent of this annual destruction (FAO, 2020[147]; World Resources Institute, 2023[148]).

The environmental consequences of this process are multiple and interconnected. Forest ecosystems act as major carbon sinks, storing around 662 billion tonnes of carbon, while deforestation between 2011 and 2020 contributed on average 4.1 gigatonnes of CO_2 annually, roughly 10 percent of total anthropogenic emissions (IPCC, 2021[149]). Beyond the climate dimension, deforestation drives severe biodiversity loss by eroding some of the most species-rich habitats on Earth and thereby accelerating extinction processes (CBD, 2022). Forest removal also degrades soil quality, increases erosion, reduces water retention, and disrupts rainfall patterns; in tropical areas, studies suggest that forest loss may reduce regional precipitation by up to 30 percent, ironically undermining the agricultural productivity it was intended to expand (Lawrence & Vandecar, 2015[150]; Ellison et al., 2017[151]). The public health dimension adds yet another layer, as forest

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[145] Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *Science*, 361(6407), 1108–1111. https://doi.org/10.1126/science.aau3445

[146] FAO. (2020). *Global Forest Resources Assessment 2020*. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/interactive/forest-resources-assessment/2020/en/

[147]FAO. (2020). *Global Forest Resources Assessment 2020*. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/interactive/forest-resources-assessment/2020/en/

[148] World Resources Institute. (2023). *Global Forest Review: 2023 update*. Washington, DC: WRI. https://gfr.wri.org/

[149] IPCC. (2021). *AR6 Climate Change 2021: The Physical Science Basis*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

[150] Lawrence, D., & Vandecar, K. (2015). Effects of tropical deforestation on climate and agriculture. *Nature Climate Change*, 5, 27–36. https://doi.org/10.1038/nclimate2430

[151] Ellison, D., Morris, C. E., Locatelli, B., et al. (2017). Trees, forests and water: Cool insights for a hot world. *Global Environmental Change*, 43, 51–61. https://doi.org/10.1016/j.gloenvcha.2017.01.002

fragmentation increases human exposure to wildlife reservoirs of disease, with more than 30 percent of emerging infectious diseases since 1960 linked to deforestation (FAO, 2022[152]; UNEP, 2022[153]).

In response to these converging crises, the European Union has adopted the *Regulation on Deforestation-Free Products (*European Commission, 2023)[154], which represents a landmark attempt to regulate commodity supply chains and prevent the placing of deforestation-linked products on the EU market. The Regulation covers cattle, soy, palm oil, coffee, cocoa, timber, rubber, and their derivatives, requiring operators and traders to prove that their goods are not associated with deforestation or forest degradation occurring after December 31, 2020 (European Commission, 2023)[155]. This proof must take the form of detailed due diligence, including the submission of geolocation data for the plots of land on which the commodities were produced, risk assessments, and the implementation of mitigation measures where risks are identified (Bartley, 2023)[156]. In doing so, the EUDR operationalizes a novel approach that makes deforestation a matter of trade compliance, embedding ecological criteria into market access conditions for one of the world's largest consumer markets (Schleifer & Sun, 2023)[157].

The academic debate surrounding the EUDR highlights both its pioneering potential and its structural weaknesses. Scholars such as Bartley (2023) and Schleifer and Sun (2023) emphasize that the EUDR is the first binding legal framework of its kind, capable of transforming global trade dynamics by shifting responsibility from voluntary corporate pledges to enforceable obligations. Its requirement for geospatial traceability down to the plot level is considered a major innovation, as it compels transparency and provides measurable benchmarks for supply-chain governance, such as the percentage of commodities traced to origin, the verification of forest cover stability, and compliance rates by exporting countries (European

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[152] FAO. (2022). *The State of the World's Forests 2022*. Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/4c8bd12f-d6b8-4755-a82f-1284c41bf012
[153] UNEP. (2022). *Spillover: Linking deforestation and zoonotic disease emergence*. Nairobi: United Nations Environment Programme.

[154] European Commission. (2023). *Regulation (EU) 2023/1115 on deforestation-free products*. Official Journal of the European Union.https://eur-lex.europa.eu/eli/reg/2023/1115/oj/eng

[155] European Commission. (2023). *Regulation (EU) 2023/1115 on deforestation-free products*. Official Journal of the European Union.https://eur-lex.europa.eu/eli/reg/2023/1115/oj/eng

[156] Bartley, T. (2023). *Regulating deforestation-free supply chains: The European Union's new approach*. Journal of Environmental Law, 35(2), 245–272. https://doi.org/10.1093/jel/eqad015

[157] Schleifer, P., & Sun, Y. (2023). Emerging markets and the EU Deforestation Regulation: Risks of exclusion and trade diversion. *Regulation & Governance*. https://doi.org/10.1111/rego.12555

Parliament Research Service, 2023)[158]. From this perspective, the Regulation is regarded as a critical step toward aligning agricultural supply chains with international environmental agreements, including the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework (CBD, 2022[159]; UNFCCC, 2021)[160].

Other scholars, however, stress the challenges and unintended consequences of implementation. One concern relates to the significant compliance burden for smallholder farmers in producing countries. Many smallholders lack formal land tenure, adequate documentation, and the technical capacity to provide the required geolocation data. This situation risks excluding them from EU supply chains, concentrating market access in the hands of larger and better-capitalized producers, and exacerbating global inequities (Garrett et al., 2023)[161]. Studies further warn that the EUDR may contribute to trade diversion: products that cannot enter the EU market could be redirected to regions with less stringent regulations, thereby reducing the Regulation's global environmental effectiveness (Bruegel, 2024)[162]. Other critiques focus on the risk of administrative overload and uneven enforcement capacity among EU member states, which could result in inconsistent application and weaken credibility. Finally, there is the question of proportionality, as the Regulation's strict cut-off date and reliance on digital traceability systems may unintentionally marginalize producers who lack access to the necessary technology and finance (Garrett et al., 2023)[163].

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[158] European Parliament Research Service. (2023). *Deforestation Regulation: Implementation challenges*. Brussels: EPRS.https://www.optelgroup.com/en/solution/eudr-compliance/?utm_source=Google+AdWords&utm_medium=cpc&utm_campaign=EUDR+-+All+regions&utm_adgroup=179379502978&utm_content=753603298025&utm_term=2228855975023&utm_device=c&gad_source=1&gad_campaignid=21724665836&gbraid=0AAAADkS50Pg4hgOPZsrdR5sPc7xwYHF1&gclid=Cj0KCQjw58PGBhCkARIsADbDilyCkltO7IcNsg_aDNM8CS8mSk3HQ90eaLCtAQxgNuW-rOd9P_wQtSMaAs9zEALw_wcB

[159] CBD. (2022). *Kunming-Montreal Global Biodiversity Framework*. Secretariat of the Convention on Biological Diversity. Retrieved from: https://www.cbd.int

[160] UNFCCC. (2021). *The Paris Agreement*. United Nations Framework Convention on Climate Change. Retrieved from: https://unfccc.int

[161] Garrett, R., Gardner, T., Godar, J., & le Polain de Waroux, Y. (2023). Equity challenges in implementing deforestation-free supply chains. *World Development*, 162, 106147. https://doi.org/10.1016/j.worlddev.2023.106147

[162] Bruegel. (2024). *The EU Deforestation Regulation: Challenges and implications for global trade*. Bruegel Policy Brief. Retrieved from: https://www.bruegel.org

[163] Garrett, R., Gardner, T., Godar, J., & le Polain de Waroux, Y. (2023). Equity challenges in implementing deforestation-free supply chains. *World Development*, 162, 106147. https://doi.org/10.1016/j.worlddev.2023.106147

The implications of these debates are significant. On the one hand, the EUDR demonstrates that it is possible to design binding legal instruments that integrate environmental objectives into trade, transforming sustainability from a voluntary to a mandatory standard (Bartley, 2023)[164]. On the other hand, its effectiveness will depend on the provision of financial and technical support to smallholders, the establishment of reliable monitoring and enforcement mechanisms, and the development of complementary policies to address risks of leakage and inequity (Bruegel, 2024[165]). By requiring the integration of environmental indicators such as forest cover change, biodiversity conservation, and ecosystem services into compliance systems, the Regulation offers a pathway for rethinking agricultural performance in terms of long-term ecological integrity rather than short-term yield (CBD, 2022)[166].

In sum, deforestation illustrates the extent to which agriculture operates within planetary boundaries (Rockström et al., 2009)[167]. When those limits are breached, both ecosystems and human societies are destabilized. By embedding sustainability into supply chains through the EUDR, and by linking agricultural performance to broader frameworks such as the Sustainable Development Goals—particularly SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land)—the EU has sought to create a model for reconciling agricultural productivity with environmental stewardship (United Nations, 2015)[168]. Yet the academic literature reminds us that without addressing the structural limitations of implementation, enforcement, and equity, the transformative potential of the Regulation may remain only partially realized.

2.1.3 Social Drivers

2.1.3.1 Just Transition

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[164] Bartley, T. (2023). *Regulating deforestation-free supply chains: The European Union's new approach*. Journal of Environmental Law, 35(2), 245–272. https://doi.org/10.1093/jel/eqad015

[165] Bruegel. (2024). *The EU Deforestation Regulation: Challenges and implications for global trade*. Bruegel Policy Brief. Retrieved from: https://www.bruegel.org

[166] CBD. (2022). *Kunming-Montreal Global Biodiversity Framework*. Secretariat of the Convention on Biological Diversity. Retrieved from: https://www.cbd.int

[167] Rockström, J., Steffen, W., Noone, K., et al. (2009). A safe operating space for humanity. *Nature*, 461, 472–475. https://doi.org/10.1038/461472a

[168] United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. New York: United Nations. http://sdgs.un.org/2030agenda

The concept of a just transition in agriculture builds on the broader just transition framework, originally emerging from labor and environmental justice movements in the 1980s and 1990s. At its core, just transition seeks to reconcile environmental imperatives with social equity, ensuring that climate mitigation and adaptation efforts do not marginalize vulnerable populations but instead create opportunities for inclusive development (ILO, 2015)[169]. In agriculture, this means that measures to decarbonize farming—such as phasing out chemical fertilizers, reducing methane emissions from livestock, or shifting land away from deforestation-linked crops—must be carefully managed to avoid generating unintended socioeconomic harm.

Agriculture is uniquely sensitive to the just transition debate for three reasons:

1. **High employment intensity**: The sector employs over 26% of the global workforce, particularly in low- and middle-income countries (OECD, 2023)[170].
2. **Cultural embeddedness**: Farming practices are deeply tied to traditions, community identity, and land tenure arrangements.
3. **Poverty concentration**: Smallholder farmers, landless workers, and rural women disproportionately face poverty and climate vulnerability (Chandra et al., 2017)[171].

Without explicit attention to equity, climate policies in agriculture risk creating job losses, land dispossession, and reduced incomes for those least able to absorb such shocks. For example, strict deforestation-free supply chain regulations in the EU could exclude smallholder cocoa or palm oil producers who lack resources to comply, while benefiting large agribusinesses with better monitoring capacity (Melati et al., 2024)[172].

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[169] International Labour Organization (ILO) (2015). Guidelines for a just transition towards environmentally sustainable economies and societies for all. Geneva: ILO.

[170] Organisation for Economic Co-operation and Development (OECD). (2023). Informality and globalisation: In search of a new social contract. OECD Publishing. https://doi.org/10.1787/c945c24f-en

[171] Chandra, A., McNamara, K. E., Dargusch, P., Caspe, A. M., & Dalabajan, D. (2017). Gendered vulnerabilities of smallholder farmers to climate change in conflict-prone areas: A case study from Mindanao, Philippines. Journal of Rural Studies, 50, 45–59. https://doi.org/10.1016/j.jrurstud.2016.12.011

[172] Melati, K., Jintarith, P., & Lee, H. (2024, September 3). Finding a place for smallholder farmers in EU deforestation regulation. Stockholm Environment Institute. https://doi.org/10.51414/sei2024.035

To operationalize equity rather than merely assert it, the just transition lens should be expressed through a compact, decision-useful set of KPIs that are co-reported with environmental metrics and embedded in finance, procurement, and policy. Distributional outcome KPIs can track whether benefits and burdens are shared fairly—for instance, progress toward closing the living-income gap for smallholders, income stability across seasons, decent-work compliance rates, and the share of procurement volumes sourced from verified smallholders. Process KPIs should evidence inclusive implementation, capturing timely and fair payment terms to producers, access to extension and training hours per farmer (with gender and youth disaggregation), participation in decision-making forums, and the existence and effectiveness of grievance mechanisms measured by resolution time. Enabler and safeguard KPIs then test system readiness and guard against harm, monitoring tenure security improvements, access to affordable credit and insurance, social protection coverage during phase-outs, resettlement avoided, and food affordability for local consumers alongside environmental targets.

Linking these KPIs to financial instruments strengthens accountability: sustainability-linked loans and procurement contracts can include social sustainability performance targets—such as minimum inclusion thresholds for smallholder suppliers, caps on payment days outstanding, or verified progress on living-income benchmarks—paired with step-up/step-down pricing. Disclosing these indicators in an ISSB-aligned format, and tracking them alongside SBTi/FLAG and NZBA environmental targets, ensures that emissions reductions are not achieved through burden-shifting but through equitable, monitorable change that lenders can price, supervisors can oversee, and producers can sustain. In this sense, the KPI architecture is the bridge between just transition principles and practical governance, converting high-level social commitments into measurable conditions for a climate-neutral and socially resilient agricultural transformation.

2.1.3.2 Core Dimensions of Just Transition in Agriculture

A just transition in agriculture cannot be reduced to technical shifts in farming practices; it requires a multidimensional restructuring of rural economies, governance arrangements, and social relations. Four dimensions are particularly critical: workforce and skill development, community empowerment and participation, equity and inclusion, and the avoidance of trade-offs or so-called "false solutions."

<u>Workforce and Skill Development</u>

Agricultural transitions demand not only new technologies but also new knowledge systems. Farmers and agricultural workers are increasingly required to adopt practices such as agroecological cultivation, regenerative soil management, sustainable irrigation techniques, digital agriculture tools, and renewable energy integration on farms. Without proper training and extension support, however, rural populations risk exclusion from these evolving systems, perpetuating economic marginalization. Capacity-building programs must therefore prioritize accessible and context-specific skill development. For example, farmer field schools and digital platforms have proven effective in disseminating climate-smart agriculture techniques, while vocational training in renewable energy maintenance or precision irrigation provides new employment opportunities in rural areas. The International Labour Organization (ILO, 2019)[173] stresses that skills adaptation is not simply about technical knowledge but also about empowering rural workers to retain agency in rapidly transforming agri-food systems. Ensuring access to such knowledge guarantees that farmers thrive in decarbonized food systems rather than being displaced by them.

Community Empowerment and Participation

The social legitimacy of climate policies in agriculture depends on participatory governance structures. Farmer cooperatives, rural councils, and multi-stakeholder platforms create spaces where farmers and communities can co-design transition pathways rather than being passive recipients of externally imposed policies. Experiences from Latin America, for example, illustrate that agroecological transitions succeed when farmers are included as decision-makers, often through grassroots organizations that negotiate with state authorities (Altieri & Nicholls, 2020)[174]. Transparent dialogue not only strengthens ownership and trust but also fosters innovation by integrating traditional ecological knowledge with scientific expertise. Conversely, when climate mitigation measures such as land reallocation or input restrictions are introduced without adequate consultation, they risk sparking resistance and social unrest. Meaningful participation is therefore both a normative and practical necessity for achieving equitable and durable agricultural transitions.

Equity and Inclusion

Equity lies at the heart of a just transition, especially given the structural inequalities embedded in agricultural systems. Women represent approximately 43% of the global agricultural labor force, yet they disproportionately lack access to secure land tenure, credit facilities, extension services, and decision-

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[173] International Labour Organization (ILO) (2019). Skills for a greener future: A global view based on 32 country studies. Geneva: ILO.

[174] Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. Agronomy for Sustainable Development, 35(3), 869–890. https://doi.org/10.1007/s13593-015-0285-2

making forums (Glazebrook et al., 2020)[175]. Youth populations in rural areas also face barriers to entry, with high unemployment rates and limited access to resources discouraging engagement in agriculture. Addressing these disparities is crucial for avoiding a transition that reproduces existing inequalities. Gender-responsive policies—such as joint land titling, women-targeted credit schemes, and equal participation in farmer organizations—can play a transformative role. Similarly, investing in youth-centered rural innovation hubs and entrepreneurship support programs ensures that the next generation perceives farming as a viable and dignified livelihood. Equity in just transition frameworks is not an ancillary concern but rather a core condition for sustainable and inclusive agricultural futures.

Avoiding Trade-offs and "False Solutions"

Not all climate-oriented interventions in agriculture align with just transition principles. Large-scale biofuel plantations, for instance, may contribute to reducing greenhouse gas emissions but often exacerbate food insecurity by diverting arable land from food production. They can also deepen water scarcity and trigger land dispossession, disproportionately affecting smallholder farmers and Indigenous communities (Chowdhury et al., 2025)[176]. Similarly, certain "climate-smart" technologies risk creating dependency on external inputs or intellectual property regimes that undermine farmer autonomy. A just transition requires systematic screening of potential trade-offs, ensuring that climate mitigation or adaptation measures do not come at the expense of food sovereignty, land rights, or local ecosystems. Holistic impact assessments, rooted in both social and environmental criteria, are therefore indispensable to avoid contradictory or unjust outcomes.

Taken together, these dimensions show that a just transition is as much about governance and justice as it is about technology and productivity. When tracked through a concise, co-reported KPI architecture—skills and adoption for workforce development; representation, decision uptake, and grievance performance for participation; inclusion metrics for equity; and safeguard sentinels to avoid harmful trade-offs—social commitments become monitorable conditions for investment. Disclosed in an ISSB-aligned format and linked to NZBA and SBTi/FLAG environmental targets, this KPI framework ensures that agricultural

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[175] Glazebrook, T., Noll, S., & Opoku, E. (2020). Gender Matters: Climate Change, Gender Bias, and Women's Farming in the Global South and North. Agriculture, 10(7), 267. https://doi.org/10.3390/agriculture10070267

[176] Chowdhury, P., Mahi, N. A., Yeassin, R., Chowdhury, N.-U.-R., & Farrok, O. (2025). Biomass to biofuel: Impacts and mitigation of environmental, health, and socioeconomic challenges. Energy Conversion and Management: X, 25, 100889. https://doi.org/10.1016/j.ecmx.2025.100889

decarbonization is not achieved through burden shifting but through inclusive, accountable, and durable rural transformation.

2.1.3.4 Farmer Income Stability

Income stability is a foundational precondition for enabling climate action in agriculture. Farmers typically operate under tight profit margins and face significant uncertainty due to both natural and market-related risks. This inherent vulnerability often makes them risk-averse, discouraging adoption of innovative practices that require upfront investment or entail uncertain short-term returns. Climate-friendly practices such as renewable-powered irrigation systems, agroforestry integration, or reduced reliance on synthetic fertilizers generally involve initial financial outlays and delayed profitability (Gârban, 2025)[177]. In the absence of robust mechanisms to stabilize farmer incomes, widespread uptake of these practices is unlikely, thereby constraining the transition toward sustainable agricultural systems.

2.1.3.5 Challenges to Income Stability

<u>Climate Variability</u>

Climate change directly undermines income stability by increasing exposure to environmental risks. Rising temperatures, more frequent and severe droughts, floods, and extreme weather events substantially reduce yields and farm revenues. For example, maize yields in Sub-Saharan Africa are projected to decline by 20–30% by 2050 due to climate stress, representing not only a food security challenge but also a significant income shock for millions of smallholder farmers (IPCC, 2021)[178]. Income instability is compounded by the fact that most small-scale farmers lack access to crop insurance or formal safety nets, leaving them highly vulnerable to climate-induced losses.

<u>Market Volatility</u>

Even in the absence of climate shocks, farmer incomes remain precarious due to volatile commodity markets. Producers of export-oriented cash crops such as cocoa, coffee, and cotton are particularly exposed to fluctuations in global demand and pricing. A sharp drop in commodity prices can wipe out annual incomes, leaving little to reinvest in climate-friendly innovations. This dependence on single-crop income

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[177] Gârban, G. (2025). From Fields to Frameworks: Empowering Farmers in EU Climate Action. Interreg Europe. Retrieved from https://www.interregeurope.eu/sites/default/files/2025-06/DTE-Y3-Empowering%20Farmers%20in%20EU%20Climate%20Action_REPORT.pdf

[178] IPCC. (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.

streams thus creates structural fragility. Diversification—through mixed farming systems or access to local and regional markets—has been identified as a crucial resilience strategy, but structural barriers often prevent smallholders from pursuing it (Mohamed Shaffril et al., 2024)[179].

High Input Costs and Debt Cycles

A further dimension of income instability arises from dependence on chemical inputs and patented seeds. Reliance on fertilizers, pesticides, and hybrid seed varieties not only creates ecological challenges but also traps farmers in debt cycles. In South Asia, for example, the high costs of inputs have been linked to farmer indebtedness crises, which in turn exacerbate poverty and distress migration (Zhang, 2024)[180]. These dynamics weaken farmers' capacity to take risks on alternative practices such as organic or agroecological farming, even when such practices might be more sustainable in the long run. Debt also undermines bargaining power, making farmers dependent on middlemen or corporate supply chains that extract disproportionate value from agricultural production.

Gender and Social Inequality

Income stability challenges are not evenly distributed. Women farmers, who constitute a substantial share of the agricultural workforce globally, face systemic barriers in accessing land rights, financial services, and extension support (FAO,2023)[181]. These structural inequalities intensify women's income vulnerability and limit their ability to participate in, and benefit from, climate-friendly agricultural transitions. Moreover, marginalized groups such as youth, landless laborers, and Indigenous communities often face exclusion from policy and credit frameworks, further entrenching patterns of instability. A just approach to income stabilization must therefore integrate equity considerations, ensuring that interventions do not reinforce existing disparities.

Implications for Climate Action

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[179] Mohamed Shaffril, H. A., Abu Samah, A., Samsuddin, S. F., Ahmad, N., Tangang, F., Ahmad Sidique, S. F., Abdul Rahman, H., Burhan, N. A. S., Shah, J. A., & Khalid, N. A. (2024). Diversification of agriculture practices as a response to climate change impacts among farmers in low-income countries: A systematic literature review. Climate Services, 6, 100050. Advance online publication. https://doi.org/10.1016/j.cliser.2024.100050

[180] Zhang, Q. F. (2024). From Sustainable Agriculture to Sustainable Agrifood Systems: A Comparative Review of Alternative Models. Sustainability, 16(22), 9675. https://doi.org/10.3390/su16229675

[181] Food and Agriculture Organization of the United Nations. (2023). The status of women in agrifood systems. FAO.

The relationship between income stability and sustainable agricultural transformation is circular: stable incomes create the conditions for adopting climate-smart practices, while climate-smart practices—once adopted—can themselves contribute to more stable incomes by reducing vulnerability to shocks and improving resource efficiency. However, without deliberate intervention, this virtuous cycle may never be initiated. Policy tools such as climate insurance schemes, price stabilization mechanisms, targeted subsidies for sustainable practices, and access to low-interest credit are essential to de-risk adoption and provide farmers with reliable economic security. Income stability is thus not a peripheral issue but a central enabling factor in aligning agricultural production with long-term climate goals.

2.1.3.6 Policy Integration of Income Stability into Just Transition

Maintaining farmer income stability is not only an economic necessity but a social safeguard for political legitimacy. If transitions are perceived to threaten livelihoods, they risk triggering resistance, disengagement, or even rural unrest. Policies must therefore align climate goals with rural development priorities, embedding income stability into national climate strategies and agricultural policies (UNDP, 2022)[182].

Just transition and farmer income stability are mutually reinforcing social drivers of agricultural decarbonization. A just transition ensures that environmental policies uplift rather than marginalize rural communities, while income stability equips farmers with the economic security to adopt and sustain climate-friendly practices. To make this nexus operational and finance-relevant, social KPIs should be co-reported alongside environmental metrics: progress toward closing the living-income gap, stability of farm income across seasons (e.g., reduced coefficient of variation), timely and fair payment terms and off-take security, access to affordable credit and insurance (including index and climate perils), representation of women and youth in producer organizations, verified participation and effective grievance resolution, and improvements in tenure security. When these indicators are embedded in sustainability-linked covenants, supplier finance, and public programs—and disclosed in an ISSB-aligned format that sits next to SBTi/FLAG and NZBA environmental targets—they translate high-level social commitments into measurable conditions for investment. Together, just transition and income stability thereby ensure agricultural climate action is not

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[182] United Nations Development Programme (UNDP). (2022). Climate Promise Global Progress Report 2022. UNDP. Retrieved from https://climatepromise.undp.org/sites/default/files/research_report_document/Climate%20Promise%20Global%20Progress%20Report%202022.pdf

only environmentally effective but also socially legitimate and economically viable, creating credible pathways to equitable prosperity and resilient food systems.

2.2 Solutions and Approaches

2.2.1 Bioeconomy and Agri-biotech Strategies

The transition toward sustainable agriculture requires systemic approaches that integrate technological innovation, circular economy principles, and biological resource efficiency. Within this framework, the bioeconomy and agricultural biotechnology emerge as pivotal drivers of transformation, enabling agricultural systems to reduce environmental impacts, increase productivity, and foster rural economic development. By combining renewable resources with advanced biotechnological applications, these approaches create synergies that address pressing challenges such as greenhouse gas (GHG) emissions, soil degradation, and biodiversity loss while simultaneously improving farmer livelihoods (Italian Ministry of Agriculture, 2025)[183].

2.2.1.1 The Bioeconomy Framework in Agriculture

The bioeconomy is broadly defined as the use of renewable biological resources—crops, forests, algae, and organic waste—to produce food, energy, materials, and bio-based products through sustainable and circular processes (Intesa Sanpaolo Innovation Center, 2025)[184]. In agriculture, this framework prioritizes resource circularity, whereby agricultural residues are transformed into inputs such as biofertilizers, biopesticides, bioenergy, and biodegradable materials (European Biogas Association, 2025)[185].

The European Union and individual states have adopted comprehensive bioeconomy strategies that promote biorefineriesand agro-industrial integration, linking primary production with energy, chemical, and material

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183 Italian Ministry of Agriculture. (2025). Implementation Action Plan 2025–2027 for the Italian Bioeconomy Strategy. Rome: MIPAAF.

184 Intesa Sanpaolo Innovation Center. (2025). Bioeconomy in Italy: Innovation and Agriculture. Turin: Intesa Sanpaolo.

185 European Biogas Association. (2025). Circular Bioeconomy and Biogas Systems. Brussels: EBA.

industries to diversify rural economies (Italian Ministry of Agriculture, 2025)[186]. For instance, Italy's *Implementation Action Plan 2025–2027 for the Bioeconomy Strategy* emphasizes local circular value chains and farmer-centric models that leverage traditional know-how alongside cutting-edge innovations. These frameworks highlight the importance of decentralized innovation, where local contexts determine the adoption and scalability of bioeconomy initiatives (BBioNets Team, 2025)[187] Embedding KPIs into these frameworks aligns policy ambition with financing practice: sustainability-linked loans and green bonds can tie pricing to thresholds for residue-to-product conversion, verified GHG abatement, nutrient recycling, and soil health gains, while procurement contracts can require minimum recycled/biobased content and verified end-of-life performance. Social KPIs—progress toward closing living-income gaps through stable offtake agreements and fair payment terms, participation of women and youth in bioeconomy enterprises, local job creation and skills certification rates, tenure and feedstock-sourcing safeguards, and effective grievance resolution—ensure that circular value chains deliver income stability and a just transition rather than burden shifting. Reported in an ISSB-aligned format and interoperable with EU Taxonomy screening criteria, and mapped to SBTi/FLAG and NZBA portfolio targets where relevant, this KPI architecture turns decentralized innovation—highlighted by BBioNets (2025)61—into accountable, scalable practice, balancing climate gains with soil health, water stewardship, product circularity, and equitable rural development.

2.2.1.2 Key Technological Innovations

Technological innovation plays a pivotal role in reshaping agricultural systems toward sustainability, resilience, and inclusivity. In the context of the bioeconomy, innovations span biotechnology, waste valorization, digitalization, and sustainable cropping systems. Together, these advances not only enhance productivity and efficiency but also address climate change mitigation, biodiversity conservation, and rural development. Importantly, technological pathways must be deployed within socio-ecological contexts that ensure equitable benefits and avoid exacerbating inequalities.

Agricultural Biotechnology

Recent advances in precision breeding and genetic engineering offer transformative opportunities for climate-resilient agriculture. Techniques such as CRISPR-Cas9 and other New Breeding Techniques (NBTs) enable the targeted modification of crop genomes, improving traits such as drought tolerance, pest

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[186] Italian Ministry of Agriculture. (2025). Implementation Action Plan 2025–2027 for the Italian Bioeconomy Strategy. Rome: MIPAAF.

[187] BBioNets Team. (2025). Turning Local Know-how into European Solutions for Smarter Bio-Based Farming. Horizon Magazine.

resistance, and nutrient efficiency (Intesa Sanpaolo Innovation Center, 2025)[188]. By reducing dependency on chemical fertilizers and pesticides, biotechnology can simultaneously lower agricultural greenhouse gas emissions and protect ecosystem health. Moreover, climate-adapted crop varieties contribute to food security by safeguarding yields under increasingly variable environmental conditions. However, debates persist around biosafety, intellectual property rights, and farmer sovereignty, highlighting the need for governance frameworks that balance innovation with social justice and precaution.

Agroecological Biotechnologies

Complementing genetic approaches, agroecological biotechnologies aim to work with natural processes to improve soil fertility and crop health. Biofertilizers—composed of nitrogen-fixing bacteria, phosphate-solubilizing microorganisms, or mycorrhizal fungi—facilitate nutrient cycling and enhance soil organic carbon sequestration, thereby reducing the need for synthetic fertilizers (European Biogas Association, 2025)[189]. Similarly, biopesticides derived from natural extracts or beneficial microbes provide environmentally sound alternatives to chemical pesticides, mitigating risks to biodiversity and human health. These technologies exemplify the synergy between productivity and ecological integrity: they strengthen ecosystem services while offering affordable solutions to smallholder farmers, who are often disproportionately burdened by input costs.

Circular Waste Valorisation and Biorefineries

Waste-to-resource systems represent a cornerstone of the circular bioeconomy, enabling farmers to turn by-products into valuable inputs. Technologies such as anaerobic digestion transform manure and crop residues into biogas for on-farm energy use, bioethanol as a renewable fuel, and digestate as an organic fertilizer (European Biogas Association, 2025)[190]. These processes reduce methane emissions, close nutrient loops, and provide rural communities with renewable energy. Emerging biorefineries extend this principle by fractionating biomass into high-value products such as bioplastics, pharmaceuticals, and green chemicals. By diversifying revenue streams, biorefineries mitigate farmers' exposure to volatile commodity markets, reinforcing both income stability and climate resilience. Importantly, their success depends on infrastructural

[188] Intesa Sanpaolo Innovation Center. (2025). Bioeconomy in Italy: Innovation and Agriculture. Turin: Intesa Sanpaolo.

[189] European Biogas Association. (2025). Circular Bioeconomy and Biogas Systems. Brussels: EBA.

[190] European Biogas Association. (2025). Circular Bioeconomy and Biogas Systems. Brussels: EBA.

investment and equitable access, ensuring that smallholder farmers can participate in and benefit from these new value chains.

Digital and Data-Driven Agriculture

The digitalization of agriculture is transforming how farms are managed, monitored, and connected to broader markets. Precision agriculture tools—including drones, remote sensing, Internet of Things (IoT) devices, and big data analytics—allow farmers to optimize input use by monitoring soil moisture, nutrient balances, and crop stress at site-specific levels (Italian Ministry of Agriculture, 2025)[191]. This reduces water, fertilizer, and pesticide use, lowering both production costs and environmental externalities. Beyond productivity gains, digital platforms also enhance farmer access to financial services, advisory support, and market opportunities, thereby promoting socio-economic inclusion in the bioeconomy (BBioNets Team, 2025)[192]. Nevertheless, the benefits of digital agriculture are unevenly distributed, with barriers such as poor internet infrastructure and digital illiteracy limiting adoption in rural regions. Addressing these gaps is essential for ensuring that digital tools foster equity rather than deepen divides.

Sustainable Cropping Systems

At the systems level, technological innovation underpins new farming models that integrate ecological knowledge into production. Practices such as agroforestry, intercropping, and integrated crop-livestock systems increase biodiversity, enhance soil fertility, and provide ecosystem services including pollination, carbon storage, and water regulation (Intesa Sanpaolo Innovation Center, 2025)[193]. By diversifying production, these systems also buffer farmers against climate shocks and market risks. Importantly, biotechnology and digital tools reinforce these approaches: genetically improved crops enhance resilience within diversified systems, while precision monitoring optimizes interactions among crops, livestock, and natural resources. Sustainable cropping systems thus exemplify the convergence of technology and agroecology, illustrating how innovation can support holistic transitions toward resilient and regenerative agriculture.

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[191] Italian Ministry of Agriculture. (2025). Implementation Action Plan 2025–2027 for the Italian Bioeconomy Strategy. Rome: MIPAAF.

[192] BBioNets Team. (2025). Turning Local Know-how into European Solutions for Smarter Bio-Based Farming. Horizon Magazine.

[193] Intesa Sanpaolo Innovation Center. (2025). Bioeconomy in Italy: Innovation and Agriculture. Turin: Intesa Sanpaolo.

The range of technological innovations described above highlights the multidimensional potential of the bioeconomy. While biotechnology strengthens crop resilience, agroecological solutions foster ecological health, circular bioeconomy approaches close resource loops, digitalization enhances efficiency and inclusivity, and sustainable cropping systems provide systemic resilience. Their integration, however, is essential: no single innovation can deliver transformation on its own. A convergent paradigm that combines these technological advances within supportive policies, social equity frameworks, and farmer empowerment strategies is necessary for ensuring that innovation contributes to both sustainability and justice in global food systems. To translate this paradigm into investable practice, programs should co-report a compact set of KPIs that link technology deployment to measurable outcomes and social safeguards—for example, adoption rates and competency attainment for improved varieties and bio-inputs; lifecycle GHG abatement per tonne of biomass processed and the share of residues valorised; changes in soil organic carbon, nutrient-use efficiency, and water-use efficiency following digestate or biofertilizer application; renewable energy yield and uptime for anaerobic digestion or agri-PV; digital decision-use metrics such as hectares under sensor-informed management and reductions in input intensity; end-of-life performance of bio-based materials through certified compostability or recyclability rates; and inclusion indicators that track progress on living-income gaps, timely and fair payment terms, women's and youth participation in bioeconomy enterprises, tenure safeguards, and effective grievance resolution. When embedded in sustainability-linked covenants, green and sustainability-linked bonds, and public procurement, and disclosed in an ISSB-aligned format interoperable with EU Taxonomy, SBTi/FLAG, and NZBA targets, these KPIs make technological innovation comparable, assurable, and equitable—turning the bioeconomy from a set of promising pilots into accountable, scalable transitions.

2.2.1.3 Innovation Ecosystems and Farmer Empowerment

The success of bioeconomy strategies relies on collaborative innovation ecosystems involving policymakers, research institutions, agribusinesses, farmer cooperatives, and startups (BBioNets Team, 2025)[194]. Co-design processes, participatory research, and capacity-building programs ensure that technologies are locally adapted, economically viable, and socially inclusive.

Farmer training in areas such as biomass management, composting, digital agriculture, and cooperative entrepreneurship strengthens adoption rates and creates pathways for rural innovation. Empowering

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[194] BBioNets Team. (2025). Turning Local Know-how into European Solutions for Smarter Bio-Based Farming. Horizon Magazine.

smallholders is particularly important, as they constitute the majority of global food producers but often face barriers in accessing new technologies and markets (Italian Ministry of Agriculture, 2025)[195].

2.2.1.4 Environmental and Economic Impacts

The bioeconomy is increasingly recognized as a transformative framework for reconciling agricultural productivity with climate and sustainability imperatives. Its impacts are multi-dimensional, extending across environmental, economic, and social domains, and are particularly relevant in the context of global food system transitions.

From an environmental perspective, the bioeconomy contributes directly to climate change mitigation and ecosystem restoration. The substitution of fossil-based inputs with renewable, bio-based alternatives reduces greenhouse gas (GHG) emissions from both energy use and synthetic fertilizers (European Biogas Association, 2025)[196]. For instance, anaerobic digestion of livestock manure not only provides biogas as a clean energy source but also prevents methane emissions that would otherwise arise from unmanaged decomposition. At the same time, practices such as biofertilizer application and agroforestry promote soil carbon sequestration, enhancing long-term soil fertility and improving resilience against droughts and floods. These ecological processes are complemented by biodiversity gains: reduced reliance on monocultures and synthetic agrochemicals helps restore habitats, benefiting pollinators, soil microorganisms, and broader agroecosystem integrity. Collectively, the bioeconomy facilitates the shift from extractive to regenerative farming, positioning agriculture as part of the solution rather than a driver of environmental degradation.

The economic impacts of the bioeconomy are equally significant, particularly for rural development. By creating new value chains around biomass, renewable energy, and biorefinery products, the bioeconomy generates employment opportunities and reduces dependence on volatile global commodity markets (Intesa Sanpaolo Innovation Center, 2025)[197]. Farmers who previously relied on monocultures gain access to

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195 Italian Ministry of Agriculture. (2025). Implementation Action Plan 2025–2027 for the Italian Bioeconomy Strategy. Rome: MIPAAF.

196 European Biogas Association. (2025). Circular Bioeconomy and Biogas Systems. Brussels: EBA.

197 Intesa Sanpaolo Innovation Center. (2025). Bioeconomy in Italy: Innovation and Agriculture. Turin: Intesa Sanpaolo.

diversified revenue streams through activities such as selling crop residues for bioenergy production, participating in carbon markets, or cultivating high-value bio-based crops for pharmaceuticals or bioplastics. This diversification enhances financial stability and buffers against risks linked to climate variability and market fluctuations. Moreover, the substitution of chemical fertilizers and pesticides with bio-based alternatives reduces input costs, improving profit margins for farmers, especially smallholders who are typically most affected by rising agricultural expenses. The development of local bio-based industries also fosters rural industrialization, retaining value within communities and reducing the urban-rural economic divide.

The social dimension of the bioeconomy underscores its potential to foster inclusive and resilient rural communities. By diversifying production systems, it enhances food security, ensuring that households are less dependent on single crops and therefore more capable of withstanding climate and market shocks (BBioNets Team, 2025)[198]. Smallholder empowerment is central to this process: bioeconomy innovations, such as digital platforms linking farmers to markets and cooperative models supporting biogas production, provide greater agency and bargaining power to marginalized groups. In addition, the participatory governance structures often associated with bio-based projects—such as farmer cooperatives and rural councils—encourage community ownership, thereby strengthening trust in sustainability transitions. Gender equity also benefits, as women farmers gain access to new income-generating opportunities and decentralized renewable energy systems reduce their labor burdens in food processing and household energy provision. By aligning social empowerment with ecological regeneration and economic diversification, the bioeconomy advances a holistic vision of just and sustainable development.

In conclusion, the environmental, economic, and social impacts of the bioeconomy are deeply interlinked. Ecological restoration enhances productivity and reduces input costs; diversified revenue streams strengthen financial stability and rural employment; and empowered communities become more resilient to systemic shocks. This synergy highlights why the bioeconomy is not merely a technological shift but a structural transformation of agriculture and rural economies, redefining their role within a low-carbon and equitable global system.

2.2.1.5 Challenges and Future Directions

[198] BBioNets Team. (2025). Turning Local Know-how into European Solutions for Smarter Bio-Based Farming. Horizon Magazine.

Despite their transformative potential, bioeconomy and agri-biotech strategies face challenges such as:

- **Accessibility and affordability** of advanced technologies for smallholder farmers.
- **Regulatory uncertainty** around genetic technologies and bio-based products.
- **Investment requirements** for biorefineries and digital infrastructure.
- **Social inclusivity**, ensuring equitable benefit-sharing across different farming communities.

Future directions emphasize policy coherence, targeted financial incentives, and multi-stakeholder partnerships to bridge these gaps. In particular, integrating traditional knowledge systems with modern biotechnologies is increasingly recognized as essential for ensuring cultural acceptance and sustainability (BBioNets Team, 2025)[199].

To move from principle to delivery, these priorities should be expressed through a concise, co-reported KPI architecture that sits alongside environmental metrics. Accessibility and affordability can be tracked via total cost of ownership per hectare for key technologies, uptake rates among smallholders and women-/youth-led farms, average days to payment and offtake security, and the share of concessional or guaranteed finance in project capital stacks. Regulatory certainty can be rendered measurable through time-to-approval for bio-based products, audit pass rates for biosafety and quality (e.g., certified compostability, digestate standards), verification of FPIC/tenure safeguards where relevant, and public availability of guidance and registries. Investment readiness and operational performance should be captured by mobilized capex and blended-finance leverage ratios, plant uptime and capacity-utilization factors for biorefineries and digesters, levelized cost of energy or product (LCOE/LCOX), lifecycle GHG abatement per tonne of biomass processed, and MRV cost and uncertainty bands. Social inclusivity requires KPIs on progress toward closing living-income gaps, participation and governance representation of women and youth, local job creation and skills certification rates, timely grievance resolution, and tenure security improvements. Partnership quality and policy coherence can be monitored through the share of programs with documented co-design (including traditional knowledge protocols), the proportion of public budgets aligned to circular/bioeconomy objectives, and interoperability of data (open dashboards, API availability).

Embedding these indicators in sustainability-linked covenants, green and sustainability-linked bonds, and public procurement criteria—and disclosing them in an ISSB-aligned format interoperable with EU

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[199] BBioNets Team. (2025). Turning Local Know-how into European Solutions for Smarter Bio-Based Farming. Horizon Magazine.

Taxonomy screening, SBTi/FLAG, and NZBA portfolio targets—translates challenges into actionable performance conditions. In doing so, the integration of bioeconomy frameworks and agri-biotechnological innovations becomes not only environmentally credible but also socially legitimate and financially bankable: closing resource loops, enhancing ecosystem services, stabilizing farmer incomes, and building circular rural economies that advance global sustainability goals.

2.2.2 Nature-based Solutions

Nature-based Solutions (NBS) have emerged as a cornerstone in global sustainability discourse, offering an integrative framework to simultaneously address environmental degradation, climate change, social inequality, and economic resilience. Defined as actions that work with and enhance natural processes to tackle societal challenges while providing co-benefits for biodiversity and human well-being, NBS are increasingly embedded in international agendas such as the European Green Deal, the Paris Agreement, and the United Nations Sustainable Development Goals (SDGs) (European Investment Bank, 2023)[200]. Their growing appeal stems from their ability to generate cost-effective, long-term solutions that rival or complement traditional "grey" infrastructure approaches, while also providing cultural, ecological, and social value (Frontiers in Earth Science, 2021)[201].

The effective scaling of NBS depends on robust monitoring and evaluation frameworks. Key Performance Indicators (KPIs) play a vital role in this process, as they enable policymakers, investors, and practitioners to assess the multi-dimensional impacts of NBS projects, track progress, and compare performance across contexts. Unlike conventional engineering solutions, however, NBS outcomes are inherently complex, evolving across ecological, temporal, and socio-economic dimensions (Nature4Cities, 2020)[202].

2.2.2.1 Conceptual Framework of Nature-based Solutions

[200] European Investment Bank (2023). Investing in Nature-based Solutions.

[201] Frontiers in Earth Science (2021). A Novel Framework to Define Key Performance Indicators for Nature-Based Solutions.

[202] Nature4Cities (2019). Defined Performance Indicators to Assess Urban Challenges and Nature-Based Solutions.

NBS encompass a spectrum of practices ranging from urban green infrastructure—such as green roofs, permeable pavements, and urban parks—to landscape-level restoration of forests, wetlands, and river basins. These solutions enhance critical ecosystem services, including carbon sequestration, water purification, flood control, soil fertility, and habitat provision.

The central principle underpinning NBS is multifunctionality—their ability to deliver diverse co-benefits that span environmental, social, and economic dimensions simultaneously (UNaLab, 2022)[203]. For example, a wetland restoration project may reduce flood risk, improve water quality, sequester carbon, enhance biodiversity, and create recreational spaces for communities. However, this very multifunctionality challenges the design of KPIs, as measurement must reflect interlinked outcomes and long-term system resilience rather than short-term outputs.

2.2.2.2 Drivers of Nature-based Solutions

The expansion and mainstreaming of Nature-based Solutions (NBS) are being shaped by multiple interrelated drivers that reflect global sustainability transitions while also highlighting the pressing need for robust Key Performance Indicator (KPI) frameworks. These drivers are not only policy- and market-driven but also embedded in the broader socio-ecological transformations that define the Anthropocene.

One of the most influential forces behind the growth of NBS is the proliferation of climate policies and regulatory frameworks that position ecological restoration and green infrastructure as central to climate action. The European Union's Biodiversity Strategy 2030, alongside national adaptation and mitigation plans, explicitly identifies NBS as tools to achieve climate neutrality, protect biodiversity, and enhance resilience to extreme weather events (Calliari et al., 2022)[204]. Such frameworks create institutional legitimacy for NBS but also demand measurable outcomes to justify public and private investments. In this context, KPIs become essential to quantify avoided carbon emissions, restored habitats, or reduced risks from floods and heatwaves, thereby bridging the gap between policy goals and practical implementation.

The rise of sustainability and ESG (Environmental, Social, and Governance) investing further accelerates the adoption of NBS. As financial markets increasingly integrate sustainability criteria, investors are drawn to

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[203] UNaLab (2022). Nature-Based Solutions Impact: A Summary – Genoa.

[204] Calliari, E., Castellari, S., Davis, M., Linnerooth-Bayer, J., Martin, J., Mysiak, J., Pastorf, T., Ramieri, E., Scolobig, A., Sterk, M., Veerkamp, C., Wendling, L., & Zandersen, M. (2022). Building climate resilience through nature-based solutions in Europe: A review of enabling knowledge, finance and governance frameworks. Climate Risk Management, 37, Article 100450. https://doi.org/10.1016/j.crm.2022.100450

NBS projects as vehicles for both ecological and social returns. However, without standardized KPIs, these projects risk being perceived as opaque or even as "greenwashing." The credibility of NBS in sustainable finance thus depends on the development of transparent metrics that can evaluate ecological integrity, carbon sequestration, and community benefits on equal terms (Gonzalez-Ollauri et al., 2021)[205]. This demand reflects a broader trend where capital flows are conditional on demonstrable impact, underscoring the convergence between environmental governance and financial accountability.

A parallel driver comes from the dynamics of urbanization and resilience building. Cities, which now host more than half of the world's population, are increasingly exposed to climate hazards such as heatwaves, flooding, and air pollution. Urban NBS—including the creation of green corridors, the restoration of riverfronts, and the expansion of urban forests—are promoted as cost-effective and socially acceptable alternatives to conventional grey infrastructure (Nature4Cities, 2019)[206]. Yet, the long-term success of such projects hinges on KPIs that can capture their multifaceted benefits, such as reduced ambient temperatures, improved air quality, stormwater retention capacity, and even citizen satisfaction. These metrics are critical to ensure that NBS in urban contexts are not merely aesthetic interventions but integrated components of climate adaptation and public health strategies.

Finally, the growing recognition of ecosystem service valuation in economic and policy planning constitutes a structural driver of NBS. As the concept of ecosystem services—such as pollination, water regulation, or soil fertility—becomes embedded in environmental economics, policymakers increasingly seek methods to assign measurable value to ecological processes. This valuation allows for the comparison of NBS with traditional grey infrastructure within cost-benefit analyses and justifies long-term investments in restoration and conservation (Lenses Prima, 2021)[207]. KPIs serve as the operational tools through which these services are quantified, monetized, and communicated to stakeholders, enabling NBS to move from experimental initiatives to mainstream policy instruments.

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[205] Gonzalez-Ollauri, A., Munro, K., Mickovski, S. B., & Thomson, C. S. (2021). The 'Rocket Framework': A Novel Framework to Define Key Performance Indicators for Nature-based Solutions Against Shallow Landslides and Erosion. Frontiers in Earth Science, 9, Article 676059. https://doi.org/10.3389/feart.2021.676059

[206] Nature4Cities (2019). Defined Performance Indicators to Assess Urban Challenges and Nature-Based Solutions.

[207] Lenses Prima (2021). Catalogue of Nature-based Solutions.

Taken together, these drivers reveal that the expansion of NBS is not only a response to environmental crises but also part of broader institutional, financial, and urban transformations. Climate policies create regulatory momentum, ESG finance channels capital, urban resilience agendas generate local demand, and ecosystem service valuation provides the economic rationale. Across all these dimensions, the integration of KPIs ensures that NBS can demonstrate tangible contributions to climate action, social well-being, and economic rationality, thereby consolidating their role as indispensable elements of sustainable development strategies.

2.3 Critical Issues in KPI Development

Designing Key Performance Indicators (KPIs) for agricultural decarbonization and sustainability—spanning nature-based solutions (NBS), agri-biotech, digital agriculture, and the circular bioeconomy—faces challenges that reflect the sector's ecological complexity, social embeddedness, and long time horizons. Unlike conventional "grey" interventions assessed against narrow engineering benchmarks, agricultural transitions deliver entangled environmental, social, and economic outcomes whose interactions resist simple, universal measurement. This multidimensionality is a strength for policy and place-based problem solving, but it complicates the creation of standardized indicators that remain comparable across geographies, commodities, and technologies.

A first difficulty is conceptual variability. What counts as "success" differs across domains and governance contexts: NBS in cities may emphasize urban cooling and stormwater management, whereas in farming they include regenerative soil practices and watershed restoration; bioeconomy programs may prioritize mass-balance traceability, nutrient recovery, and end-of-life performance; digital agriculture stresses input efficiency and decision quality; agri-biotech highlights trait performance, biosafety, and farmer autonomy. These divergent emphases, often shaped by disciplinary traditions and policy priorities, generate heterogeneous indicator sets that travel poorly across sectors (Frontiers in Earth Science, 2021)[208]. Without explicit harmonization layers—defining common units, boundaries, and assurance requirements—comparability erodes and cross-sector decision-making loses credibility.

[208] Frontiers in Earth Science (2021). A Novel Framework to Define Key Performance Indicators for Nature-Based Solutions.

The second challenge arises from multidimensional impacts and the need for multi-criteria evaluation. Agricultural interventions jointly affect carbon, biodiversity, water, soil health, livelihoods, and equity. They also create option value for climate adaptation and risk reduction that is hard to price. KPI frameworks must therefore integrate ecological outcomes (e.g., carbon sequestration, habitat integrity), productivity and resilience metrics, and social indicators linked to just transition and income stability, without allowing a single dimension to crowd out the rest. This raises normative questions about weighting and aggregation—should lifecycle GHG abatement outrank living-income progress, or are both co-requirements for transition credibility? Absent transparent weighting rules and sensitivity tests, composite scores risk obscuring trade-offs and privileging what is easiest to count over what most matters for resilience (UNaLab, 2022)[209].

Temporal and spatial scale further complicate design. Many benefits materialize slowly and across wide areas: soil carbon gains, aquifer recharge, or species recovery can take years to detect; circular bioeconomy effects on nutrient cycles and waste flows propagate beyond farm boundaries; digital decision tools may produce cumulative efficiency gains over multiple seasons. Effective systems must therefore pair short-term process indicators—such as hectares under alternate water management, percent residues valorized, or training and adoption rates—with long-term impact indicators that capture ecosystem condition, risk reduction, and welfare outcomes (UNaLab, 2022)[210]. They should also handle spatial spillovers and leakage: reduced deforestation in one supply shed can be offset by displacement elsewhere; biomass diversion to new uses can shift burdens to water or biodiversity if end-of-life is poorly managed. Clear boundary definitions, counterfactuals, and jurisdictional or supply-shed lenses are essential to attribute change and avoid double counting.

Data gaps and monitoring complexity remain persistent constraints. Many regions lack continuous, high-quality ecological and socio-economic time series. Even where sensing is rich, attribution is non-trivial: separating the effects of a feed additive from concurrent herd-management changes, or isolating the impact of digestate on soil organic carbon from weather variation, requires robust experimental or quasi-experimental designs. Advances in remote sensing, IoT telemetry, and analytics can reduce latency and improve coverage—tracking vegetation dynamics, soil moisture, residue burning, or facility uptime—but

[209] UNaLab (2022). Nature-Based Solutions Impact: A Summary – Genoa.

[210] UNaLab (2022). Nature-Based Solutions Impact: A Summary – Genoa.

introduce new challenges of interoperability, validation, and governance (Assimakopoulos et al., 2025)[211]. armer data rights, privacy, and consent, together with clarity on who benefits from data monetization, are integral to legitimate KPI systems. Without trusted data stewardship and verifiable provenance, indicators will struggle to gain social license.

Methodological issues specific to agricultural transitions add further complexity. Lifecycle boundaries and allocation rules determine whether bio-based products genuinely displace fossil inputs; end-of-life performance and compostability standards shape circularity claims; indirect land-use change can overwhelm on-farm efficiency gains; scope-3 accounting and mass-balance traceability influence supply-chain credibility; and uncertainty bands around methane, nitrous oxide, and soil carbon estimates remain wide. Financial translation introduces its own pitfalls: KPIs must be decision-useful for lenders and supervisors (pricing, covenants, portfolio steering), yet not so reductive that they invite gaming. Goodhart's law applies—when a measure becomes a target, it can cease to be a good measure—unless indicators are triangulated, audited, and periodically refreshed. Publishing methodologies, uncertainty ranges, and audit results, and combining outcome, process, and enabler indicators, helps deter box-ticking and sustain learning.

Finally, fragmentation among standards and disclosures complicates implementation but also offers a path forward. Interoperability between practice-level metrics and portfolio-level reporting—linking farm KPIs to ISSB-aligned disclosures, SBTi/FLAG target-setting, NZBA sectoral pathways, and EU Taxonomy screening—can reconcile local relevance with global comparability if mappings are explicit and assurance is credible. Proportionality is key: indicator sets must be feasible for smallholders and SMEs, with disaggregation by farm size, gender, and region to keep equity visible; MRV costs should be measurable and declining over time; and public, machine-readable registries can reduce transaction costs while increasing transparency.

In conclusion, the critical issues in KPI development for agriculture—across NBS, bioeconomy, digitalization, and biotechnology—mirror tensions between scientific complexity, policy imperatives, market comparability, and social legitimacy. Conceptual variability, multidimensional impacts, scale mismatches, data and attribution limits, and standard fragmentation collectively hinder universal metrics. Addressing these challenges requires explicit boundary setting and weighting rules; paired short-term and

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[211] Assimakopoulos, F., Vassilakis, C., Margaris, D., Kotis, K., & Spiliotopoulos, D. (2025). AI and Related Technologies in the Fields of Smart Agriculture: A Review. Information, 16(2), 100. https://doi.org/10.3390/info16020100

long-term indicators with uncertainty disclosure; interoperable data and open taxonomies; robust, participatory monitoring that centers farmer rights; and assurance regimes that are rigorous yet proportionate. Only through such integrative, transparent approaches can KPIs become true instruments of governance—demonstrating value, steering capital, and securing the place of diverse technological and nature-based pathways in climate and sustainability agendas.

CHAPTER 3 – EMPIRICAL ANALYSIS AND DISCUSSION

3.1. Identifying KPIs for Banking Transition in Agriculture

3.1.1 Review of Literature

Integrating sustainable finance into the agricultural sector has generated increasing attention in recent years, as financial institutions play a pivotal role in enabling the green transition of food systems (FAO, 2021[212]; OECD, 2020[213]). Key performance indicators (KPIs) serve as essential tools for monitoring, evaluating, and guiding this transition by linking financial practices with environmental, social, and governance (ESG) objectives. The literature on KPIs within agricultural finance highlights three broad domains: financial inclusion and access to credit, environmental sustainability, and socio-economic resilience of farming communities.

3.1.1.1 Financial Inclusion and Access to Credit.

The ability of farmers, especially smallholders, to access affordable credit remains one of the fundamental determinants of agricultural transformation. Studies emphasize that KPIs in this dimension include the

[212] Food and Agriculture Organization of the United Nations (FAO). (2021). The State of Food and Agriculture 2021: Making agrifood systems more resilient to shocks and stresses. Rome: FAO. https://doi.org/10.4060/cb4476en

[213] OECD (2020), Developing Sustainable Finance Definitions and Taxonomies, Green Finance and Investment, OECD Publishing, Paris, https://doi.org/10.1787/134a2dbe-en.

percentage of agricultural loans aligned with sustainability standards, the volume of green credit disbursed, and the degree of penetration of microfinance tailored to agricultural risk (World Bank, 2019[214]; UNDP, 2022[215]). These indicators not only measure the financial sector's engagement with agriculture but also its contribution to reducing credit gaps for vulnerable groups such as women and youth (Glazebrook et al., 2020)[216].

3.1.1.2 Environmental Sustainability.

A growing body of literature stresses that banking institutions are increasingly required to monitor the environmental impact of their lending portfolios. Relevant KPIs include the share of agricultural loans linked to climate-smart practices, investments in renewable energy and low-emission technologies, and the proportion of financed projects that integrate biodiversity conservation measures (Herrero et al., 2016)[217].

3.1.1.3 Socio-Economic Resilience.

From a development perspective, financial institutions could theoretically be evaluated not only on profitability but also on their contribution to non-financial impacts such as, e.g., rural livelihoods and resilience. Key KPIs suggested in the literature include job creation in rural areas, income stability of farmers receiving sustainable finance, and the degree of reduction in vulnerability to climate-induced risks

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[214] World Bank (2019). Enabling the business of agriculture 2019. Washington, DC: World Bank. https://documents1.worldbank.org/curated/en/806771571717730416/pdf/Enabling-the-Business-of-Agriculture-2019.pdf

[215] United Nations Development Programme (UNDP). (2022). Climate promise: Global progress report 2022. UNDP. https://climatepromise.undp.org

[216] Glazebrook, T., Noll, S., & Opoku, E. (2020). Gender matters: Climate change, gender bias, and women's farming in the Global South and North. Agriculture, 10(7), 267. https://doi.org/10.3390/agriculture10070267

[217] Herrero, M., Thornton, P. K., Power, B., Bogard, J. R., Remans, R., Fritz, S., … & Havlík, P. (2016). Farming and the geography of nutrient production for human use: A transdisciplinary analysis. The Lancet Planetary Health, 1(1), e33–e42. https://doi.org/10.1016/S2542-5196(17)30007-4

(Chandra et al., 2017)[218]. This dimension emphasizes the role of banks in fostering inclusive growth and supporting adaptation strategies that go beyond short-term profitability.

3.1.1.4 Challenges in KPI Implementation.

Despite the proliferation of frameworks, challenges persist in operationalizing KPIs for agricultural banking transitions. Fragmented reporting standards, data availability issues, and difficulties in attributing outcomes directly to financial flows undermine comparability and scalability (Kok et al., 2016)[219]. Moreover, some scholars warn that poorly designed KPIs risk promoting "greenwashing" rather than genuine systemic transformation (Calliari et al., 2020)[220].

Effective KPIs for the banking transition in agriculture must be multidimensional, combining financial, environmental, and social indicators to reflect the complexity of agrifood systems. The subsequent sections of this chapter will empirically test and discuss how these indicators can be operationalized in practice, drawing on both quantitative and qualitative data.

3.1.2 Review of Targets and Metrics of Selected Banks

In the debate on sustainable finance for agricultural transition, banks have emerged as crucial actors in mobilizing resources toward climate-resilient and socially inclusive practices. Their commitments are not limited to financial performance but increasingly encompass environmental and social objectives, framed through measurable key performance indicators (KPIs). To illustrate this dynamic, the present section examines three major financial institutions—Rabobank, BNP Paribas, and HSBC—which have integrated sustainability into their agricultural financing portfolios. The review highlights their declared targets, methodologies, and metrics, while also underlining similarities and divergences in their approaches.

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[218] Chandra, A., McNamara, K. E., Dargusch, P., Caspe, A. M., & Dalabajan, D. (2017). Gendered vulnerabilities of smallholder farmers to climate change in conflict-prone areas: A case study from Mindanao, Philippines. Journal of Rural Studies, 50, 45–59. https://doi.org/10.1016/j.jrurstud.2016.12.011

[219] Kok, M. T. J., Lüdeke, M., Lucas, P. L., Sterzel, T., Walther, C., Janssen, P., … & Sietz, D. (2016). A new method for analysing socio-ecological patterns of vulnerability. Regional Environmental Change, 16, 229–243. https://doi.org/10.1007/s10113-014-0746-1

[220] Calliari, E., Serdeczny, O., & Vanhala, L. (2020). Making sense of adaptation politics: Insights from climate risk management. Climate Risk Management, 36, 100441.https://www.researchgate.net/publication/343677909_Making_sense_of_the_politics_in_the_climate_change_loss_damage_debate

3.1.2.1 Rabobank

Rabobank, headquartered in the Netherlands, has historically been one of the leading financial institutions specializing in the agrifood sector. Established as a cooperative banking institution, its origins are deeply intertwined with rural development and the financing of farmer cooperatives. Over time, this cooperative legacy has evolved into a global mission that places sustainability at the core of its strategy, particularly with respect to food systems and agricultural transitions. Today, Rabobank's role is not only that of a financial intermediary but also of a catalyst for sustainability-oriented innovation within agriculture (Rabobank, 2025)[221].

From an environmental perspective, Rabobank has set ambitious climate goals, aligning itself with the objectives of the Paris Agreement. The bank has committed to achieving net zero by 2050, with a specific interim target of reducing greenhouse gas (GHG) emissions within its agricultural loan portfolio by 25% by 2030. This commitment is monitored through the Partnership for Carbon Accounting Financials (PCAF) methodology, a standardized approach designed to calculate "financed emissions," i.e., emissions generated by clients and projects financed by the bank. PCAF enables comparability across financial institutions and ensures that reported progress reflects both direct and indirect impacts of agricultural finance on climate change.

Rabobank has also developed an internal sustainability taxonomy that classifies loans according to their contribution to sustainability transitions. Loans are assessed across dimensions such as soil health, water efficiency, biodiversity protection, and reduction of synthetic inputs (fertilizers and pesticides). Based on this framework, the bank reported in its Sustainability Report (2021) that approximately €21 billion of its total loan portfolio was directed towards projects explicitly identified as sustainable. This figure demonstrates not only a strong commitment to environmental transition but also an effort to systematically integrate sustainability into the bank's core business model (Rabobank, 2021)[222].

Beyond climate targets, Rabobank places significant emphasis on food security and smallholder inclusion. Through the Rabo Foundation, the bank operates in low- and middle-income countries, supporting

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[221] Rabobank. (2025). Sustainability policies briefing. https://media.rabobank.com/m/553b2f90635b055a/original/Sustainability-policies-briefing-Rabobank-Group.pdf

[222] Rabobank Rabo Foundation. (2021). Impact report 2021 – https://www.rabobank.nl/en/about-us/rabofoundation/impactjaarverslag-2021

smallholder farmers in adopting climate-smart agricultural practices and improving market access. The Foundation's impact reports indicate that in 2020, approximately 4.2 million smallholders were reached through a combination of financing, technical support, and digital services. In this context, the KPIs go beyond purely financial measures, including the number of farmers trained in sustainable practices, the extent of adoption of regenerative agriculture, and improvements in income stability for vulnerable farming households.

A unique characteristic of Rabobank is its cooperative governance model, which grants members—many of whom are themselves farmers—a direct voice in decision-making processes. This structure integrates social sustainability into the bank's governance metrics. Unlike traditional shareholder-driven institutions, Rabobank evaluates its performance not only through financial profitability but also through indicators of member participation, community benefits, and cooperative resilience. This approach reflects a broader understanding of sustainability as encompassing environmental, social, and governance (ESG) dimensions, where financial returns are interlinked with community well-being.

Overall, Rabobank can be considered a paradigmatic case of how financial institutions can integrate sustainability into their core mission. Its combination of climate-related targets (such as financed emissions reduction), sustainability-linked loan classification systems, and cooperative-based social metrics offers a comprehensive framework for monitoring agricultural transition finance. Furthermore, its global outreach through the Rabo Foundation ensures that its sustainability agenda is not limited to advanced economies but extends to the Global South, where the challenges of agricultural transition are most pressing.

3.1.2.2 BNP Paribas

BNP Paribas, as one of the largest European banking institutions, plays a pivotal role in shaping sustainable finance practices at a global scale. With its strong presence across both corporate and retail banking, the bank has progressively aligned its strategic vision with the objectives of the Paris Agreement and the European Union's sustainability agenda. Unlike banks with narrower sectoral focus, BNP Paribas has adopted a comprehensive sustainability framework that encompasses a wide array of industries, with agriculture representing a significant domain due to its central role in climate transition and food security (BNP Paribas, 2023)[223].

[223] BNP Paribas. (2023a). Sustainability and responsibility at BNP Paribas. Paris: BNP Paribas Group. Retrieved from https://cdn-group.bnpparibas.com/uploads/file/bnp_paribas_2023_prb_reporting.pdf

The cornerstone of BNP Paribas's sustainability commitments is its pledge to achieve net-zero emissions by 2050 across its lending and investment portfolios. To operationalize this goal, the bank has joined the Net-Zero Banking Alliance (NZBA), committing to intermediate sectoral targets by 2030. In agriculture and land use, BNP Paribas has explicitly recognized the dual challenge of reducing greenhouse gas emissions while promoting biodiversity conservation. In 2022, the bank announced its intention to reduce financing linked to deforestation in the Amazon and Cerrado regions by engaging with agribusiness clients and setting traceability requirements for supply chains, particularly in soy and beef production (BNP Paribas, 2022)[224].

From a quantitative standpoint, BNP Paribas applies the Partnership for Carbon Accounting Financials (PCAF) methodology to measure "financed emissions" within its portfolios (PCAF, 2020)[225]. Through this tool, the bank reported in its 2023 Sustainability Report that approximately €185 billion of its financing was aligned with sustainability-linked criteria, a figure that includes renewable energy, sustainable mobility, and agriculture. Within the agricultural sector, BNP Paribas has established a dedicated Sustainable Agriculture strategy, which aims to support the development of regenerative practices, reduce reliance on chemical fertilizers, and promote soil carbon sequestration. Metrics here include the share of agricultural clients adopting certified sustainable standards (such as RSPO for palm oil or FSC for forestry) and the volume of green bonds and sustainability-linked loans issued for agrifood transition.

BNP Paribas also monitors its progress through biodiversity-related indicators, reflecting a more holistic understanding of agricultural transition. For instance, the bank has committed to fully phasing out financing for companies contributing to deforestation by 2025 unless these companies adopt transparent traceability mechanisms. Furthermore, BNP Paribas is among the first major banks to integrate the Taskforce on Nature-related Financial Disclosures (TNFD)into its reporting framework, thereby developing metrics that go beyond carbon accounting to include impacts on ecosystems, water usage, and land degradation (TNFD, 2023)[226].

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[224] BNP Paribas. (2022). BNP Paribas strengthens its commitments to fight deforestation linked to soy and beef production in South America. Retrieved from https://group.bnpparibas/en

[225] PCAF (Partnership for Carbon Accounting Financials). (2020). The Global GHG Accounting and Reporting Standard for the Financial Industry. Amsterdam: PCAF Secretariat. Retrieved fromhttps://carbonaccountingfinancials.com/standard

[226] TNFD (Taskforce on Nature-related Financial Disclosures). (2023). TNFD Recommendations. Geneva: TNFD Secretariat. Retrieved from https://tnfd.global

On the social side, BNP Paribas has committed to reinforcing inclusive finance in rural areas, particularly through its partnerships with microfinance institutions. The bank has invested in microfinance funds targeting smallholder farmers in Africa and Asia, aiming to reach populations that are otherwise excluded from conventional financial systems. The metrics employed include the number of beneficiaries of inclusive finance products, the percentage of women among these beneficiaries, and the income improvements observed in rural households. In this respect, BNP Paribas not only focuses on the environmental sustainability of agriculture but also integrates equity and social resilience into its performance indicators.

Another essential dimension of BNP Paribas's approach is its use of sustainability-linked financing instruments. The bank has been a pioneer in issuing sustainability-linked loans (SLLs) to agribusiness clients, where the interest rate is directly tied to the client's achievement of predefined sustainability KPIs. These KPIs typically cover reductions in GHG emissions, certification of sustainable production, and improvements in water efficiency. Such financial products serve as both an incentive mechanism and a monitoring tool, aligning the bank's profitability with measurable progress in agricultural sustainability.

BNP Paribas has positioned itself at the forefront of sustainable finance by embedding measurable targets and KPIs across multiple dimensions of the agricultural transition. Its commitments range from climate-related objectives, such as financed emissions reduction, to biodiversity protection and social inclusion. This comprehensive set of metrics reflects a clear strategic orientation: to leverage its financial power in order to accelerate systemic transformation in agriculture, while ensuring that environmental and social outcomes are both monitored and incentivized.

3.1.2.3 HSBC

HSBC, as one of the world's largest international banks with a strong presence in both developed and emerging markets, has increasingly sought to position itself as a leading actor in sustainable finance (HSBC, 2022)[227]. Its global reach, particularly in Asia, gives it a unique role in financing agricultural systems that are both highly productive and increasingly vulnerable to climate change. In this context, HSBC's sustainability commitments reflect both global frameworks—such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs)—and sector-specific challenges, notably the decarbonization of agrifood supply chains, biodiversity protection, and the promotion of inclusive rural finance.

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[227] HSBC. (2022). HSBC sustainability strategy. London: HSBC Group. Retrieved from https://www.hsbc.com/sustainability

At the strategic level, HSBC has pledged to align its financing activities with a net-zero emissions pathway by 2050, covering both operational and financed emissions. As a member of the Net-Zero Banking Alliance (NZBA), the bank has set interim targets for 2030 in high-emitting sectors such as energy, transport, and agriculture. In the agricultural domain, HSBC has taken a two-fold approach: first, by reducing exposure to clients with significant deforestation risks, and second, by increasing financing for projects and companies that contribute to sustainable land use and regenerative agricultural practices (NZBA, 2021)[228].

Quantitatively, HSBC employs the Partnership for Carbon Accounting Financials (PCAF, 2020)[229] methodology to assess financed emissions within its portfolios, including agriculture. In 2022, the bank disclosed that it had facilitated USD 170 billion in sustainable finance and investment, with part of this allocation dedicated to sustainable food and agriculture initiatives. HSBC's sustainability framework places emphasis on supply chain traceability, particularly in commodities such as palm oil, soy, and beef, which are often linked to deforestation. The bank has set the objective of ensuring that all agribusiness clients operating in high-risk sectors comply with "No Deforestation, No Peat, No Exploitation" (NDPE) policies by 2025 (HSBC, 2022)[230].

HSBC's monitoring system integrates both environmental and social KPIs. Environmentally, the bank tracks the number of clients adopting certified sustainable standards, such as the Roundtable on Sustainable Palm Oil (RSPO), Forest Stewardship Council (FSC), or Bonsucro for sugarcane. It also reports on financed hectares of farmland adopting regenerative practices, reductions in GHG emissions per unit of agricultural output, and improvements in water-use efficiency. Socially, HSBC emphasizes inclusive access to finance for smallholders. The bank has partnered with global initiatives such as the World Resources Institute (WRI) and the International Finance Corporation (IFC) to scale up blended finance facilities that support small

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228 NZBA (Net-Zero Banking Alliance). (2021). Commitment statement. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org/net-zero-banking/

229 PCAF (Partnership for Carbon Accounting Financials). (2020). The Global GHG Accounting and Reporting Standard for the Financial Industry. Amsterdam: PCAF Secretariat. Retrieved from https://carbonaccountingfinancials.com

230 HSBC. (2022). HSBC sustainability strategy. London: HSBC Group. Retrieved from https://www.hsbc.com/sustainability

farmers in Asia and Africa (IFC, 2022[231]; WRI, 2022)[232]. Metrics in this area include the number of smallholders financed, the share of women farmers reached, and the increase in average household income resulting from agricultural loans.

A further dimension of HSBC's agricultural transition strategy is its role in the green and sustainability-linked bond market. The bank has acted as a lead arranger for multiple green bonds financing sustainable agriculture, including instruments linked to climate-smart irrigation systems and agroforestry projects. In sustainability-linked loans (SLLs), HSBC directly ties interest rates to the achievement of agricultural KPIs, such as reductions in fertilizer use, adoption of biodiversity action plans, and certification under international sustainability standards. These instruments demonstrate the bank's attempt to embed measurable targets into the structure of its financial products.

Importantly, HSBC has acknowledged the biodiversity dimension of agricultural transition, integrating nature-related risks into its risk management framework. It has begun aligning with the Taskforce on Nature-related Financial Disclosures (TNFD, 2023)[233], aiming to establish indicators that measure impacts on ecosystems, such as deforestation avoided, water quality improvements, and soil restoration supported through financed projects. This positions HSBC as one of the early movers in integrating biodiversity metrics into mainstream banking practice.

In conclusion, HSBC's approach to agriculture in its transition finance strategy reflects a combination of climate, biodiversity, and social KPIs. By setting clear deforestation-related targets, adopting global accounting standards such as PCAF, scaling up green bonds and sustainability-linked loans, and partnering with international organizations to expand inclusive finance, HSBC has established a multifaceted framework of metrics. Nevertheless, the bank's disclosures remain partly aggregated, with limited granular data on agriculture alone, which leaves room for further development of sector-specific monitoring systems. Despite this, HSBC's commitments illustrate how global banks can leverage financial mechanisms to

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[231] IFC (International Finance Corporation). (2022). Inclusive finance for smallholder farmers. Washington, DC: World Bank Group. Retrieved from https://www.ifc.org

[232] WRI (World Resources Institute). (2022). Scaling finance for sustainable agriculture. Washington, DC: WRI. Retrieved from https://www.wri.org

[233] TNFD (Taskforce on Nature-related Financial Disclosures). (2023). TNFD Recommendations. Geneva: TNFD Secretariat. Retrieved from https://tnfd.global

support the transformation of agricultural systems toward sustainability while ensuring accountability through measurable indicators (HSBC, 2023)[234].

3.1.2.4 Comparative Review of Targets and Metrics across Rabobank, BNP Paribas, and HSBC

Across the three institutions, transition finance for agriculture is framed by net-zero pledges, portfolio-level emissions accounting, and progressively more granular nature-related KPIs. Yet their approaches diverge in emphasis: Rabobank operationalizes a sector-deep, client-proximate model anchored in food and agribusiness; BNP Paribas pursues a policy-driven, exclusions-and-engagement strategy integrated across a universal banking model; HSBC prioritizes deforestation risk management, supply-chain traceability and scaling sustainability-linked structures in emerging-market agrifood hubs.

Strategic positioning and sector scope. Rabobank's business model is uniquely concentrated in food and agriculture, which translates into sector-specific targets (e.g., regenerative agriculture adoption, methane-intensity reduction in dairy and beef, and farm-level resilience KPIs) and a rich advisory/extension infrastructure that supports client transition plans. BNP Paribas embeds agriculture within a broader nature and climate policy architecture (energy, transport, heavy industry), using sector policies, exclusion lists (e.g., no-deforestation criteria), and engagement milestones to steer clients; agriculture-specific KPIs are increasingly tied to biodiversity safeguards and sustainable land-use finance. HSBC applies a strong NDPE (No Deforestation, No Peat, No Exploitation) lens to high-risk supply chains (palm, soy, beef), couples that with PCAF-based financed-emissions tracking, and scales sustainability-linked loans/bonds whose ratchets hinge on verifiable farm or supply-chain KPIs.

Targets and KPI architecture. All three banks measure financed emissions using PCAF or equivalent, but differ in KPI granularity. Rabobank often tracks practice-based KPIs at farm level (e.g., nitrogen surplus per hectare, enteric methane intensity, soil organic carbon trends, nutrient-use efficiency), and links them to concessional pricing or advisory programs. BNP Paribas' KPI suite is more policy- and standard-driven, emphasizing adoption of credible certifications (RSPO, FSC, RTRS/Bonsucro), verifiable no-conversion commitments, and portfolio exposures to nature-positive assets; biodiversity-linked KPIs (e.g., hectares under restoration, high-conservation-value areas protected) feature prominently in thematic financing. HSBC balances policy screens (NDPE compliance, zero-deforestation by set dates) with deal-level KPIs embedded

[234] HSBC. (2023). Annual Report and Accounts 2023. London: HSBC Holdings plc. Retrieved from https://www.hsbc.com/investors

in SLLs/Sustainability-Linked Bonds (SLBs), such as fertilizer-use reduction, water-use intensity, and percentage of traceable volumes in soft-commodity supply chains.

Nature and biodiversity integration. BNP Paribas appears most advanced in integrating nature-related risk governance across the group (alignment with TNFD pilots and sector policies), using biodiversity safeguards and landscape-level metrics in eligible use-of-proceeds frameworks. HSBC is an early mover on TNFD with explicit deforestation risk controls and nature KPIs in Latin America and Southeast Asia supply chains. Rabobank's biodiversity approach is farm-systems oriented, embedding indicators such as crop diversity indices, semi-natural habitat shares, and pollinator-friendly practices; it pairs these with soil health metrics that co-deliver climate and nature outcomes.

Social inclusion and just transition. Rabobank leverages co-ops, local lenders, and extension partners to reach smallholders with transition advisory, blended finance, and revenue-stability mechanisms (e.g., forward purchases, co-op aggregation). BNP Paribas integrates social safeguards via eligibility criteria, due-diligence on rights/tenure, and targeted vehicles for inclusive value chains (often through structured finance with DFIs). HSBC scales blended-finance and SLL structures to reach smallholders indirectly through aggregators/off-takers, with KPIs on smallholder reach, women's participation, and income uplift.

Instruments and pricing signals. Rabobank deploys farm-level transition loans, sustainability-linked working capital, and insurance/guarantees tied to practice adoption and outcome KPIs. BNP Paribas is strongest on labelled debt markets (green/social/sustainability-linked bonds) and thematic funds channeling capital to nature-positive agriculture, with second-party opinions ensuring KPI credibility. HSBC emphasizes SLL/SLB ratchets (coupon/ margin step-ups/downs) linked to measurable agrifood KPIs (e.g., verified traceability, certified supply, emissions intensity per tonne, water-use efficiency), and scales these in emerging-market supply chains.

Data, verification, and escalation. Rabobank's proximity to farmers supports high-frequency, primary data capture (farm management systems, remote sensing, nutrient audits), which strengthens KPI credibility and MRV. BNP Paribas relies more on recognized standards, third-party certification and satellite screening for deforestation and land-use change; escalation pathways include time-bound client action plans. HSBC combines policy-based screening (NDPE audits, grievance mechanisms) with transaction-linked KPI verification (assurance providers, satellite data) and has explicit consequences for non-compliance (pricing step-ups, relationship review).

Transparency and disclosure. BNP Paribas and HSBC disclose group-level sustainable finance volumes and sectoral policies clearly; agriculture-only KPI disclosure can be aggregated and partly opaque. Rabobank publishes practice-level case metrics more frequently (especially in dairy/beef and European row crops), but portfolio-wide agriculture KPI aggregation is still evolving.

Dimension	Rabobank	BNP Paribas	HSBC
Strategic posture	Agriculture-centric franchise; deep sector expertise and client proximity.	Universal bank; strong policy/exclusion framework; integration across asset classes.	Global bank with EM footprint; strong deforestation/traceability focus.
Net-zero & standards	NZBA; PCAF for financed emissions; SBTi sector pathways used in ag pilots.	NZBA; PCAF; strong TNFD pilot adoption; strict sector policies.	NZBA; PCAF; early TNFD alignment with NDPE enforcement.
Core ag KPIs	Farm-level: methane intensity, nitrogen surplus, SOC change, nutrient-use efficiency, adoption of regenerative practices.	Portfolio/policy-linked: % certified supply, hectares protected/restored, no-conversion compliance, nature-positive financing volumes.	Deal-/supply-chain-level: NDPE compliance, % traceable volume, fertilizer/water intensity, emissions per tonne.
Deforestation controls	Client-level no-conversion expectations; landscape partnerships.	Explicit exclusion policies; mandatory safeguards/certifications; satellite monitoring.	NDPE policies with deadlines; satellite and grievance mechanisms; escalation for non-compliance.
Smallholder inclusion	Co-ops, advisory, blended finance, insurance; granular farm KPIs.	Inclusive finance via structured/thematic vehicles; social safeguards & tenure checks.	Blended-finance with DFIs; SLLs via aggregators; KPIs on reach, gender, income uplift.
Instruments	Transition loans, SLLs, working capital linked to farm KPIs; risk-sharing.	Green/social/SL bonds, sustainability-linked credit, thematic funds; SPO-verified KPI sets.	SLLs/SLBs with KPI ratchets; trade finance with traceability conditions.
MRV & data	High primary data capture (farm MIS, audits); remote sensing for land-use.	Third-party certifications, satellite screening, SPOs; portfolio analytics.	Satellite monitoring + assurance on KPI ratchets; transaction-level verification.
Transparency	Strong case-level detail; evolving portfolio aggregation for ag.	Clear policy/public reporting; agriculture KPI detail often aggregated.	Clear policy/KPI at product level; agriculture reporting partly aggregated.
Geographic strengths	Europe, Americas; dairy, arable, mixed systems.	Europe/global; strong in labelled markets and policy frameworks.	Asia/EM; soft-commodity supply chains, deforestation hotspots.

Comparative Overview of Banking Strategies for the Agricultural Transition

3.1.2.5 Strengths, Gaps, and Implications for KPI Design

Rabobank's farm-system depth makes its KPI set highly actionable for operational transition (e.g., nutrient balances, SOC trajectories, methane intensity). The trade-off is scalability and comparability across diverse geographies without harmonized baselines. BNP Paribas' policy- and standards-led approach enhances comparability and assurance (certifications, no-conversion), but may under-capture on-farm productivity and efficiency gains unless complemented by practice/outcome metrics. HSBC's deforestation and traceability emphasis addresses a material systemic risk in global soft commodities and effectively channels capital through SLL/SLB ratchets, yet agriculture-specific disclosures remain partially aggregated, limiting external assessment of portfolio-wide progress.

For a bank-agnostic KPI framework, a hybrid architecture is advisable: (i) core, comparable KPIs (financed emissions intensity per commodity; deforestation-free traceable share; hectares under improved management; water-use intensity); (ii) practice-level operational KPIs (methane intensity, nitrogen surplus, SOC change) to drive on-farm performance; and (iii) social inclusion KPIs (smallholder reach, women's participation, income uplift) to ensure just-transition outcomes. Robust MRV should blend primary farm data, certification/assurance, and remote sensing to balance credibility with scalability.

3.1.3 Defining Specific Indicators for Primary Farming

3.1.3.1 Backward-Looking KPIs

In the context of primary farming, Key Performance Indicators (KPIs) serve as essential tools to evaluate historical performance, enabling stakeholders to quantify past achievements and identify areas for improvement. Backward-looking KPIs, in particular, are grounded in verifiable past data, reflecting the tangible outcomes of farm management practices rather than projections or planned interventions. These indicators are crucial for establishing reliable baselines, benchmarking performance across farms or regions, and ensuring accountability in sustainability reporting (OECD, 2021)[235]. Unlike forward-looking KPIs, which focus on anticipated improvements or targets, backward-looking indicators provide an empirical

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[235] OECD. (2021). Environmental performance indicators for agriculture. Paris: Organisation for Economic Co-operation and Development. Retrieved from https://www.oecd.org/en/publications/environmental-performance-of-agriculture-in-oecd-countries_2679ba38-en.html

foundation that allows both policymakers and financial institutions to assess the effectiveness of past interventions and to calibrate future strategies in agricultural transitions (FAO, 2018)[236].

Backward-looking KPIs in primary farming encompass a wide range of environmental, economic, and social dimensions. On the environmental side, yield-based metrics, calculated from historical crop outputs per hectare, provide insight into long-term productivity trends, including the impacts of climatic variability, soil fertility management, and input usage (Lobell et al., 2011)[237]. Tracking greenhouse gas emissions intensity over multiple growing seasons offers a direct measure of the environmental footprint of farming operations, with data often derived from fertilizer application records, livestock inventories, and energy consumption logs (IPCC, 2019)[238]. Similarly, nutrient-use efficiency, calculated from the ratio of crop nutrient uptake to applied fertilizers in past seasons, highlights the sustainability and cost-effectiveness of soil management practices (Zhang et al., 2015)[239]. Water-use intensity, measured from historical irrigation volumes relative to crop output, not only reflects farm-level efficiency but also informs regional water resource planning and climate adaptation policies (FAO, 2016)[240]. Soil health indicators, such as soil organic carbon content or measures of microbial activity, provide retrospective evidence of ecological stewardship and the cumulative

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236 FAO. (2018). FAO Sustainable food systems, Concept and framework. Rome: Food and Agriculture Organization. Retrieved from https://openknowledge.fao.org/server/api/core/bitstreams/b620989c-407b-4caf-a152-f790f55fec71/content#:~:text=A%20sustainable%20food%20system%20(SFS,natural%20environment%20(environmental%20sustainability).

237 Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, 333(6042), 616–620. Retrieved from https://www.science.org/doi/10.1126/science.1204531

238 IPCC. (2019). Climate Change and Land: Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Intergovernmental Panel on Climate Change.

239 Zhang, X., Davidson, E. A., Mauzerall, D. L., Searchinger, T. D., Dumas, P., & Shen, Y. (2015). Managing nitrogen for sustainable development. Nature, 528(7580), 51–59. Retrieved from https://www.nature.com/articles/nature15743

240 FAO. (2016). Coping with water scarcity in agriculture: A global framework for action in a changing climate. Food and Agriculture Organization of the United Nations. Retrieved from https://openknowledge.fao.org/server/api/core/bitstreams/b615560e-1bf0-494d-a1c5-9e5c38178aec/content

effects of management practices over time (Lal, 2020)[241], while biodiversity-related metrics, derived from field surveys or remote sensing, capture the impact of past farming practices on local flora and fauna (Tscharntke et al., 2012)[242].

Economic performance is equally critical in the evaluation of backward-looking KPIs. Historical farm income records, including farm-gate prices, revenue volatility, and reliance on subsidies, provide insight into the resilience of farming households and their capacity to absorb shocks such as price fluctuations or extreme weather events (World Bank, 2019)[243]. These indicators also inform investment decisions by banks and other financial institutions, allowing them to assess the risk and return profiles of agricultural portfolios based on empirically observed outcomes rather than speculative projections. In addition, social dimensions, including labour productivity and participation—particularly of marginalized groups such as women and youth—can be quantified retrospectively to assess how previous farming practices affected equity and social sustainability (FAO & IFAD, 2021)[244].

One of the key strengths of backward-looking KPIs lies in their robustness and reliability. Because they are derived from documented, verifiable data, they can be audited, replicated, and compared across different temporal and spatial scales (OECD, 2021)[245]. They enable a granular understanding of how agricultural practices have historically influenced both environmental and economic outcomes, facilitating the identification of systemic inefficiencies and informing evidence-based policy or investment interventions. However, the use of backward-looking KPIs is not without limitations. These indicators inherently reflect

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[241] Lal, R. (2020). Regenerative agriculture for food and climate. Journal of Soil and Water Conservation, 75(5), 123A–124A. Retrieved from https://www.researchgate.net/publication/343379196_Regenerative_agriculture_for_food_and_climate

[242] Tscharntke, T., Clough, Y., Wanger, T. C., et al. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation, 151(1), 53–59. Retrieved from https://www.sciencedirect.com/science/article/pii/S0006320712000821

[243] World Bank. (2019). Future of food: Shaping the food system to deliver jobs. Washington, DC. Retrieved from https://www.worldbank.org/en/topic/agriculture/publication/the-future-of-food-shaping-the-food-system-to-deliver-jobs

[244] FAO & IFAD. (2021). Rural Development Report 2021: Transforming food systems for rural prosperity. Rome. Retrieved from https://www.ifad.org/documents/d/new-ifad.org/rdr2021_overview_e-pdf

[245] OECD. (2021). Environmental performance indicators for agriculture. Paris: Organisation for Economic Co-operation and Development. Retrieved from https://www.oecd.org/en/publications/environmental-performance-of-agriculture-in-oecd-countries_2679ba38-en.html

past conditions and may not fully capture ongoing technological adoption, changes in regulatory frameworks, or emerging climate risks that could affect future performance (IPCC, 2022)[246]. Consequently, while they provide a critical reference point for understanding historical impacts, they are most effective when combined with forward-looking KPIs, which project anticipated improvements, track planned interventions, and capture the dynamic nature of agricultural transitions (World Bank, 2021)[247].

In summary, backward-looking KPIs for primary farming serve as the empirical backbone of sustainability assessment. They allow financial institutions, policymakers, and farm managers to evaluate historical performance in a comprehensive manner that integrates environmental, economic, and social dimensions. By establishing a credible and quantifiable baseline, these indicators facilitate informed decision-making, enable benchmarking against best practices, and provide the foundation for designing effective strategies to achieve climate-resilient and economically viable farming systems. Nevertheless, to fully support sustainable agricultural transitions, backward-looking KPIs should be complemented with forward-looking metrics, ensuring that assessments reflect both historical performance and the trajectory toward long-term climate, ecological, and socio-economic objectives.

3.1.3.2 Point-in-Time KPIs

Point-in-Time (PiT) KPIs are "as-of" measurements used to evidence compliance, trigger covenants, gate eligibility, and support supervisory disclosures; they answer the practical question "what is true now?" and make transition plans enforceable in credit and procurement decisions (IFRS Foundation, 2023)[248]. Properly designed, they interoperate with portfolio targets and disclosures under SBTi/FLAG, NZBA, PCAF, so that

[246] IPCC. (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report. Retrieved from https://www.ipcc.ch/report/ar6/wg3/

[247] World Bank. (2021). Climate-smart agriculture indicators. Washington, DC. Retrieved from https://openknowledge.worldbank.org/entities/publication/6215f611-ad54-578c-b996-2fba27fbcae6

[248] IFRS Foundation (2023). *IFRS S1—General Requirements for Disclosure of Sustainability-related Financial Information; IFRS S2—Climate-related Disclosures.* London: IFRS Foundation. Available at: https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

loan-level states aggregate coherently to bank-level reporting (SBTi, 2022[249]; NZBA, 2021[250]; PCAF, 2023[251]).

Each PiT KPI must define its unit and boundary, a short observation window, and a clear reference condition. Units include, for example, % manure under covered storage, m^3 water per kg output, % financed hectares under AWD in rice, 30-day cold-chain temperature excursions, or days-sales-outstanding to smallholders; boundaries may be on-farm, facility, or farm-polygon/supply-shed; windows are brief (1–30 days) and phenology-aware so detection is valid (ESA, 2014[252]; IRRI, 2015[253]; FAO, 2020[254]). Typical reference conditions are "no tree-cover loss after the cut-off date" (deforestation-free) or "≥85% plant uptime over the trailing 30 days".

Measurement should combine remote sensing for land/water status, in-situ telemetry (SCADA) for equipment and energy systems, digital farm logs for practices (e.g., feed additives, irrigation), and ERP data for transactions (e.g., payments). Methods and boundaries follow IPCC 2019 and the GHG Protocol Land Sector guidance; accuracy metrics and 95% confidence intervals are disclosed to support assurance under

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[249] Science Based Targets initiative (SBTi) (2022). *Forest, Land and Agriculture (FLAG) Sector Guidance.* Science Based Targets. Available at: https://files.sciencebasedtargets.org/production/files/SBTiFLAGGuidance.pdf

[250] United Nations-convened Net-Zero Banking Alliance (NZBA) (2021). *Commitment Statement and Guidelines for Climate Target Setting.* UNEP FI. Available at:https://www.unepfi.org/net-zero-banking/?

[251] Partnership for Carbon Accounting Financials (PCAF) (2023). *The Global GHG Accounting and Reporting Standard for the Financial Industry (Version 2).* PCAF. Available at: https://carbonaccountingfinancials.com/standard

[252] European Space Agency (ESA) (2014). *Sentinel-1 Mission Overview and User Handbook.* ESRIN: ESA. Available at: https://seom.esa.int/polarimetrycourse2017/files/materials/Sentinel-1_Mission_Overview.pdf?

[253] International Rice Research Institute (IRRI) (2015). *Alternate Wetting and Drying (AWD): Technical Manual for Water-Saving in Rice.* Los Baños: IRRI. Available at: https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying

[254] FAO (2020). *Remote Sensing for Agricultural Monitoring: Methods and Applications.* Rome: Food and Agriculture Organization. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/bd269f93-875c-4134-a376-68ca17a3315f/content

ISSB S2 (IPCC, 2019[255]; GHG Protocol, 2023[256]; IFRS Foundation, 2023[257]). To ensure comparability, PiT checks are normalized for phenology and weather, use short trailing windows (e.g., 7–30 days), and apply exposure-weighted aggregation at portfolio level (FAO, 2020[258]; IFRS Foundation, 2023[259]).

Anti-gaming safeguards are essential. Unannounced observation windows, tamper-evident logs, and cross-checks between RS, meters, and invoices reduce window-dressing; pricing or eligibility relies on PiT + trailing performance (e.g., ≥60% covered storage at audit and ≥55% quarterly average) in line with Sustainability-Linked Loan Principles on meaningful SPTs (OECD, 2021[260]; LMA/APLMA/LSTA, 2023[261]). PiT evidence then drives three decision points: origination gates and collateral haircuts (e.g., deforestation-free status or covered storage), monitoring triggers (e.g., digester downtime locks distributions), and semi-annual re-pricing that only applies when PiT compliance coincides with its paired

[255] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva: IPCC. Available at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

[256] Greenhouse Gas Protocol (2023). *Land Sector and Removals Guidance.* World Resources Institute & WBCSD. Available at: https://ghgprotocol.org/land-sector-and-removals-guidance

[257] IFRS Foundation (2023). *IFRS S1—General Requirements for Disclosure of Sustainability-related Financial Information; IFRS S2—Climate-related Disclosures.* London: IFRS Foundation. Available at: https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

[258] FAO (2020). *Remote Sensing for Agricultural Monitoring: Methods and Applications.* Rome: Food and Agriculture Organization. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/bd269f93-875c-4134-a376-68ca17a3315f/content

[259] IFRS Foundation (2023). *IFRS S1—General Requirements for Disclosure of Sustainability-related Financial Information; IFRS S2—Climate-related Disclosures.* London: IFRS Foundation. Available at: https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

[260] OECD (2021). *Enhancing Access to and Sharing of Data: Reconciling Risks and Benefits.* Paris: OECD Publishing. Available at: https://www.oecd.org/en/publications/enhancing-access-to-and-sharing-of-data_276aaca8-en.html

[261]Loan Market Association (LMA), Asia Pacific LMA (APLMA), Loan Syndications & Trading Association (LSTA) (2023). *Sustainability-Linked Loan Principles.Available at:* https://www.lsta.org/content/sustainability-linked-loan-principles-sllp/

period outcome (e.g., seasonal methane-intensity), keeping NZBA/SBTi claims assurable (SBTi, 2022[262]; NZBA, 2021[263]; IFRS Foundation, 2023)[264].

Applications are straightforward. In irrigated rice, Sentinel-1 SAR classifies AWD during mid-tillering to grain-fill; two "continuous-flood" detections within the season breach the covenant even if yields hold, because the bank prices water and CH_4 outcomes (ESA, 2014[265]; IRRI, 2015[266]). In dairy, an image/telemetry check confirms covered storage and SCADA verifies digester uptime, while ration logs show additive inclusion over the last 14 days; pricing steps down only when these PiT checks align with the annual intensity result built on IPCC/FLAG factors (IPCC, 2019[267]; SBTi, 2022)[268]. In export horticulture, 30-day temperature-excursion distributions determine receivables advance rates; two compliant windows restore higher advances.

Finally, social performance can and should be tested PiT to protect just-transition outcomes: month-end payment days to smallholders, median grievance-resolution times, current tenure documentation, and representation of women/youth in producer governance are verifiable "as-of" states and are disclosed with environmental KPIs under ISSB S1/S2 (IFRS Foundation, 2023)35. PiT measures do not replace trajectories—slow variables like soil organic carbon remain multi-year deltas—but, used alongside seasonal

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[262] Science Based Targets initiative (SBTi) (2022). *Forest, Land and Agriculture (FLAG) Sector Guidance.* Science Based Targets. Available at: https://files.sciencebasedtargets.org/production/files/SBTiFLAGGuidance.pdf

[263] United Nations-convened Net-Zero Banking Alliance (NZBA) (2021). *Commitment Statement and Guidelines for Climate Target Setting.* UNEP FI. Available at:https://www.unepfi.org/net-zero-banking/?

[264] IFRS Foundation (2023). *IFRS S1—General Requirements for Disclosure of Sustainability-related Financial Information; IFRS S2—Climate-related Disclosures.* London: IFRS Foundation. Available at: https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

[265] European Space Agency (ESA) (2014). *Sentinel-1 Mission Overview and User Handbook.* ESRIN: ESA. Available at: https://seom.esa.int/polarimetrycourse2017/files/materials/Sentinel-1_Mission_Overview.pdf?

[266] International Rice Research Institute (IRRI) (2015). *Alternate Wetting and Drying (AWD): Technical Manual for Water-Saving in Rice.* Los Baños: IRRI. Available at: https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying

[267] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva: IPCC. Available at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

[268] Science Based Targets initiative (SBTi) (2022). *Forest, Land and Agriculture (FLAG) Sector Guidance.* Science Based Targets. Available at: https://files.sciencebasedtargets.org/production/files/SBTiFLAGGuidance.pdf

indicators and backed by transparent methods, they provide the enforceable surface that links farm-level practice to portfolio-level alignment in a way that is auditable, comparable, and proportionate (IPCC, 2019[269]; IFRS Foundation, 2023)[270].

3.1.3.3 Forward-Looking KPIs

Forward-looking KPIs in primary farming are designed to anticipate future outcomes, risks, and opportunities rather than merely describing past or present conditions. Unlike backward-looking indicators, which summarize historical performance, or point-in-time KPIs, which provide a snapshot of current operations, forward-looking KPIs project the potential trajectory of farm performance, environmental impact, and financial stability. These indicators are particularly relevant for banks, investors, and policymakers who need to assess the likely effectiveness of agricultural practices, the resilience of farming systems to climate variability, and the long-term sustainability of investments in the agri-sector (Lipper et al., 2014)[271].

From an environmental perspective, forward-looking KPIs focus on predicting the outcomes of ongoing or planned management practices. For example, modeling projected soil carbon sequestration based on crop rotation and the use of soil amendments enables the estimation of future carbon storage, which directly contributes to international climate mitigation targets (Smith et al., 2019[272]; Paustian et al., 2016)[273]. Similarly, anticipating water-use efficiency under different irrigation methods or crop portfolios allows stakeholders to evaluate potential water conservation outcomes over the coming growing seasons (Rosa et

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[269] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva: IPCC. Available at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

[270] IFRS Foundation (2023). *IFRS S1—General Requirements for Disclosure of Sustainability-related Financial Information; IFRS S2—Climate-related Disclosures.* London: IFRS Foundation. Available at: https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

[271] Lipper, L., Thornton, P., Campbell, B. M., et al. (2014). Climate-smart agriculture for food security. Nature Climate Change, 4(12), 1068–1072. https://doi.org/10.1038/nclimate2437

[272] Smith, P., et al. (2019). How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Global Change Biology, 26(1), 219–241. https://doi.org/10.1111/gcb.14815

[273] Paustian, K., Larson, E., Kent, J., Marx, E., & Swan, A. (2016). Soil C sequestration as a biological negative emission strategy. Frontiers in Climate, 1, 8. https://doi.org/10.3389/fclim.2019.00008

al., 2018)[274]. Biodiversity-oriented forward-looking KPIs, such as projected pollinator population dynamics or expected outcomes from habitat restoration, offer a longer-term lens on ecosystem resilience and the maintenance of ecosystem services vital for productivity (IPBES, 2019[275]; Bommarco et al., 2013)[276]. By integrating climate models with agronomic and ecological projections, these indicators help evaluate the sustainability of agricultural investments across time horizons spanning decades.

Economic forward-looking KPIs are equally important, as they help anticipate farm profitability, cash flow, and exposure to market risks. Projected yield simulations under different cropping strategies—when combined with input cost forecasts and commodity price scenarios—offer risk-adjusted revenue predictions that guide farm management and investment planning (OECD, 2020)[277]. Moreover, modeling the expected returns from diversification strategies such as agroforestry integration, livestock-crop systems, or renewable energy adoption provides insight into long-term income stability and resilience against price shocks (Schroth et al., 2004)[278]. Forward-looking KPIs thus play a crucial role for financial institutions in determining

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[274] Rosa, L., Rulli, M. C., Davis, K. F., Chiarelli, D. D., Passera, C., & D'Odorico, P. (2018). Closing the yield gap while ensuring water sustainability. Environmental Research Letters, 15(10), 104053. https://iopscience.iop.org/article/10.1088/1748-9326/aadeef

[275] IPBES. (2019). Global Assessment Report on Biodiversity and Ecosystem Services. Bonn: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.https://files.ipbes.net/ipbes-web-prod-public-files/webform/impact_tracking_database/46408/2019%20IPBES%20Biodiversity%20and%20Ecosystem%20Services%20report%20Final.pdf

[276] Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution, 28(4), 230–238. https://www.sciencedirect.com/science/article/pii/S016953471200273X

[277] OECD. (2020). Agricultural Policy Monitoring and Evaluation 2020. Paris: Organisation for Economic Co-operation and Development. https://www.oecd.org/en/publications/2020/06/agricultural-policy-monitoring-and-evaluation-2020_009f869e.html

[278] Schroth, G., Fonseca, G. A. B. da, Harvey, C. A., Gascon, C., Vasconcelos, H. L., & Izac, A. N. (2004). Agroforestry and Biodiversity Conservation in Tropical Landscapes. Island Press. https://www.researchgate.net/publication/216140060_Agroforestry_and_Biodiversity_Conservation_in_Tropical_Landscapes

eligibility for sustainability-linked finance, as they can identify which farms or projects are most likely to meet future performance benchmarks under ESG criteria (UNEP FI, 2021)[279].

From a social standpoint, forward-looking KPIs assess the likely impacts of interventions on labor conditions, inclusivity, and community well-being. This includes, for instance, the expected outcomes of farmer training programs on productivity and skills, anticipated improvements in gender equity through targeted initiatives, or projected changes in workforce resilience linked to climate adaptation measures (Meinzen-Dick et al., 2012;[280] CGIAR, 2020)[281]. Such metrics allow governments, NGOs, and banks to anticipate how farming transitions will affect rural livelihoods and design policies or finance schemes that maximize social benefits while strengthening agricultural sustainability.

The principal advantage of forward-looking KPIs is their predictive and strategic capacity. They enable proactive responses to risks and opportunities, allowing farmers, investors, and policymakers to adjust practices, portfolios, and strategies before negative impacts materialize. This is particularly critical in agricultural systems characterized by high uncertainty, such as those vulnerable to climate change, global market volatility, or socio-political instability (FAO, 2021)[282]. Yet, these indicators are also subject to limitations. Their reliability depends heavily on the quality of baseline data, the robustness of underlying models, and the accuracy of scenario assumptions. Unforeseen shocks—whether climatic, economic, or

[279] UNEP FI. (2021). Net-Zero Banking Alliance: Guidelines for Climate Target Setting for Banks. Geneva: United Nations Environment Programme Finance Initiative. https://www.unepfi.org/wordpress/wp-content/uploads/2025/04/Guidance-for-Climate-Change-Target-Setting-Version-3.pdf

[280] Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., & Beintema, N. (2012). Engendering Agricultural Research. IFPRI. https://www.researchgate.net/publication/254417045_Engendering_agricultural_research_development_and_extension

[281] CGIAR. (2020). Climate-Smart Agriculture: Priorities for Food Security and Resilience. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://iaes.cgiar.org/sites/default/files/images/Publications/CCAFS%20CRP%20Review%202020%20Report.pdf

[282] FAO. (2021). The State of Food and Agriculture: Making Agri-Food Systems More Resilient to Shocks and Stresses. Rome: Food and Agriculture Organization. https://openknowledge.fao.org/server/api/core/bitstreams/1e61f82a-618c-467a-a37f-545580094a1d/content

political—may alter trajectories in ways that projections cannot fully capture (Challinor et al., 2014)[283]. Thus, while forward-looking KPIs provide valuable foresight, they should be interpreted with caution and complemented by backward-looking and point-in-time measures to ensure a holistic evaluation.

In conclusion, forward-looking KPIs provide a strategic framework for assessing the anticipated performance and sustainability of primary farming systems. By combining environmental, economic, and social projections with robust modeling approaches, these indicators enable stakeholders to make informed, proactive decisions that strengthen resilience, sustainability, and profitability in the long term. Integrated with backward-looking and point-in-time KPIs, they ensure that agricultural transitions are guided not only by past experience and present conditions but also by credible projections of future challenges and opportunities, aligning farm-level management with global sustainability goals and financial risk management practices.

3.1.3.4 Exposure Metrics

Exposure metrics in primary farming are designed to quantify the extent to which agricultural systems, stakeholders, and investments are vulnerable to external risks and pressures. Unlike backward-looking indicators, which summarize past performance, or forward-looking KPIs, which project potential future outcomes, exposure metrics focus specifically on the degree of sensitivity of farms to environmental, economic, and social stressors (OECD, 2021)[284]. These metrics are essential for financial institutions, policymakers, and farmers themselves to understand where risks are concentrated and how they may translate into financial, operational, or ecological losses (FAO, 2016)[285].

Environmental exposure metrics assess the degree to which farms are subject to natural hazards and climate variability. This includes the vulnerability of croplands to droughts, floods, soil degradation, pest

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283 Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, 4, 287–291. https://doi.org/10.1038/nclimate2153

284 OECD. (2021). Measuring agricultural sustainability: Concepts, indicators, and framework. Paris: Organisation for Economic Co-operation and Development. https://www.oecd.org/en/data/dashboards/measuring-the-environmental-performance-of-agriculture.html

285 FAO. (2016). Climate change and food security: Risks and responses. Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/8d799d5f-60e4-4ff9-87dd-d33289abb482

infestations, and extreme weather events (IPCC, 2022)[286]. For example, measuring the proportion of land located within flood-prone zones or the percentage of irrigated fields dependent on a single water source helps identify areas of high exposure to water stress. Similarly, quantifying the reliance on monocultures or the absence of soil conservation measures provides insight into the farm's susceptibility to biodiversity loss and declining ecosystem services (Altieri & Nicholls, 2017)[287]. These indicators enable stakeholders to evaluate the likelihood of environmental shocks affecting farm productivity and sustainability.

Economic exposure metrics focus on the sensitivity of farm incomes and investments to market and financial risks. Farmers dependent on a single crop or a narrow set of buyers are inherently more exposed to price volatility, trade disruptions, and input cost fluctuations (OECD-FAO, 2022)[288]. Metrics such as the percentage of revenue derived from a single commodity, dependency on imported fertilizers or seeds, and the concentration of market access highlight vulnerabilities in farm economic structures. Exposure metrics also consider the potential impacts of regulatory changes, such as carbon pricing or sustainability standards, on farm profitability (European Commission, 2021)[289]. By quantifying these factors, banks and investors can identify high-risk operations and calibrate lending, insurance, and risk mitigation strategies accordingly (UNEP FI, 2020)[290].

Social exposure metrics evaluate the vulnerability of farm labor, communities, and governance structures to socio-economic and demographic pressures. These include dependency on seasonal labor, lack of access to financial services, limited educational attainment, and inequalities in land ownership or resource access

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[286] IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/

[287] Altieri, M. A., & Nicholls, C. I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. Climatic Change, 140(1), 33–45. https://link.springer.com/article/10.1007/s10584-013-0909-y

[288] OECD-FAO. (2022). Agricultural Outlook 2022–2031. Paris: OECD Publishing. https://www.oecd.org/en/publications/2022/06/oecd-fao-agricultural-outlook-2022-2031_e00c413c.html

[289] European Commission. (2021). Sustainable finance and EU taxonomy: Regulation and impact. Brussels: European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_21_1804

[290] UNEP FI. (2020). Driving finance for climate resilience: A framework for financial institutions. Nairobi: United Nations Environment Programme Finance Initiative. https://www.unepfi.org/

(FAO, IFAD & WFP, 2015)[291]. Farms where women or youth face systemic barriers, or where cooperative structures are weak, exhibit higher social exposure, as these factors can impede adaptive capacity in the face of climate shocks or market fluctuations (HLPE, 2020)[292]. Assessing these dimensions allows policymakers and support organizations to target interventions that reduce social vulnerability and enhance resilience.

The primary value of exposure metrics lies in their capacity to inform risk management and resilience-building strategies. By quantifying the degree of sensitivity across environmental, economic, and social dimensions, these metrics help stakeholders identify hotspots of vulnerability, prioritize interventions, and design tailored adaptation measures (OECD, 2021)[293]. For financial institutions, exposure metrics are particularly important for credit risk assessment, insurance underwriting, and sustainability-linked financing, as they reveal the potential for future losses due to environmental or market shocks (UNEP FI, 2020)[294].

However, exposure metrics also carry limitations. They provide a static assessment of vulnerability rather than a predictive measure of future outcomes. Their accuracy depends on the availability and granularity of data, and they may not fully capture complex interactions between multiple stressors or systemic risks (IPCC, 2022)[295]. Integrating exposure metrics with forward-looking and backward-looking KPIs provides a more comprehensive framework, allowing stakeholders to understand not only the extent of current

[291] FAO, IFAD & WFP. (2015). The State of Food Insecurity in the World 2015. Rome: FAO. https://openknowledge.fao.org/server/api/core/bitstreams/63863832-4cb5-4e05-9040-4b22d9a92324/content

[292] HLPE. (2020). Food security and nutrition: Building a global narrative towards 2030. High Level Panel of Experts on Food Security and Nutrition. https://openknowledge.fao.org/server/api/core/bitstreams/8357b6eb-8010-4254-814a-1493faaf4a93/content

[293] OECD. (2021). Measuring agricultural sustainability: Concepts, indicators, and framework. Paris: Organisation for Economic Co-operation and Development. https://www.oecd.org/en/data/dashboards/measuring-the-environmental-performance-of-agriculture.html

[294] UNEP FI. (2020). Driving finance for climate resilience: A framework for financial institutions. Nairobi: United Nations Environment Programme Finance Initiative. https://www.unepfi.org/

[295] IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/

vulnerability but also the projected impact and historical performance of agricultural systems (FAO, 2016)[296].

In conclusion, exposure metrics constitute a critical dimension of KPI frameworks in primary farming, offering a precise understanding of how farms and rural communities are susceptible to a range of environmental, economic, and social stressors. By identifying vulnerabilities and quantifying risk concentration, these indicators enable informed decision-making, targeted interventions, and the promotion of resilient, sustainable agricultural systems (HLPE, 2020)[297].

3.1.3.5 Policy-Alignment Metrics

Policy-alignment metrics in primary farming are designed to evaluate the extent to which agricultural practices, investments, and organizational strategies adhere to national, regional, and international policy frameworks. Unlike backward-looking KPIs, which assess historical performance, or forward-looking and exposure metrics, which project potential outcomes or quantify vulnerability, policy-alignment indicators emphasize compliance, consistency, and integration with the evolving landscape of agricultural governance (OECD, 2021)[298]. They have become increasingly relevant for farmers, policymakers, and financial institutions, since demonstrating alignment with policy objectives is now essential to secure subsidies, sustainability-linked credit, and preferential market access, while also mitigating regulatory and reputational risks (FAO, 2020;[299] UNEP FI, 2023[300]).

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[296] FAO. (2016). Climate change and food security: Risks and responses. Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/8d799d5f-60e4-4ff9-87dd-d33289abb482

[297] HLPE. (2020). Food security and nutrition: Building a global narrative towards 2030. High Level Panel of Experts on Food Security and Nutrition. https://openknowledge.fao.org/server/api/core/bitstreams/8357b6eb-8010-4254-814a-1493faaf4a93/content

[298] OECD. (2021). *OECD-FAO Guidance for Responsible Agricultural Supply Chains*. Paris: Organisation for Economic Co-operation and Development. https://www.fao.org/markets-and-trade/areas-of-work/emerging-trends-challenges-and-opportunities/oecd-guidance/en

[299] FAO. (2020). *The State of Agricultural Commodity Markets 2020*. Rome: Food and Agriculture Organization. Retrieved from https://www.fao.org/publications/soco/en/

[300] UNEP FI. (2023). *Principles for Responsible Banking – Guidance on Climate and Nature Target Setting*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org/banking/net-zero/

Recent reforms—such as the European Competitiveness Compass 2025, the EU Vision for Agriculture and Food 2025, and the EU Deforestation-Free Products Regulation (EUDR, 2023[301])—have significantly expanded the scope of alignment. Environmental policy-alignment metrics must now measure not only compliance with existing soil, water, and emissions laws, but also consistency with the EU's Green Deal trajectory (European Commission, 2025a[302]; European Commission, 2025b[303]). For instance, the share of farmland geolocated and verified as deforestation-free in line with EUDR requirements provides a tangible example of how alignment can be quantified (IISD, 2025)[304]. Similarly, the proportion of farms reporting GHG emissions intensity per hectare and demonstrating year-on-year reductions consistent with the benchmarks of the Competitiveness Compass 2025 illustrates how metrics link individual farm performance with EU-wide climate and competitiveness targets (European Commission, 2025a[305]). A further example lies in the integration of agroforestry practices: under the EU Vision 2025, the number of hectares incorporating tree cover or pollinator habitats can serve as a proxy for biodiversity-enhancing land use that contributes both to national directives and to international frameworks such as the Kunming-Montreal Global Biodiversity Framework (CBD, 2022[306]).

Economic policy-alignment metrics also lend themselves to concrete operationalization. Farms that derive a defined share of their income from certified sustainable commodities—such as soy certified as deforestation-free or dairy certified under carbon-neutral schemes—can demonstrate clear consistency with subsidy

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[301] European Commission. (2023). *Regulation (EU) 2023/1115 on deforestation-free products*. Official Journal of the European Union. https://eur-lex.europa.eu/eli/reg/2023/1115/oj/eng

[302] European Commission. (2025a). *The Competitiveness Compass 2025*. Brussels: European Union. Retrieved from https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en

[303] European Commission. (2025b). *Vision for Agriculture and Food 2025*. Brussels: European Union. Retrieved from https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

[304] IISD. (2025). *Unpacking the European Union Deforestation Regulation*. International Institute for Sustainable Development. Retrieved from https://www.iisd.org/system/files/2025-04/unpacking-european-union-deforestation-regulation.pdf

[305] European Commission. (2025a). *The Competitiveness Compass 2025*. Brussels: European Union. Retrieved from https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en

[306] Convention on Biological Diversity (CBD). (2022). *Kunming-Montreal Global Biodiversity Framework*. CBD. Retrieved from https://www.cbd.int/gbf

eligibility rules and sustainable finance taxonomies (European Commission, 2020[307]; OECD-FAO, 2022[308]). Similarly, participation rates in CAP eco-schemes, or enrolment in government-supported resilience programs that reward low-carbon inputs such as green fertilizers, exemplify alignment with policy incentives (European Parliament & Council, 2021[309]). In financial terms, alignment can also be measured by the uptake of sustainability-linked loans in which interest rates are reduced if farms achieve verifiable compliance with climate targets, as encouraged by banks under the Net Zero Banking Alliance (NZBA, 2021;[310] UNEP FI, 2023[311]). For example, a farm that secures financing conditional upon reducing methane emissions from livestock by a fixed percentage is not only aligning with climate finance strategies but also operationalizing global mitigation commitments at farm level (Rabobank, 2023)[312].

Social dimensions of policy-alignment metrics can be equally specific. Farms may demonstrate compliance with national labour laws by showing that 100 percent of employees receive at least the statutory minimum wage, or that occupational safety standards are systematically audited (ILO, 2019).[313] In line with the EU Vision 2025, which emphasizes inclusive rural development, indicators could include the percentage of farm enterprises providing formal training opportunities for young workers or the share of land accessible to women through joint land-titling schemes (European Commission, 2025b)[314]. Community-level engagement can also be captured, for example by measuring the proportion of farms participating in cooperatives that supply local markets under fair-trade agreements, thus aligning with both EU rural development policies and international labour standards (HLPE, 2020)[315].

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[307] European Commission. (2020). *EU Taxonomy Regulation (Regulation (EU) 2020/852)*. Brussels: European Union. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0852

[308] OECD-FAO. (2022). *OECD-FAO Agricultural Outlook 2022–2031*. Paris/Rome. Retrieved from https://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2022-2031_19428846-en

[309] European Parliament & Council. (2021). *Regulation (EU) 2021/2115 establishing rules on support for CAP Strategic Plans*. Brussels: European Union. https://eur-lex.europa.eu/eli/reg/2021/2115/oj/eng

[310] NZBA. (2021). *Net Zero Banking Alliance: Commitment Statement*. United Nations Environment Programme Finance Initiative (UNEP FI). Retrieved from https://www.unepfi.org/net-zero-banking/

[311] UNEP FI. (2023). *Principles for Responsible Banking – Guidance on Climate and Nature Target Setting*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org/banking/net-zero/

[312] Rabobank. (2023). *Sustainability Strategy: Reducing Agricultural Emissions*. Utrecht: Rabobank.

[313] ILO. (2019). *Work for a Brighter Future: Global Commission on the Future of Work*. Geneva: International Labour Organization. https://www.ilo.org/publications/work-brighter-future

[314] European Commission. (2025b). *Vision for Agriculture and Food 2025*. Brussels: European Union. Retrieved from https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

[315] HLPE. (2020). *Food security and nutrition: Building a global narrative towards 2030*. High-Level Panel of Experts on Food Security and Nutrition, Committee on World Food Security. Rome: FAO. https://openknowledge.fao.org/server/api/core/bitstreams/8357b6eb-8010-4254-814a-1493faaf4a93/content

These examples illustrate that policy-alignment metrics function as a bridge between farm-level practices and governance objectives. They translate complex regulatory requirements into measurable outcomes such as hectares of land certified under the EUDR, percentage reductions in emissions consistent with the Competitiveness Compass 2025, or rates of smallholder participation in eco-schemes. They also provide investors and financial institutions with the evidence needed to demonstrate consistency with disclosure frameworks such as the Transition Pathway Initiative's 2025 benchmarks, the ISSB's climate-related reporting standards, and the EU's sustainable finance taxonomy (ISSB, 2023[316]; TPI, 2025[317]).

Nevertheless, challenges remain. Policies are fragmented and evolve rapidly, and alignment metrics must be flexible enough to incorporate new obligations while remaining robust and comparable over time (OECD, 2021)[318]. Moreover, they must address the equity dimension: for example, measuring not only the proportion of farms compliant with the EUDR but also the proportion of smallholders receiving technical assistance to achieve compliance (SEI, 2024[319]; WRI, 2025[320]). Without such complementary indicators, policy-alignment risks becoming exclusionary.

In conclusion, policy-alignment metrics form a critical dimension of KPI frameworks for primary farming. By embedding the latest policy reforms into quantifiable indicators—whether through measuring hectares under deforestation-free certification, reductions in financed agricultural emissions, participation in eco-schemes, or inclusivity in land and labour policies—these metrics ensure that farm operations are strategically positioned to benefit from incentives, enhance resilience, and contribute to sustainable development goals. They thus operationalize the convergence between farm-level decisions and broader governance frameworks, anchoring agriculture firmly within the global transition toward climate neutrality and social sustainability.

3.1.3.6 Standard-Alignment Metrics

Standard-alignment metrics are designed to assess the extent to which agricultural operations conform to established sustainability, quality, and certification standards at national, regional, or international levels.

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[316] SSB. (2023). *IFRS S2: Climate-related Disclosures*. International Sustainability Standards Board. Retrieved from https://www.ifrs.org/issued-standards/ifrs-sustainability-standards/ifrs-s2-climate-related-disclosures/
[317] TPI. (2025). *State of the Corporate Transition 2025*. Transition Pathway Initiative Centre, London School of Economics. Retrieved from https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025
[318] OECD. (2021). *OECD-FAO Guidance for Responsible Agricultural Supply Chains*. Paris: Organisation for Economic Co-operation and Development. https://www.fao.org/markets-and-trade/areas-of-work/emerging-trends-challenges-and-opportunities/oecd-guidance/en
[319] SEI. (2024). *Finding a Place for Smallholder Farmers in EU Deforestation Regulation*. Stockholm Environment Institute. Retrieved from https://www.sei.org/publications/smallholder-farmers-eu-deforestation/
[320] WRI. (2025). *EUDR Compliance Is Feasible, Already Underway and Essential for Smallholder Inclusion*. World Resources Institute. Retrieved from https://www.wri.org/technical-perspectives/eu-deforestation-regulation-compliance-underway

Unlike policy-alignment metrics, which focus on adherence to regulations and legal frameworks, standard-alignment indicators measure conformity with voluntary frameworks, industry best practices, and globally recognized benchmarks, such as ISO certifications, GLOBALG.A.P., Rainforest Alliance, or Fairtrade standards (ISO, 2015[321]; GLOBALG.A.P., 2025[322]; Rainforest Alliance, 2025[323]; Fairtrade International, 2024[324]). These metrics are particularly relevant for financial institutions, investors, and supply chain actors, as alignment with recognized standards can mitigate reputational and operational risk, enhance market access, and improve resilience to environmental and social challenges (OECD–FAO, 2016/2022)[325].

Environmental standard-alignment metrics focus on the adoption of sustainable agricultural practices that are certified or benchmarked against recognized standards. Examples include the proportion of farmland managed under organic certification, the percentage of operations adhering to integrated pest management (IPM) guidelines, or compliance with soil and water conservation protocols specified by GLOBALG.A.P. (FAO, n.d.;[326] GLOBALG.A.P., 2022/2025)[327]. These metrics provide a quantifiable measure of farm sustainability and enable investors to evaluate the environmental credibility of agricultural production. By

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321 ISO (2015) ISO 14001:2015 – Environmental management systems. Geneva: International Organization for Standardization. Available at. https://www.iso.org/standard/60857.html?

322 GLOBALG.A.P. (2022–2025) Integrated Farm Assurance (IFA) v6 – Principles & Criteria, National Interpretation Guidelines, and solution add-ons (e.g., SPRING; Biodiversity). Cologne: FoodPLUS GmbH. Available at: https://documents.globalgap.org/documents/220929_IFA_Smart_PCs_FV_v6_0_Sep22_en.pdf?

323 Rainforest Alliance (2025) 2020 Sustainable Agriculture Standard – Farm & Supply Chain Requirements. New York/Amsterdam: Rainforest Alliance. Available at: https://www.rainforest-alliance.org/resource-item/2020-sustainable-agriculture-standard-farm-requirements/?

324 Fairtrade International (2024) Fairtrade Standard for Small-scale Producer Organizations (SPO). Bonn: Fairtrade International. Available at: https://www.fairtrade.net/content/dam/fairtrade/fairtrade-international/standards/small-scale-producer/SPO_EN.pdf?

325 OECD–FAO (2016/2022) Guidance for Responsible Agricultural Supply Chains and implementation materials. Paris/Rome: OECD and FAO. Available at: https://www.oecd.org/en/publications/oecd-fao-guidance-for-responsible-agricultural-supply-chains_9789264251052-en.html?

326 FAO (n.d.) Integrated Pest Management (IPM). Rome: Food and Agriculture Organization of the United Nations. Available at:https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/?

327 GLOBALG.A.P. (2022–2025) Integrated Farm Assurance (IFA) v6 – Principles & Criteria, National Interpretation Guidelines, and solution add-ons (e.g., SPRING; Biodiversity). Cologne: FoodPLUS GmbH. Available at: https://documents.globalgap.org/documents/220929_IFA_Smart_PCs_FV_v6_0_Sep22_en.pdf?

tracking compliance with standards, stakeholders can identify farms that reduce chemical inputs, enhance biodiversity, and optimize resource efficiency in line with best-practice guidelines (Rainforest Alliance, 2025[328]).

Economic standard-alignment metrics measure compliance with standards that influence market access, product quality, and value chain participation. These indicators include the share of crops certified under Fairtrade or Rainforest Alliance, adherence to supply chain traceability protocols, or the percentage of production meeting Good Agricultural Practices (GAP) standards (Fairtrade International, 2024[329]; Rainforest Alliance, 2025[330]; ISO, 2007[331]; ISO, 2020[332]; GLOBALG.A.P., 2025)[333]. By conforming to such standards, farmers not only secure access to premium markets but also demonstrate financial and operational reliability, reducing credit risk for banks and improving investment attractiveness. Moreover, alignment with economic standards often complements policy incentives, allowing farmers to access subsidies, preferential financing, and technical assistance.

Social standard-alignment metrics assess conformity with labor, health, and community-focused standards. Metrics in this category might capture the proportion of workers trained under safety and hygiene programs, adherence to fair labor practices, or engagement with programs promoting gender equality, youth inclusion,

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[328] Rainforest Alliance (2025) 2020 Sustainable Agriculture Standard – Farm & Supply Chain Requirements. New York/Amsterdam: Rainforest Alliance. Available at: https://www.rainforest-alliance.org/resource-item/2020-sustainable-agriculture-standard-farm-requirements/?

[329] Fairtrade International (2024) Fairtrade Standard for Small-scale Producer Organizations (SPO). Bonn: Fairtrade International. Available at: https://www.fairtrade.net/content/dam/fairtrade/fairtrade-international/standards/small-scale-producer/SPO_EN.pdf?

[330] Rainforest Alliance (2025) 2020 Sustainable Agriculture Standard – Farm & Supply Chain Requirements. New York/Amsterdam: Rainforest Alliance. Available at: https://www.rainforest-alliance.org/resource-item/2020-sustainable-agriculture-standard-farm-requirements/?

[331] ISO (2007) ISO 22005:2007 – Traceability in the feed and food chain. Geneva: International Organization for Standardization. Available at: https://www.iso.org/standard/36297.html?

[332] ISO (2020) ISO 22095:2020 – Chain of custody — General terminology and models (and subsequent amendment notes). Geneva: International Organization for Standardization. Available at: https://www.iso.org/standard/72532.html?

[333] GLOBALG.A.P. (2022–2025) Integrated Farm Assurance (IFA) v6 – Principles & Criteria, National Interpretation Guidelines, and solution add-ons (e.g., SPRING; Biodiversity). Cologne: FoodPLUS GmbH. Available at: https://documents.globalgap.org/documents/220929_IFA_Smart_PCs_FV_v6_0_Sep22_en.pdf?

and community development as required by specific certifications (ILO, 1998/2022[334]; Fairtrade International, 2020/2024)[335]. These indicators provide insight into how farms uphold human rights, social equity, and workforce well-being, which are increasingly critical for ESG-aligned investment and corporate responsibility reporting.

Standard-alignment metrics are also critical in establishing credibility and trust between producers, investors, and consumers. They provide a transparent framework for demonstrating compliance with internationally recognized practices, enabling comparability across farms, regions, and supply chains. Additionally, these metrics allow stakeholders to monitor the effectiveness of interventions, measure sustainability outcomes, and integrate performance data into ESG reporting frameworks and financial assessments.

However, measuring standard-alignment presents certain challenges. Variability among standards, differences in certification rigor, and evolving international requirements necessitate flexible yet rigorous indicators. Data collection and verification can be resource-intensive, requiring robust monitoring, auditing, and reporting mechanisms. Despite these challenges, incorporating standard-alignment metrics alongside backward-looking, forward-looking, exposure, and policy-alignment indicators provides a comprehensive KPI framework that captures performance, resilience, compliance, and credibility in agricultural operations (GRI, 2021[336]; IFRS/ISSB, 2023–2024;[337] European Commission/CSRD, 2022–2025[338]).

In conclusion, standard-alignment metrics serve as a key dimension of KPIs for primary farming, allowing stakeholders to evaluate how agricultural operations adhere to globally recognized best practices. They not

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[334] ILO (1998/2022) ILO Declaration on Fundamental Principles and Rights at Work (as amended in 2022). Geneva: International Labour Organization. Available at: https://www.ilo.org/sites/default/files/2024-04/ILO_1998_Declaration_EN.pdf?

[335] Fairtrade International (2024) Fairtrade Standard for Small-scale Producer Organizations (SPO). Bonn: Fairtrade International. Available at: https://www.fairtrade.net/content/dam/fairtrade/fairtrade-international/standards/small-scale-producer/SPO_EN.pdf?

[336] GRI (2021) GRI Universal Standards 2021 (GRI 1, GRI 2, GRI 3) and related resources. Amsterdam: Global Reporting Initiative. Available at: https://www.globalreporting.org/media/wtaf14tw/a-short-introduction-to-the-gri-standards.pdf?

[337] IFRS Foundation/ISSB (2023–2025) IFRS S1 General Requirements for Sustainability-related Financial Disclosuresand IFRS S2 Climate-related Disclosures, with implementation materials. London: IFRS Foundation. Available at: https://www.ifrs.org/news-and-events/news/2023/06/issb-issues-ifrs-s1-ifrs-s2/?

[338] European Commission (2022–2025) Corporate Sustainability Reporting Directive (CSRD) and related guidance/updates. Brussels: European Commission. (Directive (EU) 2022/2464; updates 2024–2025). Available at: https://eur-lex.europa.eu/eli/dir/2022/2464/oj/eng?

only ensure operational credibility and market competitiveness but also support sustainable, socially responsible, and resilient farming systems, which are critical for achieving long-term environmental, economic, and social objectives.

3.1.4 Overview of Indicators for Primary Farming

The development of specific indicators for primary farming represents a critical step in assessing, managing, and financing sustainable agricultural practices. By encompassing multiple dimensions—backward-looking, point-in-time, forward-looking, exposure, policy-alignment, standard-alignment, and issues-specific (climate & environment and just transition)—these KPIs offer a comprehensive framework to capture the environmental, social, and economic performance of farming operations.

Backward-looking metrics provide a retrospective view, enabling the evaluation of historical performance in areas such as production efficiency, resource use, and emissions trends. Point-in-time indicators allow for the monitoring of current operational status, facilitating immediate risk assessment and portfolio management. Forward-looking metrics, in contrast, focus on the anticipated impacts of planned or ongoing interventions, helping financial institutions and policymakers anticipate future risks and benefits. Exposure metrics quantify the vulnerability of farming operations to climate, market, or regulatory shocks, highlighting areas where risk mitigation and adaptation measures are most needed. Policy-alignment and standard-alignment KPIs evaluate the compliance of farms with international standards, national policies, and best-practice frameworks, ensuring that agricultural practices adhere to broader sustainability objectives. Finally, issue-specific metrics address the substantive challenges of climate change, environmental degradation, and social equity, embedding principles of climate-smart agriculture and just transition into operational evaluation.

Together, these indicators form an integrated toolkit that enables holistic performance assessment. They allow banks, investors, and policymakers to identify sustainable and resilient farming practices, allocate resources efficiently, and align financial decision-making with ESG commitments. At the farm level, these KPIs support targeted improvements, incentivize adoption of climate-friendly and socially inclusive practices, and facilitate transparent reporting to stakeholders.

However, implementing this comprehensive set of indicators also entails challenges, including data availability, monitoring complexity, and context-specific adaptation. Despite these obstacles, the combined use of multidimensional KPIs ensures that primary farming can be assessed not only on productivity and profitability but also on sustainability, resilience, and social inclusivity. This multidimensional approach is essential for supporting the transition toward environmentally responsible and socially equitable agricultural systems, guiding both practice and investment toward long-term resilience and sustainable development.

CHAPTER 4 – GAP ANALYSIS AND COMPARISON OF BANKING FRAMEWORKS

4.1. Comparison of Banking Strategies and Agricultural Sector Needs

4.1.1 Analysis of Current Banking Frameworks and Policies

Over the past decade, the global financial system has been reshaped by the rapid consolidation of climate- and sustainability-related frameworks. Banks have shifted from being treated as neutral financial intermediaries to being recognised as transition enablers, responsible for directing capital flows in ways that are consistent with net-zero targets, biodiversity protection, and resilience-building. Within this broader realignment, agriculture is emerging as one of the most challenging sectors. The sector is indispensable for food security and rural livelihoods but also contributes disproportionately to climate change through methane, nitrous oxide, and land-use emissions, while simultaneously driving deforestation, soil degradation, and biodiversity loss (FAO, 2021[339]; IPCC, 2019)[340]. These dual characteristics make agriculture a litmus test for whether financial institutions can align profitability, regulatory compliance, and environmental stewardship in practice.

4.1.1.1 Transition alliances and science-based frameworks

A first layer of governance derives from voluntary alliances and science-based initiatives designed to guide financial institutions in aligning their portfolios with net-zero targets. The Net-Zero Banking Alliance (NZBA), launched under the umbrella of the Glasgow Financial Alliance for Net Zero (GFANZ), has

[339] Food and Agriculture Organization of the United Nations (FAO). (2021). *The State of Food and Agriculture 2021: Making Agrifood Systems More Resilient to Shocks and Stresses*. Rome: FAO. https://www.fao.org/publications/sofa/2021/en/

[340] Intergovernmental Panel on Climate Change (IPCC). (2019). *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Geneva: IPCC. https://www.ipcc.ch/srccl/

committed members to achieving portfolio alignment with net-zero emissions by 2050, including the adoption of interim targets for 2030. While NZBA initially attracted wide membership, its credibility has recently been tested. In 2024 and 2025, major banks such as UBS, Barclays, and HSBC announced or initiated their exit from the alliance, citing regulatory complexity, reputational pressures, and concerns about potential antitrust conflicts (Reuters, 2025[341]). These departures highlight both the fragility of voluntary coalitions and the difficulty of maintaining sectoral consistency when net-zero strategies collide with profitability concerns. Agriculture has been particularly affected by this uncertainty: while NZBA provides a broad commitment, few banks have developed agricultural decarbonisation roadmaps with clear implementation milestones.

Complementing NZBA, the Science-Based Targets initiative (SBTi) has developed its Forest, Land and Agriculture (FLAG) guidance, published in 2022, which obliges institutions to cover land-based emissions explicitly when setting science-based targets. FLAG is particularly significant for agriculture, as it addresses biogenic emissions, soil carbon, and land-use change—elements often excluded from traditional carbon accounting frameworks. Despite its importance, uptake in banking has been limited, with many institutions citing data scarcity and methodological uncertainty as barriers to integration. As of 2025, only a handful of financial institutions globally have published FLAG-aligned targets, reflecting the challenge of applying science-based approaches in a sector with fragmented monitoring, reporting, and verification (MRV) capacity (SBTi, 2022;[342] UNEP FI, 2024)[343].

The Partnership for Carbon Accounting Financials (PCAF) provides an additional methodology, offering a harmonised approach to calculating financed emissions across asset classes, including agriculture, forestry, and land use. By mid-2025, PCAF had grown to include over 600 signatories, highlighting its role as the de facto standard for financed-emissions disclosure (PCAF, 2025)[344]. Yet the reliance of PCAF on granular activity-level data has proven especially problematic in agriculture, where farm-level emissions monitoring

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341 Reuters. (2025, January). *BMO becomes first Canadian bank to withdraw from Net-Zero Banking Alliance*. Retrieved from https://www.reuters.com/business/finance/bmo-becomes-first-canadian-bank-withdraw-net-zero-banking-alliance-2025-01-17/

342 Science Based Targets initiative (SBTi). (2022). *Forest, Land and Agriculture (FLAG) Science-Based Target-Setting Guidance*. London: SBTi. https://sciencebasedtargets.org/sectors/forest-land-and-agriculture

343 UNEP FI. (2024). *Driving Finance for Sustainable Food Systems: A Framework for Action*. Geneva: United Nations Environment Programme Finance Initiative. Available at: https://www.unepfi.org/publications/driving-finance-for-sustainable-food-systems

344 PCAF. (2025). *PCAF Disclosure Checklist for Part A – Financed Emissions*.
Available at: https://carbonaccountingfinancials.com/files/disclosure_checklist/PCAF-Disclosure-Checklist-Part-A-Financed-Emissions-May-2025.pdf

remains expensive and inconsistent across geographies. As a result, banks often resort to using default emission factors or sector averages, which dilute accuracy and comparability. This gap reduces the credibility of financed-emissions reporting for agriculture and underscores the importance of moving beyond portfolio averages toward farm- and value-chain-specific KPIs.

4.1.1.2 Disclosure and supervisory standards

Alongside alliances, disclosure frameworks have become a critical driver of financial sector governance. The International Sustainability Standards Board (ISSB) has developed a global baseline for sustainability-related disclosure, most notably through IFRS S1 and IFRS S2 standards. These standards have been widely adopted as a reference point for investors and regulators, but debates continue about their scope. In early 2025, the ISSB announced potential revisions to streamline Scope 3 requirements for financial institutions, reflecting recognition of the methodological challenges in capturing indirect and financed emissions, particularly in complex land-based sectors (ICAEW, 2025)[345].

The European Union's Corporate Sustainability Reporting Directive (CSRD) has gone further by embedding the principle of double materiality: banks are obliged to disclose not only how sustainability issues affect them, but also how their financing affects climate, biodiversity, and communities (European Commission, 2022[346]). For agricultural portfolios, this means banks are expected to disclose dependencies on soil health, water resources, and biodiversity, as well as exposure to deforestation risks. While pioneering in scope, CSRD poses practical difficulties: many institutions lack the systems to measure these dependencies at the loan level, leading to disclosures that aggregate agricultural exposures into broad categories such as "agribusiness" or "food and beverage." Such aggregation masks material differences between subsectors—dairy, irrigated rice, export horticulture, or bioenergy projects—each of which presents distinct risk and mitigation pathways.

Supervisory authorities have reinforced these expectations. The European Banking Authority (EBA), through its Guidelines on ESG risks, requires integration of environmental and social factors into banks' Internal Capital Adequacy Assessment Process (ICAAP), governance structures, and risk management

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345 ICAEW. (2025). *ISSB proposal to reduce Scope 3 reporting requirements*. Institute of Chartered Accountants in England and Wales. Available at: https://www.icaew.com/insights/viewpoints-on-the-news/2025/may-2025/issb-proposal-to-reduce-scope-3-reporting-requirements

346 European Commission. (2022). *Corporate Sustainability Reporting Directive (CSRD)*. Brussels: European Commission. https://finance.ec.europa.eu/regulation-and-supervision/company-reporting/corporate-sustainability-reporting_en

systems (EBA, 2025[347]). The European Central Bank (ECB) has similarly intensified its scrutiny, warning in its 2024 climate risk assessment that many banks still lack adequate methodologies to translate transition risks into capital planning (ECB, 2024[348]). Agriculture remains a particular blind spot: while banks may disclose financed emissions at a high level, few are able to demonstrate how climate and nature-related risks in their agricultural exposures are systematically integrated into stress testing or capital adequacy frameworks.

4.1.1.3 European policy architecture and trade regulations

In the European Union, agriculture is governed by one of the most comprehensive policy architectures linking farming to environmental outcomes. The European Green Deal sets the overarching goal of climate neutrality by 2050, while the Farm to Fork Strategy outlines specific objectives for reducing fertiliser and pesticide use, promoting organic farming, and increasing biodiversity protection (European Commission, 2020)[349]. These objectives are operationalised through the reformed Common Agricultural Policy (CAP), which for the 2023–2027 period has embedded environmental conditionality and eco-schemes as central mechanisms. This shift ties farmers' income support directly to environmental performance, altering not only their production choices but also the creditworthiness signals perceived by financial institutions (European Commission, 2021[350]).

The EU Deforestation Regulation (EUDR), effective from December 2024, further raises the stakes by obliging companies placing certain commodities—soy, beef, cocoa, coffee, palm oil, and rubber—on the EU market to prove that they are deforestation-free, based on geolocation-anchored traceability. For financial institutions, this regulation creates new compliance and reputational risks: financing clients without robust traceability systems could expose banks to accusations of financing deforestation, even if indirectly. As of

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European Banking Authority (EBA). (2025). *Final report on guidelines on the management of ESG risks*. European Banking Authority. Retrieved from https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

[348] ECB. (2024). The ECB's climate and nature plan 2024-2025. Retrieved from https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202402_08~ce78a64ada.en.html

[349] European Commission. (2020). *A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System*. Brussels: European Commission. https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

[350] European Commission. (2021). *The New Common Agricultural Policy: 2023–2027*. Brussels: European Commission. https://agriculture.ec.europa.eu/cap-overview/cap-2023-27_en

early 2025, several industry associations have warned that smallholder farmers in the Global South may face exclusion from EU markets due to the cost and complexity of compliance, raising equity concerns that are also material to banks' social risk assessments (Gupta et al., 2024[351]).

The regulatory momentum has also been reinforced by broader decarbonisation policies. In June 2025, the European Commission and the European Investment Bank (EIB) announced expanded financing under the Clean Industrial Deal, designed to support investments in low-carbon technologies, including those in agri-food supply chains (European Commission & EIB, 2025)[352]. This places additional expectations on banks to align their agricultural portfolios not only with climate mitigation but also with the EU's industrial competitiveness agenda, highlighting the strategic interlinkages between agricultural finance, trade, and industrial decarbonisation.

4.1.1.4 Practice to date: ambition without translation

Despite the density of frameworks, disclosures, and regulations, banks' agricultural practices remain partial and inconsistent. Major institutions such as Rabobank, BNP Paribas, and HSBC publicly disclose net-zero targets, report financed emissions and adopt sectoral exclusion policies for high-deforestation commodities. However, their agricultural lending strategies are often embedded within general ESG frameworks rather than tailored to the sector's unique characteristics. Few institutions systematically disaggregate methane and nitrous oxide from overall emissions disclosures, even though these gases dominate agricultural footprints. Soil carbon and water-use efficiency, central to both productivity and resilience, are rarely integrated into loan covenants or pricing models. Biodiversity remains largely invisible, despite its prominence in EU policy frameworks.

This reflects a deeper structural challenge: frameworks are prescriptive about *what* must be achieved (net-zero alignment, deforestation-free supply chains, double materiality disclosure), but they are vague on *how* these goals should be operationalised at the level of loan design, collateralisation, and risk modelling. As a result, banks often default to ESG overlays and exclusion lists rather than embedding sector-specific KPIs

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[351] Gupta, J., et al. (2024). *A just world on a safe planet: A Lancet Planetary Health–Earth Commission report on Earth-system boundaries, translations, and transformations*. Lancet Planetary Health. Retrieved from https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(24)00042-1/fulltext

[352] European Commission & EIB. (2025). *European Commission and EIB renew support for decarbonisation projects under the Innovation Fund*. Press release. Retrieved from https://www.eib.org/en/press/all/2025-227-european-commission-and-eib-to-further-support-decarbonisation-projects-from-the-innovation-fund

into agricultural products. This creates a credibility gap: banks appear aligned at the level of global commitments but fail to deliver alignment at the level of client relationships and transaction structures.

It is precisely in this space—between ambitious frameworks and weak operationalisation—that structural discrepancies arise. These discrepancies, examined in detail in the next section include mismatched repayment structures, exclusionary collateral frameworks, backward-looking underwriting models, and prohibitive MRV systems. Unless these are addressed, agricultural finance will remain simultaneously under-inclusive for farmers and under-credible for supervisors, leaving banks exposed to both transition and physical risks without adequate tools for management.

4.1.2 Discrepancies between Financial Approaches and Agricultural Needs

The misalignments identified in the previous section reveal a broader structural problem: financial products are frequently conceived for industrial or urban enterprises and then applied to agriculture with minimal adaptation. This reflects a legacy of financial intermediation that emphasises uniformity, efficiency, and replicability across sectors. While such designs may be effective for businesses with continuous revenues, enforceable collateral, and standardised risk profiles, they are fundamentally ill-suited for farming systems shaped by biological cycles, climatic volatility, and fragmented data. The result is a set of persistent discrepancies that simultaneously restrict farmers' access to credit and undermine the credibility of banks' transition strategies (UNEP FI, 2024a[353]; ECB, 2024)[354].

4.1.2.1 Temporal misalignment of credit structures

The temporal mismatch between financial products and agricultural cashflows remains the most visible discrepancy. Standard loan products, built around monthly or quarterly amortisation schedules, reflect the revenue structures of salaried households or service-sector SMEs. Agriculture, however, generates seasonal or multi-annual income streams. Annual crops such as wheat, rice, or vegetables provide cash inflows only

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[353] UNEP Finance Initiative (UNEP FI). (2024a). *Driving finance for sustainable food systems: Key recommendations for banks and investors*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

[354] European Central Bank (ECB). (2024, January 30). *The ECB's climate and nature plan 2024-2025*. European Central Bank. Retrieved from https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202402_08~ce78a64ada.en.html

at harvest, while long-term investments in agroforestry, soil regeneration, or manure-to-energy infrastructure may require several years before returns materialise (UNEP FI, 2024b)[355].

When such biological rhythms are disregarded, liquidity stress becomes inevitable. Farmers are often forced to service debt during “lean months” when no revenue is available, resulting in arrears spikes just before harvest. In many cases, these arrears are misclassified as borrower-level credit risk rather than as the predictable result of product misfit. This misdiagnosis inflates default rates and deters further agricultural lending. It also discourages long-horizon investments central to the sustainability transition, such as carbon sequestration projects or biogas digesters. Recent supervisory reviews confirm that product-tenor misalignment continues to be one of the most underexplored vulnerabilities in banks’ agricultural portfolios (ECB, 2024)[356].

4.1.2.2 Collateral frameworks and exclusionary effects

Collateralisation practices exacerbate exclusion in agricultural lending. Conventional banking systems privilege liquid, formally titled assets such as urban real estate or marketable securities. Farmers, by contrast, typically hold biological assets (livestock, crops), movable assets (equipment), or communal tenure rights, which are either heavily discounted or excluded entirely (Deininger et al., 2017)[357].

This structural bias favours large, capital-rich agribusinesses while excluding smallholders and agri-SMEs, who constitute the majority of producers globally. As UNEP FI emphasises in its *Driving Finance for Sustainable Food Systems framework*, financial exclusion of smallholders undermines the just transition and intensifies inequality, since it denies credit precisely to those most exposed to climate risks and least able to bear compliance costs (UNEP FI, 2024a)[358]. Although alternative mechanisms exist—such as warehouse receipts, crop liens, and insurance-backed guarantees—their uptake in mainstream banking remains limited

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[355] UNEP Finance Initiative (UNEP FI). (2024b). *Principles for responsible banking: Guidance on food systems and agriculture*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

[356] European Central Bank (ECB). (2024, January 30). *The ECB’s climate and nature plan 2024-2025*. European Central Bank. Retrieved from https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202402_08~ce78a64ada.en.html

[357] Deininger, K., Selod, H., & Burns, A. (2017). *The land governance assessment framework: Identifying and monitoring good practice in the land sector*. World Bank.

[358] UNEP Finance Initiative (UNEP FI). (2024a). *Driving finance for sustainable food systems: Key recommendations for banks and investors*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

due to weak legal frameworks and high transaction costs. Without reforms to collateral practices, banks risk reinforcing systemic inequities that contradict both EU transition policies and international sustainability commitments.

4.1.2.3 Underwriting practices and risk mispricing

A further discrepancy stems from underwriting models that rely heavily on backward-looking financial statements—audited accounts, tax filings, or repayment histories. While useful in conventional credit analysis, these documents offer little predictive power in agricultural contexts, where repayment capacity is shaped by soil fertility, water availability, climate exposure, and practice adoption (OECD, 2021).[359]

This creates two distortions. First, viable farmers are excluded because they cannot produce audited financials or because their revenues are seasonal and informal. Second, credit may be extended to seemingly solid borrowers whose farming practices—such as residue burning or over-irrigation—expose them to high transition and physical risks. This paradox, where resilient farmers are excluded while risky practices are financed, reflects the absence of agronomic indicators in risk assessments.

Incorporating sector-specific KPIs into underwriting could correct these distortions. Indicators such as soil organic carbon trends, irrigation efficiency, feed conversion ratios, or manure-storage practices can reveal resilience that financial statements cannot. However, empirical assessments of leading banks, including Rabobank, BNP Paribas, and HSBC, show that such integration remains rare: their agricultural portfolios are still assessed through generic ESG overlays rather than context-specific agronomic metrics (BankTrack, 2022;[360] UNEP FI, 2024b)[361].

4.1.2.4 Monitoring and verification (MRV) constraints

Even when banks commit to sustainability-linked targets—such as methane reductions or deforestation-free supply chains—implementation is constrained by costly and fragmented MRV systems. Industrial clients often provide audited accounts or certified sustainability reports. In agriculture, especially among

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[359] OECD. (2021). *Improving agricultural finance to foster inclusive and sustainable food systems*. Organisation for Economic Co-operation and Development.

[360] BankTrack. (2022). *Banking on climate chaos: Fossil fuel finance report 2022*. BankTrack. Retrieved from https://www.banktrack.org

[361] UNEP Finance Initiative (UNEP FI). (2024b). *Principles for responsible banking: Guidance on food systems and agriculture*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

smallholders, such systems are absent. Collecting and verifying practice-level data is expensive and often exceeds feasible margins for small-ticket loans (UNEP FI, 2024a)[362].

The consequence is that banks shy away from embedding sustainability-linked covenants into agricultural products. Portfolio-level pledges may exist, but the absence of verifiable data prevents their enforcement. Farmers who adopt climate-smart practices, such as alternate wetting and drying (AWD) in rice or covered manure storage in dairy, often go unrecognised. Conversely, banks cannot demonstrate to regulators that financed emissions are falling as a result of genuine improvements. This gap has been flagged by PCAF (2025), which underscores that while agricultural financed-emissions disclosure is expanding, data reliability and verification remain critical bottlenecks. Without proportionate MRV solutions—such as remote sensing, shared registries, and digital agronomy platforms—sustainability-linked lending in agriculture risks stagnating.

4.1.2.5 The double failure of misalignment

Taken together, these discrepancies create a dual failure. From the perspective of farmers, credit products remain mismatched with biological cycles, collateral requirements systematically exclude smallholders, underwriting ignores agronomic resilience, and MRV burdens are prohibitive. From the perspective of banks, disclosures remain overly generic, risk models incomplete, and supervisory expectations unmet. Agriculture thus appears simultaneously under-financed and over-risked, reinforcing cycles of exclusion, vulnerability, and reputational exposure.

The ECB's 2024 *Climate and Nature Plan* notes that without significant improvement in data, methodologies, and sectoral tailoring, banks' agricultural portfolios will remain vulnerable to both transition and physical risks (ECB, 2024[363]). Similarly, UNEP FI (2024a) stresses that exclusionary finance and weak monitoring systems undermine the credibility of sustainability-linked banking strategies in food systems.

4.1.2.6 From discrepancy to solution: the role of KPIs

Addressing these failures requires a structural reorientation of financial approaches. Loan products must align with seasonal and biological cashflows, collateral frameworks must recognise value-chain and

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[362] UNEP Finance Initiative (UNEP FI). (2024a). *Driving finance for sustainable food systems: Key recommendations for banks and investors*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

[363] European Central Bank (ECB). (2024, January 30). *The ECB's climate and nature plan 2024-2025*. European Central Bank. Retrieved from https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202402_08~ce78a64ada.en.html

insurance-backed instruments, underwriting must integrate agronomic variables, and MRV must become proportionate and technology-enabled.

Here, key performance indicators (KPIs) provide a bridge between frameworks and practice. Properly designed, KPIs can transform high-level commitments into operational tools that are measurable, auditable, and enforceable within credit agreements. By linking repayment terms, covenants, and pricing to verifiable indicators of practice change, KPIs enable banks to simultaneously enhance farmer access and meet supervisory expectations. This transition—moving from ESG pledges to KPI-anchored loan structures—marks the critical step in making agricultural transition finance both credible and bankable (UNEP FI, 2024b[364]; PCAF, 2025)[365].

The next subsection develops this argument further, demonstrating how KPIs can be mobilised across three functions: assessing institutional performance, identifying risk drivers, and strengthening risk assessment and strategy. In doing so, it positions KPIs not as peripheral reporting instruments but as the informational backbone of a credible and inclusive agricultural transition.

4.1.3 Relevance of KPIs for Institutional Performance and Risk Assessment

The discrepancies outlined in the previous section highlight the limitations of applying conventional financial logics to agriculture. Credit structures designed for industrial firms fail to capture the biological rhythms of farming, collateral frameworks exclude the most relevant assets, underwriting models ignore agronomic drivers, and monitoring systems remain too costly or fragmented to verify practice change. In this context, key performance indicators (KPIs) emerge not as optional reporting tools but as the backbone of a new informational and governance architecture. Properly designed, KPIs offer a way to connect farm-level practices with portfolio-level oversight, aligning agricultural finance simultaneously with environmental objectives, prudential requirements, and the lived realities of farmers. Their relevance spans three interrelated functions: assessing institutional performance, identifying risk drivers, and strengthening risk assessment and strategy.

[364] UNEP Finance Initiative (UNEP FI). (2024b). *Principles for responsible banking: Guidance on food systems and agriculture*. United Nations Environment Programme Finance Initiative. Retrieved from https://www.unepfi.org

[365] Partnership for Carbon Accounting Financials (PCAF). (2025). *PCAF Agriculture, Forestry and Land Use (AFOLU) Guidance*. PCAF. Retrieved from https://carbonaccountingfinancials.com/

4.1.3.1 Assessing institutional performance

At the institutional level, KPIs provide banks with a concrete means of assessing whether their agricultural portfolios are genuinely aligned with climate and sustainability goals. Aggregate financed-emissions data—central to frameworks such as the Net-Zero Banking Alliance (NZBA) and the Partnership for Carbon Accounting Financials (PCAF)—mask the distinction between divestment-driven reductions and genuine practice change. A bank may reduce its livestock exposure to lower reported emissions, yet this strategy contributes little to the decarbonisation of the food system as a whole. By contrast, KPIs such as methane intensity per litre of milk, nitrous oxide emissions per tonne of fertiliser applied, or hectares under regenerative practices directly measure the effectiveness of financed transition strategies (SBTi, 2022[366]; PCAF, 2025[367]).

Embedding such indicators strengthens disclosures under the International Sustainability Standards Board (ISSB) and the EU's Corporate Sustainability Reporting Directive (CSRD), both of which require decision-useful information that links corporate strategy to measurable outcomes (ISSB, 2023[368]; European Commission, 2024[369]). Supervisors such as the European Central Bank (ECB) and the European Banking Authority (EBA) are increasingly attentive to whether banks can provide verifiable evidence of progress, not merely policy statements (ECB, 2024[370]; EBA, 2025[371]). By shifting from output-based metrics to outcome-based KPIs, banks demonstrate not only intent but measurable impact.

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366 Science Based Targets initiative (SBTi). (2022). *Forest, Land and Agriculture (FLAG) Sector Guidance*. Science Based Targets initiative. Retrieved from https://sciencebasedtargets.org/sectors/forest-land-and-agriculture

367 Partnership for Carbon Accounting Financials (PCAF). (2025). *Agriculture, Forestry and Other Land Use (AFOLU) Guidance*. PCAF. Retrieved from https://carbonaccountingfinancials.com

368 International Sustainability Standards Board (ISSB). (2023). *IFRS S1: General requirements for disclosure of sustainability-related financial information; IFRS S2: Climate-related disclosures*. IFRS Foundation. Retrieved from https://www.ifrs.org/issued-standards/issb-standard

369 European Commission. (2024). *Corporate Sustainability Reporting Directive (CSRD)*. European Commission. Retrieved from https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

370 European Central Bank (ECB). (2024, January 30). *The ECB's climate and nature plan 2024–2025*. European Central Bank. Retrieved from https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202402_08~ce78a64ada.en.html

371 European Banking Authority (EBA). (2025). *Final report on guidelines on the management of ESG risks*. EBA. Retrieved from https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

4.1.3.2 Identifying risk drivers

Beyond performance measurement, KPIs sharpen banks' ability to identify and differentiate risk drivers specific to agricultural lending. Conventional credit risk models, heavily reliant on historical financial statements, are poorly suited to sectors defined by climatic variability, soil fertility, and biological inputs (OECD, 2021[372]). By incorporating agronomic and operational KPIs into underwriting and monitoring, banks can move from blunt proxies to more granular diagnostics.

Soil organic carbon trends indicate the fertility and water-retention capacity of cropping systems, serving as a predictor of long-term yield stability. Irrigation efficiency provides early warnings of drought vulnerability, while digester uptime and feed-conversion efficiency in livestock systems are leading indicators of revenue continuity and emissions mitigation. In horticultural exports, cold-chain reliability and spoilage rates reflect both financial and environmental risks, linking energy use to product losses.

Equally important are social KPIs. Payment timeliness to smallholders, the presence of grievance mechanisms, or the representation of women and youth in producer organisations capture dimensions of social licence and inclusivity (OECD & FAO, 2021[373]; UNEP FI, 2024a[374]). These factors, often invisible in conventional financial analysis, can have material impacts: payment delays or weak grievance channels can trigger supply-chain disruption, reputational damage, or even default. By illuminating these drivers, KPIs allow banks to separate structural risks from informational gaps, enabling more accurate pricing of credit and more targeted support for borrowers.

4.1.3.3 Strengthening risk assessment and strategy

The third function of KPIs lies in their ability to strengthen risk assessment and strategy across the credit lifecycle. When embedded into loan covenants, KPIs convert sustainability targets from aspirational pledges into enforceable conditions. A dairy loan, for example, can integrate covenants on methane intensity and manure management, with pricing step-downs activated once third-party verification confirms compliance. Similarly, rice loans can align harvest-bulleted repayments with water-use efficiency and AWD adoption,

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[372] OECD. (2021). *Improving agricultural finance to foster inclusive and sustainable food systems*. Organisation for Economic Co-operation and Development.

[373] OECD & Food and Agriculture Organization of the United Nations (FAO). (2021). *OECD-FAO Agricultural Outlook 2021–2030*. OECD Publishing. https://doi.org/10.1787/19428846-en

[374] United Nations Environment Programme Finance Initiative (UNEP FI). (2024a). *Driving finance for sustainable food systems: Key recommendations for banks and investors*. UNEP FI. Retrieved from https://www.unepfi.org

monitored through satellite imagery (IRRI, 2017[375]; UNEP FI, 2024b[376]). These mechanisms incentivise the adoption of climate-smart practices while reducing the probability of default by synchronising repayment with biological performance.

At the portfolio level, aggregating KPI trajectories enables banks to model correlated risks with greater accuracy. For example, drought-induced declines in soil carbon, pest outbreaks in rainfed staples, or compliance failures under the EU Deforestation Regulation (EUDR) can all be incorporated into stress-testing scenarios (European Commission, 2023)[377]. This aligns directly with the prudential expectations of CRR III, CRD VI, and the EBA Guidelines on ESG risks, which require forward-looking integration of environmental and social factors into risk management (EBA, 2024; ECB, 2025[378]). Moreover, KPIs can feed into standard credit risk parameters—probability of default (PD), loss given default (LGD), and exposure at default (EAD)—by linking practice adoption and environmental performance with resilience outcomes.

4.1.3.4 KPIs as a bridge between climate alignment and commercial viability

Ultimately, the strategic value of KPIs lies in their ability to bridge climate alignment with commercial viability. Indicators that are measurable, auditable, and socially legitimate reduce uncertainty for banks while rewarding farmers with improved access to finance and lower borrowing costs. Verified methane reductions, soil carbon gains, or traceability to deforestation-free plots not only improve environmental outcomes but also enhance portfolio resilience and justify favourable pricing (ICAEW, 2025).[379]

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[375] International Rice Research Institute (IRRI). (2017). *Alternate wetting and drying (AWD): A water-saving technology for irrigated rice*. IRRI Technical Bulletin. Retrieved from https://www.irri.org/resources/publications

[376] United Nations Environment Programme Finance Initiative (UNEP FI). (2024b). *Principles for Responsible Banking: Guidance on food systems and agriculture*. UNEP FI. Retrieved from https://www.unepfi.org

[377] European Commission. (2023). *Regulation (EU) 2023/1115 on the making available on the Union market as well as the export from the Union of certain commodities and products associated with deforestation and forest degradation (EU Deforestation Regulation)*. Official Journal of the European Union. Retrieved from https://eur-lex.europa.eu/eli/reg/2023/1115/oj

[378] European Banking Authority (EBA). (2025, January 17). *Final report on guidelines on the management of ESG risks*. EBA. Retrieved from https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

[379] ICAEW. (2025). *ISSB proposal to reduce Scope 3 reporting requirements*. Institute of Chartered Accountants in England and Wales. Retrieved from https://www.icaew.com/insights/viewpoints-on-the-news/2025/may-2025/issb-proposal-to-reduce-scope-3-reporting-requirements

This dynamic converts sustainability from a compliance burden into a competitive advantage. Banks that credibly demonstrate measurable impact through KPIs strengthen their reputation with supervisors, investors, and clients. They also position themselves to access new markets for sustainability-linked finance, from green bonds to blended-finance vehicles (European Commission & EIB, 2025[380]). For agriculture, embedding KPIs into loan terms enables scalable adoption of sustainable practices while ensuring that banks can demonstrate measurable impact to regulators and markets alike.

In conclusion, KPIs are not peripheral to agricultural transition finance; they form its informational backbone. By enabling banks to assess institutional performance, identify risk drivers, and operationalise strategies across the credit lifecycle, KPIs connect high-level frameworks with farm-level realities. Their systematic integration offers a credible pathway for financial institutions to reduce risk, expand inclusion, and support the broader objectives of decarbonisation and resilience.

4.2. How to Improve Bank Strategies for the Sector

The analysis in the previous section demonstrated that the disjuncture between banking frameworks and agricultural sector realities is not incidental but structural. The persistent misalignment of loan tenors with biological production cycles, the inadequacy of collateral regimes for asset-light farming systems, the reliance on retrospective financial data over forward-looking agronomic performance, the high transaction costs of fragmented MRV systems, and the insufficient embedding of social safeguards all contribute to chronic under-financing of agriculture. These gaps are compounded by the sector's exposure to climate risk and its centrality to food security, making the status quo both financially unsustainable and socially untenable.

Addressing these deficiencies requires more than incremental product tweaks; it calls for a fundamental re-engineering of banking strategies. The stakes have only become clearer in light of recent evidence. The ECB's 2025 Climate Stress Test confirmed that agriculture constitutes one of the most significant sources of correlated risk in bank portfolios, while the OECD's 2025 Agricultural Outlook underscored that productivity gains cannot be achieved without substantial investment in climate-resilient practices. Similarly, the EU's Vision for Agriculture and Food (2025) has institutionalized just transition principles—fair incomes, gender equality, and generational renewal—as non-negotiable benchmarks for agricultural

[380] European Commission & European Investment Bank (EIB). (2025, June 3). *European Commission and EIB renew support for decarbonisation projects under the Innovation Fund*. EIB Press Release. Retrieved from https://www.eib.org/en/press/all/2025-227-european-commission-and-eib-to-further-support-decarbonisation-projects-from-the-innovation-fund

development. Meanwhile, the 2025 NZBA governance reforms highlight that banks must embed credible, sector-specific KPIs into their agricultural portfolios if they are to meet net-zero commitments.

Building on the diagnostic framework established in Section 4.1, the challenge now is to translate those identified gaps into actionable solutions. This involves redesigning loan products so that they align with seasonal and multi-year cashflows; embedding value-chain–based collateral mechanisms that reflect the realities of agricultural assets; integrating forward-looking agronomic KPIs into underwriting models and loan covenants; scaling cost-effective MRV systems through shared digital platforms; and layering risk-transfer instruments to buffer systemic shocks. Equally critical is the institutionalization of social safeguards within financial contracts to ensure that climate-aligned finance enhances rather than erodes rural livelihoods.

This section therefore advances a set of strategic improvements to banking practice, drawing on the global frameworks introduced earlier (NZBA, SBTi-FLAG, ISSB, EU Taxonomy, and PCAF) and tested against the sectoral archetypes mapped in Section 4.1. The focus is on implementation: how products, risk models, governance structures, and disclosure mechanisms can be recalibrated so that agricultural finance is simultaneously bankable, climate-aligned, and socially legitimate. In essence, if Section 4.1 identified where and why misalignments persist, Section 4.2 seeks to demonstrate how they can be overcome—moving from diagnosis to design, and from structural critique to operational strategy.

4.2.1 Design principles and empirical guardrails

Redesigning agricultural finance requires not only innovative instruments but also a clear set of design principles and empirical guardrails to ensure that new products and processes are both scalable and resilient. Without such principles, innovation risks devolving into ad hoc pilots that fail to integrate into core banking operations. The experience of the past decade shows that agricultural finance initiatives often collapse when they are misaligned with farm realities, lack verifiable performance metrics, or cannot withstand correlated climate shocks. The goal, therefore, is to establish a framework of design rules grounded in empirical evidence and consistent with the supervisory environment of 2024–2025.

Principle 1: Synchronise finance with biological and climatic cycles

The first principle is to design financial products around the temporal structure of agricultural production. Empirical evidence demonstrates that repayment stress often stems from the misfit between monthly amortisation schedules and seasonal or multi-year cashflows. Recent diagnostics confirmed that misaligned tenors were responsible for up to 30% of arrears spikes in smallholder portfolios (World Bank, 2024)[381]. Supervisory stress-testing further demonstrated that credit portfolios with seasonally aligned repayment structures exhibited lower probability of default under both drought and flood scenarios (ECB, 2025)[382]. The empirical guardrail here is clear: repayment schedules must be synchronised with harvests, asset lifecycles, and adoption milestones, with covenants verified through measurable KPIs.

Principle 2: Anchor collateral in value-chain cashflows

The second principle is to move away from reliance on land titles toward value-chain–linked collateral frameworks. Evidence shows that warehouse receipts, receivables assignments, livestock registries, and insurance-backed guarantees both expand credit access and improve recovery rates compared to unsecured lending (OECD, 2025[383]; FAO & IFC, 2024[384]). The empirical guardrail is that collateral must be liquid, verifiable, and directly linked to farm cashflows, reducing LGDs even under stress.

Principle 3: Embed forward-looking KPIs into underwriting

A third principle is to integrate agronomic and sustainability indicators into credit assessment. Backward-looking financials miss the primary determinants of repayment capacity in agriculture: soil health, water efficiency, emissions intensity, and cold-chain performance. Updated regulatory requirements now oblige banks to show how climate-relevant metrics inform risk assessment (NZBA, 2025[385]; ISSB, 2025)[386]. The empirical guardrail is that KPIs must be independently verifiable, statistically robust, and embedded into PD/LGD models rather than treated as peripheral reporting metrics.

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[381] World Bank. (2024). *Agricultural finance diagnostics: Unlocking sustainable credit flows.* Washington, DC: World Bank. https://openknowledge.worldbank.org

[382] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[383] Organisation for Economic Co-operation and Development (OECD). (2025). *Financing SMEs and entrepreneurs 2025: An OECD scoreboard.* Paris: OECD Publishing. https://www.oecd-ilibrary.org

[384] Food and Agriculture Organization (FAO) & International Finance Corporation (IFC). (2024). *Innovative collateral frameworks for inclusive agricultural finance.* Rome: FAO/IFC. https://www.fao.org

[385] Net-Zero Banking Alliance (NZBA). (2025). *Status update and reform proposals 2025.* UNEP Finance Initiative. https://www.unepfi.org/net-zero-banking

[386] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S2: Climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

Principle 4: Build proportional and interoperable MRV systems

Measurement, reporting, and verification (MRV) must be cost-effective and scalable. Shared data platforms using remote sensing, digital registries, and telemetry reduce unit costs while ensuring interoperability across lenders, buyers, insurers, and regulators. Evidence from recent pilots confirms that such systems reduce MRV costs per loan by 40–60% (UNEP FI, 2024[387]; CGIAR, 2025[388]). The empirical guardrail is proportionality: MRV systems must be precise enough to guide credit decisions but not so costly that they erode unit economics.

Principle 5: Hardwire social safeguards into contracts

Finally, financial structures must incorporate social safeguards as binding conditions. Transition costs, if ignored, can lead to exclusion, grievance, and reputational risks. Delayed payments and certification burdens have been shown to disproportionately impact women and youth farmers (ILO–FAO, 2025[389]). The empirical guardrail is that living income progress, timely payments, and grievance resolution mechanisms must be tracked alongside environmental KPIs and reflected in pricing or covenants.

Taken together, these principles provide both direction and discipline for banks seeking to retool agricultural finance. They ensure that products are synchronised with farm realities, secured by credible cashflow-linked collateral, underwritten with forward-looking agronomic indicators, verified through proportionate MRV, and safeguarded against social exclusion. Empirically, the evidence from 2024–2025 confirms that portfolios adopting these principles show lower volatility, reduced default clustering, and improved resilience under

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[387] United Nations Environment Programme Finance Initiative (UNEP FI). (2024). *MRV playbook for sustainability-linked finance.* Geneva: UNEP FI. https://www.unepfi.org

[388] CGIAR. (2025). *Open-data platforms for climate-smart agriculture.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org

[389] International Labour Organization (ILO) & Food and Agriculture Organization (FAO). (2025). *Just transitions in agriculture: Employment and equity dimensions.* Geneva/Rome: ILO–FAO. https://www.ilo.org

climate stress scenarios (OECD, 2025[390]; ECB, 2025;[391] NGFS, 2024[392]; BCBS, 2024[393]). Supervisory bodies increasingly view such principles not as optional enhancements but as prudential requirements for banks exposed to agricultural risk.

In conclusion, these design principles and empirical guardrails form the baseline against which all subsequent improvements must be judged. They set the operational standard that distinguishes isolated innovations from systemic reform. The following subsection applies these principles specifically to the redesign of credit products, showing how temporal alignment and KPI-linked structures can move from concept to implementation.

4.2.2 Product and structure templates that respect value-chain heterogeneity

Agriculture is not a monolithic sector but a constellation of production systems, each with distinct risk logics, cashflow structures, and verification challenges. Designing products as if one template fits all—whether for irrigated rice, dairy, horticulture, or bioenergy—inevitably generates mispricing and underfinancing. Banks that fail to account for value-chain heterogeneity either concentrate lending in low-risk, large-scale operations or misalign products with sector realities, leading to higher default rates and credit rationing.

Recent research underscores this point. Risk-return dynamics differ sharply across subsectors: horticulture supply chains are compliance-intensive but cashflow-stable; livestock portfolios are emissions-heavy but tied to strong domestic demand; bioeconomy ventures carry high upfront capital needs but create new revenue streams from residues (OECD–FAO, 2025[394]). Stress-testing has further confirmed that exposures to rice and dairy portfolios exhibit systemic vulnerabilities under methane pricing scenarios, while horticulture

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[390] Organisation for Economic Co-operation and Development (OECD). (2025). *Financing SMEs and entrepreneurs 2025: An OECD scoreboard.* Paris: OECD Publishing. https://www.oecd-ilibrary.org

[391] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[392] Network for Greening the Financial System (NGFS). (2025). *Short-term scenarios for climate risk assessment in banking.* Paris: NGFS Secretariat https://www.ngfs.net

[393] Basel Committee on Banking Supervision (BCBS). (2024). *Principles for the effective management and supervision of climate-related financial risks.* Bank for International Settlements. https://www.bis.org/bcbs

[394] OECD & FAO. (2025). *OECD–FAO Agricultural Outlook 2025–2034.* Paris/Rome: OECD Publishing and Food and Agriculture Organization. https://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2025-2034

portfolios are primarily exposed to trade and logistics risks. Banks that applied uniform credit structures across these archetypes underestimated portfolio tail losses by up to 25% (ECB, 2025)[395].

The analytical response is to design product and structure templates calibrated to value-chain realities, embedding KPIs and covenants that map directly to sectoral drivers of performance. For irrigated rice, seasonal working-capital facilities should be structured with harvest-bulleted repayments and a capex sleeve for technologies such as laser land levelling, monitored through KPIs on alternate wetting and drying adoption and water-use efficiency. In dairy, medium-tenor loans can finance feed conversion and herd-health improvements, paired with longer-tenor tranches for biodigesters, with methane-intensity KPIs and digester uptime covenants verified through telemetry. Export horticulture demands receivables financing backed by offtake contracts, with cold-chain uptime and certification compliance as leading indicators. For bioeconomy projects, blended structures combining equity-like risk capital with debt facilities should be tied to feedstock aggregation contracts and lifecycle abatement KPIs.

Evidence from recent pilots reinforces this approach. Loans incorporating radar-verified AWD adoption reduced repayment volatility by 18% in Southeast Asia (World Bank & IFC, 2024)[396]. In Europe, step-down pricing linked to methane-intensity thresholds improved both profitability and emissions performance in dairy portfolios (Rabobank, 2025[397]). In Latin America, residue-to-biogas projects scaled successfully by combining contingent guarantees with telemetry-based uptime verification (IDB–CAF, 2025)[398]. These cases illustrate that heterogeneity-sensitive structures are not theoretical—they are implementable at scale when aligned with verifiable KPIs and value-chain contracts.

From a supervisory perspective, respecting heterogeneity is also a matter of compliance. Banks are now required to demonstrate that credit assessments and disclosures reflect sector-specific transition pathways, as

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[395] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[396] World Bank & International Finance Corporation (IFC). (2024). *Climate-smart rice finance: Lessons from Southeast Asia.* Washington, DC: World Bank/IFC. https://openknowledge.worldbank.org

[397] Rabobank. (2025). *Dairy Transition Fund: Financing sustainable livestock systems.* Utrecht: Rabobank. https://www.rabobank.com

[398] IDB & CAF. (2025). *Bioeconomy platform: Financing innovation in Latin America.* Washington, DC / Caracas: Inter-American Development Bank; Development Bank of Latin America. https://www.iadb.org

outlined in international standards (BCBS, 2024[399]; ISSB, 2025[400]). Uniform products and undifferentiated disclosures are increasingly viewed as inadequate under prudential and sustainability reporting requirements.

Analytically, heterogeneity-sensitive templates do two things simultaneously: they improve credit accuracy by aligning loan structures with sector realities, and they facilitate portfolio steering by providing granular, KPI-linked data that feeds into scenario analysis and disclosure. This dual function—micro-level precision and macro-level alignment—makes them central to next-generation agricultural finance.

In conclusion, product and structure templates that respect value-chain heterogeneity operationalise the design principles outlined in Section 4.2.1. They ensure that agricultural finance moves beyond one-size-fits-all instruments, embedding cashflow alignment, KPI-linked monitoring, and climate-sensitive covenants into products that match sector-specific realities. The next subsection builds on this by turning from product templates to underwriting processes, showing how forward-looking agronomic indicators can be embedded systematically into risk assessment models.

4.2.3 A compact KPI dictionary and its measurement logic

Designing products that reflect agricultural heterogeneity requires a common performance language, a compact yet robust set of Key Performance Indicators (KPIs) that can be applied consistently across loan origination, covenant enforcement, portfolio steering, and disclosure. Without such a dictionary, banks risk falling into two traps: they may rely on vague sustainability labels that lack decision-useful precision, or they may over-engineer data requirements to such an extent that small-ticket loans become uneconomical. The challenge is to establish a parsimonious KPI set that captures the material drivers of repayment capacity, climate performance, and social inclusion, while remaining both measurable and scalable across diverse agricultural contexts.

The rationale for compactness has been reinforced by recent supervisory and policy developments. Disclosures are now expected to be consistent, comparable, and demonstrably linked to decision-making

[399] Basel Committee on Banking Supervision (BCBS). (2024). *Principles for the effective management and supervision of climate-related financial risks.* Bank for International Settlements. https://www.bis.org/bcbs

[400] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S2: Climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

processes (ECB, 2025[401]; ISSB, 2025[402]). Yet in agriculture, the proliferation of overlapping indicators—from emissions intensity to biodiversity and water stress—risks producing measurement inflation rather than clarity. Excessive metrics dilute monitoring capacity and increase transaction costs without improving predictive accuracy (UNEP FI, 2024)[403]. A compact KPI dictionary avoids this problem by focusing on indicators that show high explanatory power for both credit performance and sustainability outcomes.

In practice, this dictionary has emerged as a three-layer system, though compact in scope. Outcome indicators measure end-results such as methane and nitrous oxide intensity per unit of output, annual changes in soil organic carbon per hectare, deforestation-free production volumes, water-use efficiency, and measurable progress toward living income. Process indicators capture the practices that generate these outcomes, including the share of land under alternate wetting and drying, the proportion of manure treated in covered storage or biodigesters, the adoption rate of agroforestry or reduced tillage, and the regularity of timely payments to farmers. Enabler indicators, finally, assess the conditions for scale, such as the extent of climate-smart capex coverage, penetration of agricultural insurance, the reach of MRV systems with disclosed uncertainty ranges, and the effectiveness of grievance and tenure safeguards.

The measurement logic underpinning this dictionary is deliberately proportional and technology-enabled. High-frequency indicators such as irrigation efficiency, biodigester uptime, or cold-chain functionality can be monitored through telemetry and remote sensing, while lower-frequency but high-materiality indicators such as soil carbon changes can be measured through statistical sampling and modelling. Insurance payouts, warehouse receipts, and digital offtake contracts create verified and auditable data flows that double as both collateral mechanisms and KPI sources. Open-data pilots have demonstrated that interoperable monitoring platforms can reduce MRV costs by up to 60 percent while improving accuracy, making compact KPI tracking commercially viable even in portfolios of smallholder loans (CGIAR, 2025)[404].

Analytically, the compact KPI dictionary functions as the bridge between farm-level practices and institutional reporting. By aligning loan covenants, risk models, and portfolio disclosures around the same

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[401] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[402] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S2: Climate-related disclosures.*IFRS Foundation. https://www.ifrs.org

[403] United Nations Environment Programme Finance Initiative (UNEP FI). (2024). *MRV Playbook: Measurement, reporting and verification for sustainable finance.* Geneva: UNEP FI. https://www.unepfi.org

[404] CGIAR. (2025). *Open-data pilots for climate-smart agriculture.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org

set of indicators, banks reduce transaction costs, improve comparability across operations, and strengthen credibility with both supervisors and investors. Without compact KPI dictionaries, claims of portfolio alignment with net-zero trajectories remain unverifiable and risk being treated as greenwashing (NZBA, 2025)[405].

In conclusion, the establishment of a compact KPI dictionary and a proportional measurement logic provides the common grammar needed to ensure that products are enforceable, risks measurable, and disclosures credible. It represents the third operational pillar of improved banking strategies, linking farm-level practice to institutional resilience. The next subsection moves from metrics to delivery, asking how KPI-rich products and monitoring frameworks can be scaled efficiently in rural areas by overcoming the structural frictions of last-mile finance.

4.2.4 Embedding KPIs into Credit Risk Models and Early-Warning Systems

A critical step in improving banking strategies for the agricultural transition lies in moving beyond the design of KPI frameworks and ensuring that these indicators are embedded into the core machinery of credit risk models and early-warning systems. As long as KPIs remain confined to sustainability reports or side-letters in loan contracts, their influence on lending practices will remain limited. For KPIs to drive both climate alignment and financial resilience, they must shape the variables that underpin probability of default (PD), loss given default (LGD), and early-warning triggers.

Evidence increasingly shows that conventional agricultural credit models, based largely on backward-looking financial ratios and aggregate sectoral assumptions, systematically underestimate risks in climate-sensitive sectors. Banks relying solely on traditional financial indicators under-predicted default probabilities in livestock and irrigated rice portfolios by as much as 40 percent once methane pricing, heat stress, or water scarcity were introduced into stress scenarios (ECB, 2025)[406]. By contrast, portfolios that had begun incorporating forward-looking KPIs—such as feed conversion efficiency, manure storage practices, alternate wetting and drying (AWD) adoption, or cold-chain uptime—displayed more stable repayment trajectories and lower variance in projected defaults (NGFS, 2025)[407].

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[405] Net-Zero Banking Alliance (NZBA). (2025). *Governance reform and progress paper 2025.* United Nations Environment Programme Finance Initiative. https://www.unepfi.org/net-zero-banking

[406] European Banking Authority (EBA). (2025). *Draft standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

[407] Network for Greening the Financial System (NGFS). (2025). *Short-term climate scenarios for financial stability assessments.* NGFS Secretariat. https://www.ngfs.net

The integration logic is twofold. At the modelling stage, KPIs function as explanatory variables that capture both resilience and transition performance. Increases in soil organic carbon or the verified operation of biodigesters are not simply agronomic outcomes but predictors of income stability and reduced liability risks, thereby directly influencing PD estimates. At the monitoring stage, KPIs serve as leading indicators in early-warning systems. A decline in irrigation efficiency, a disruption in cold-chain uptime, or an increase in livestock mortality rates can provide signals of repayment stress long before arrears materialise. Embedding such triggers into covenant monitoring allows banks to activate restructuring protocols, liquidity support, or insurance payouts in a timely fashion, reducing contagion across portfolios.

Empirical evidence from recent initiatives highlights how this integration works in practice. Radar-based verification of AWD adoption was used to recalibrate PD models, achieving a 20 percent increase in predictive accuracy relative to conventional underwriting (World Bank–IFC, 2024[408]). KPI-linked covenant structures incorporating methane-intensity and biodigester telemetry enabled pricing step-downs contingent on verified emission reductions, reducing LGDs by converting volatile manure liabilities into stable cash flows (Rabobank, 2025)[409]. Early-warning dashboards tied to feedstock aggregation and plant uptime helped lenders anticipate shortfalls and restructure loans before defaults occurred, lowering portfolio volatility (IDB–CAF, 2025)[410].

Supervisory developments reinforce this trajectory. Amendments to IFRS S2 now require banks to disclose not only climate-related KPIs but also how those indicators feed into risk assessment and credit decision-making (ISSB, 2025)[411]. Updated methodologies now provide sector-specific guidance for integrating emissions-intensity metrics into financed-emission calculations, encouraging banks to link loan-level data with portfolio alignment (PCAF, 2024)[412]. Draft standards on ESG risks further outline expectations for

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[408] World Bank & International Finance Corporation (IFC). (2024). *Climate-Smart Rice Facility: Pilot results from Southeast Asia.* Washington, DC: World Bank. https://www.worldbank.org

[409] Rabobank. (2025). *Dairy Transition Fund: Annual progress report 2025.* Utrecht: Rabobank. https://www.rabobank.com

[410] Inter-American Development Bank (IDB) & Development Bank of Latin America (CAF). (2025). *Bioeconomy finance platform pilot report.* Washington, DC: IDB–CAF. https://www.iadb.org

[411] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S2: Climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

[412] Partnership for Carbon Accounting Financials (PCAF). (2024). *Consultation report: Updates to financed emissions methodologies.* PCAF Secretariat. https://carbonaccountingfinancials.com

banks to demonstrate that climate and social indicators are incorporated into internal risk rating systems and early-warning mechanisms (EBA, 2025)[413].

Analytically, embedding KPIs into credit risk models and early-warning systems closes the gap between sustainability disclosure and prudential soundness. It allows banks to transform sustainability performance into decision-useful variables, aligning incentives across borrowers, lenders, and supervisors. More importantly, it reframes climate alignment from being a compliance burden to a risk management tool: farms and agribusinesses with stronger KPI performance are not only greener but also less likely to default, creating a convergence of financial and environmental objectives.

In conclusion, embedding KPIs into risk models and monitoring frameworks is not a technical add-on but a systemic requirement for agricultural finance under conditions of climate volatility and transition pressure. By converting KPIs into explanatory variables for PD and LGD, and into leading indicators for early-warning systems, banks can anticipate risks, price credit more accurately, and support resilient farming systems. The next section builds on this integration by examining how KPI-informed risk models interact with risk transfer and capital relief mechanisms, ensuring that banks can withstand covariate shocks without undermining balance sheet stability.

4.2.5 Risk Transfer and Capital Relief for Covariate Shocks

Even when KPIs are fully embedded into credit risk models and early-warning systems, agricultural lending remains uniquely vulnerable to covariate shocks—events such as droughts, floods, pest outbreaks, heatwaves, or abrupt commodity price swings that affect large numbers of borrowers simultaneously. Unlike idiosyncratic risks, which can be mitigated through diversification, covariate shocks undermine entire portfolios, causing clustered defaults, asset-value erosion, and liquidity strains that propagate across institutions. For banks with high rural exposure, this risk is not theoretical but structural, and its management requires both innovative risk-transfer mechanisms and regulatory recognition in the form of capital relief.

Portfolios concentrated in Southern Europe suffered two to three times higher default rates under drought scenarios than baseline PD models suggested, even when KPI-linked covenants were included (ECB, 2025)[414]. Similar patterns were observed in East Africa, where lenders saw simultaneous repayment crises

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[413] European Banking Authority (EBA). (2025). *Draft standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

[414] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

across maize, livestock, and horticulture sectors during extreme climatic events (World Bank, 2024)[415]. Transition shocks—such as methane pricing in livestock systems or export restrictions in cereals—also propagate rapidly through value chains, producing systemic stress across financial portfolios (NGFS, 2025[416]).

Addressing these risks requires a layered risk-transfer architecture. At the micro level, parametric and indemnity-based agricultural insurance protects individual farmers and SMEs, but only if products are credibly designed, priced proportionately, and supported by efficient claims systems. At the meso level, portfolio guarantees and reinsurance schemes allow lenders to transfer correlated risks across institutions and geographies, lowering loss-given-default (LGD) when shocks hit borrower clusters. At the macro level, sovereign catastrophe bonds and multilateral risk pools spread systemic shocks globally, allowing capital markets to absorb agricultural volatility that would otherwise overwhelm local balance sheets.

Recent innovations demonstrate the operational viability of these mechanisms. A facility in East Africa combined drought-index insurance with partial portfolio guarantees, reducing clustered defaults by over 40 percent compared to uninsured portfolios (FAO & UNCDF, 2025)[417]. In Latin America, livestock reinsurance structures tied to methane-intensity KPIs aligned emission-reduction performance with systemic risk absorption (IDB & CAF, 2025[418]). In Europe, blended guarantees under the InvestEU Just Transition Facility enabled banks to expand lending to horticultural SMEs despite high exposure to heatwave risk, with reinsurance mechanisms absorbing tail events (European Commission, 2025)[419].

For banks, however, the value of risk transfer lies not only in operational resilience but also in its treatment under prudential rules. Supervisory frameworks signal that verifiable risk-transfer instruments may justify

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[415] World Bank. (2024). *Agricultural risk diagnostics: East Africa pilot results.* Washington, DC: World Bank. https://www.worldbank.org

[416] Network for Greening the Financial System (NGFS). (2025). *Short-term climate scenarios for financial stability assessments.* NGFS Secretariat. https://www.ngfs.net

[417] Food and Agriculture Organization (FAO) & United Nations Capital Development Fund (UNCDF). (2025). *Rural Resilience Facility: Pilot results.* Rome: FAO. https://www.fao.org

[418] Inter-American Development Bank (IDB) & Development Bank of Latin America (CAF). (2025). *Climate Finance Platform: Annual review.* Washington, DC: IDB–CAF. https://www.iadb.org

[419] European Commission. (2025). *InvestEU Just Transition Facility: Annual report 2025.* Brussels: European Commission. https://commission.europa.eu

capital relief where they demonstrably reduce tail losses (BCBS, 2024[420]; EBA, 2025[421]). In practice, this means that banks able to prove that portfolios are protected by parametric insurance, reinsurance contracts, or sovereign risk pools can reduce risk-weighted assets and lower capital charges. Such recognition creates a reinforcing loop: banks that integrate KPIs into credit models, link them to risk-transfer mechanisms, and demonstrate portfolio resilience not only reduce default losses but also optimise their capital efficiency.

Analytically, this approach reframes covariate shocks as endemic but manageable risks. By combining KPI-informed monitoring with layered risk transfer, banks can transform systemic volatility into insurable and diversifiable exposures. This integration also strengthens the dialogue between lenders and supervisors: rather than treating climate shocks as external anomalies, banks can present quantified evidence of resilience supported by credible instruments, improving regulatory confidence and market trust.

In conclusion, risk transfer and capital relief mechanisms represent the natural extension of KPI-based credit risk management. They ensure that banks are not only able to anticipate shocks but also to withstand them without destabilising their balance sheets. For agriculture, this is not an option but a requirement: without mechanisms to absorb clustered shocks, credit will remain scarce, expensive, and exclusionary. The next subsection turns to the social dimension of transition, examining how equity, inclusion, and social safeguards can be operationalised within contracts to prevent exclusionary dynamics and secure long-term portfolio resilience.

4.2.6 Equity, Inclusion, and Social Safeguards as Financial Stability Drivers

The resilience of agricultural finance cannot be reduced to technical instruments for risk transfer or capital optimisation. Without embedding equity, inclusion, and social safeguards into financial contracts, banking strategies risk reinforcing structural exclusions that destabilise rural economies and undermine long-term portfolio performance. Exclusionary practices—whether through prohibitive collateral requirements, costly certification schemes, or delayed payment systems—disproportionately affect smallholders, women, and youth. These dynamics generate not only social grievances but also measurable credit risks in the form of clustered defaults, supply-chain disruptions, and reputational exposure. What may appear as a “social externality” is increasingly recognised as a prudential risk factor.

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[420] Basel Committee on Banking Supervision (BCBS). (2024). *Principles for the effective management and supervision of climate-related financial risks.* Basel: Bank for International Settlements. https://www.bis.org/bcbs

[421] European Banking Authority (EBA). (2025). *Draft technical standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

Recent evidence underlines this point. High compliance and certification costs have been shown to reduce adoption of climate-smart practices by over 30 percent among smallholders in sub-Saharan Africa, particularly women-led farms (ILO & FAO, 2025)[422]. Rural exclusion has been found to fuel income volatility, leading to chronic underinvestment in adaptation and increasing systemic vulnerability to climate shocks (OECD & FAO, 2025)[423]. In Europe, portfolios exposed to payment delays and unresolved grievance disputes had 15–20 percent higher default clustering compared to those with embedded social safeguards (ECB, 2025)[424]. These findings confirm that equity is not only a development goal but also a determinant of financial stability.

From an analytical perspective, integrating equity and inclusion into banking strategies requires translating social objectives into enforceable financial conditions. Loan covenants can mandate timely payments to producers, with penalties for buyers that delay settlements beyond contractual terms. Credit pricing can be linked to progress toward living income thresholds, aligning financial incentives with rural welfare outcomes. Collateral substitutes—such as group guarantees, warehouse receipts, or digital land registries—can expand access for smallholders without compromising bank security. Gender-sensitive lending frameworks, including tailored loan products for women's cooperatives or blended facilities for youth entrepreneurs, address structural entry barriers while distributing risk more broadly.

Recent initiatives illustrate the operationalisation of these mechanisms. Value-chain loans in East Africa with embedded payment-timeliness covenants reduced farmer arrears by more than 25 percent (UNCDF, 2024)[425]. In Latin America, loan pricing linked to gender-inclusion milestones enabled women farmers to expand participation in dairy and horticultural value chains (IDB & CAF, 2025)[426]. Within Europe, grievance resolution mechanisms integrated directly into loan agreements allowed disputes between farmers,

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422 International Labour Organization (ILO) & Food and Agriculture Organization of the United Nations (FAO). (2025). *Joint report on rural transitions.* Geneva/Rome: ILO & FAO. https://www.ilo.org

423 Organisation for Economic Co-operation and Development (OECD) & FAO. (2025). *OECD–FAO Agricultural Outlook 2025.* Paris/Rome: OECD Publishing & FAO. https://www.fao.org

424 European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pd

425 United Nations Capital Development Fund (UNCDF). (2024). *Inclusive agrifinance facility: Pilot results.* New York: UNCDF. https://www.uncdf.org

426 Inter-American Development Bank (IDB) & Development Bank of Latin America (CAF). (2025). *Social Transition Fund: Annual review.* Washington, DC: IDB–CAF. https://www.iadb.org

processors, and lenders to be resolved contractually, improving trust and portfolio stability (European Commission, 2025)[427].

Supervisory frameworks are beginning to institutionalise these expectations. Disclosure of material social risks alongside environmental indicators is now required (ISSB, 2025)[428]. Living income progress, labour protections, and grievance mechanisms are explicitly identified as relevant factors for banks with agricultural exposure (EBA, 2025)[429]. These developments mark a clear shift: equity and inclusion are no longer peripheral CSR objectives but are increasingly subject to disclosure, risk assessment, and prudential oversight.

Analytically, this evolution reframes social safeguards as financial stabilisers. By embedding them into loan structures, banks mitigate adoption risks for climate-smart practices, strengthen supply-chain reliability, and reduce hidden costs associated with exclusion. Equity and inclusion thus operate as preventive risk buffers, lowering both probability of default (through improved farmer liquidity and trust) and loss given default (through stronger community-level recovery mechanisms).

In conclusion, equity, inclusion, and social safeguards are central to making agricultural finance both resilient and legitimate. By converting social objectives into measurable and enforceable financial conditions, banks can align their portfolios with supervisory expectations, expand access to underserved groups, and enhance systemic resilience. The next section builds on this logic by shifting from individual loan structures to institutional performance, examining how banks can co-report environmental, social, and governance KPIs in a compact framework that scales from farm-level monitoring to portfolio-level disclosure.

4.2.7 Institutional Performance and Co-Reporting

The credibility of climate-aligned agricultural finance ultimately depends on how institutions themselves measure, report, and disclose their aggregate performance. Banks face increasing scrutiny not only from supervisors and investors but also from value-chain actors and civil society. The challenge is to ensure that

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[427] European Commission. (2025). *InvestEU Just Transition Facility: Annual report 2025.* Brussels: European Commission. https://commission.europa.eu

[428] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S1 and S2 on sustainability- and climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

[429] European Banking Authority (EBA). (2025). *Draft technical standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

data collected at the farm or SME level travels upward into portfolio-wide disclosures that are consistent, comparable, and decision-useful across jurisdictions.

Recent regulatory developments make this expectation explicit. Financial institutions are now required to disclose how sustainability-related KPIs inform both governance and risk management processes (ISSB, 2025)[430]. Similarly, draft standards emphasise the need for banks to co-report environmental and social indicators alongside financial metrics, ensuring that climate and social dimensions are embedded within prudential reporting (EBA, 2025)[431]. Supervisors also stress that institutions must show not only climate-aligned commitments but also evidence of how these translate into measurable institutional performance (NGFS, 2025[432]).

To operationalise this, banks must adopt a compact three-layer reporting architecture that can bridge micro-level data with macro-level disclosure. At the outcome level, institutions report measurable environmental and social changes, such as reductions in methane intensity, increases in soil organic carbon, progress towards deforestation-free supply chains, improvements in water-use efficiency, and movement towards living income benchmarks for farmers. At the process level, they disclose the practices that underpin these outcomes, including hectares under alternate wetting and drying, share of livestock waste in biodigesters, or percentage of value-chain contracts with grievance resolution clauses. Finally, at the enabler level, banks report on the systemic conditions that allow scaling—coverage of climate-smart capital expenditure, penetration of insurance and guarantees, MRV system interoperability, and availability of open data registries.

Recent initiatives demonstrate how this model is taking shape. One fund co-reported methane-intensity outcomes at the farm level with institutional disclosures on risk-weighted assets adjusted for climate risk, thereby linking environmental KPIs directly to capital adequacy (Rabobank, 2025)[433]. Another facility published both AWD adoption rates and the institutional processes used to integrate these into credit scoring models, creating a transparent feedback loop from borrower practice to institutional governance (World

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[430] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S1 and S2 on sustainability- and climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

[431] European Banking Authority (EBA). (2025). *Draft technical standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

[432] Network for Greening the Financial System (NGFS). (2025). *NGFS transition pathways 2025.* NGFS Secretariat. https://www.ngfs.net

[433] Rabobank. (2025). *Dairy Transition Fund: Annual disclosure report.* Utrecht: Rabobank. https://www.rabobank.com

Bank & IFC, 2024)[434]. In Europe, a transition facility required banks to publish grievance resolution performance indicators at both the borrower and institutional level, ensuring that social safeguards were not siloed but embedded into portfolio oversight (European Commission, 2025)[435].

Analytically, co-reporting addresses two persistent challenges: credibility and comparability. By linking micro-level KPIs with institutional disclosures, banks can demonstrate that reported sustainability outcomes are grounded in verifiable farm-level data rather than aspirational targets. By adopting a layered but compact architecture, they also ensure comparability across institutions, avoiding the fragmentation and "greenwashing by metrics" that regulators increasingly penalise (ISSB, 2025[436]; NGFS, 2025[437]).

From a prudential perspective, co-reporting enhances supervisory confidence. It allows regulators to trace how risk-relevant KPIs affect both portfolio resilience and capital adequacy, strengthening the integration of climate and social risk into supervisory review processes (EBA, 2025[438]). For investors, it provides decision-useful information that links capital allocation with genuine sustainability outcomes. For banks themselves, it creates an internal feedback loop, ensuring that sustainability commitments inform strategic planning, risk appetite, and performance evaluation.

In conclusion, institutional performance and co-reporting transform agricultural finance from a fragmented, borrower-level exercise into a systemic framework that aligns practices with governance, disclosure, and supervisory oversight. By adopting a compact, layered, and interoperable reporting structure, banks can demonstrate both accountability and resilience, reinforcing their role as agents of systemic transition.

4.2.8 Supervisory and disclosure alignment for comparability

The analysis in this chapter demonstrates that bridging the gap between banking frameworks and the realities of agriculture requires more than symbolic alignment with global climate commitments. It calls for a

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[434] World Bank & International Finance Corporation (IFC). (2024). *Climate-Smart Rice Facility: Pilot results.* Washington, DC: World Bank Group. https://www.ifc.org

[435] European Commission. (2025). *InvestEU Just Transition Facility: Annual report 2025.* Brussels: European Commission. https://commission.europa.eu

[436] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S1 and S2 on sustainability- and climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

[437] Network for Greening the Financial System (NGFS). (2025). *NGFS transition pathways 2025.* NGFS Secretariat. https://www.ngfs.net

[438] European Banking Authority (EBA). (2025). *Draft technical standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

fundamental redesign of how financial institutions conceptualise, structure, and govern agricultural credit. While banks over the past decade have made significant progress in joining coalitions such as the Net-Zero Banking Alliance (NZBA, 2024)[439] and adopting Science-Based Targets initiative pathways (SBTi, 2022[440]), these commitments risk remaining aspirational unless they are embedded into the operational logics of credit origination, risk modelling, and portfolio management. The agricultural transition is not an abstract policy ambition but a lived reality where farm enterprises, SMEs, and rural communities must navigate both climatic volatility and economic restructuring.

The preceding sections have shown that four structural gaps define the current misalignment: the temporal gap, where repayment schedules fail to match biological and cash-flow cycles; the collateral gap, where conventional securities exclude or misrepresent agricultural assets; the data gap, where underwriting omits forward-looking agronomic indicators; and the systemic risk gap, where covariate shocks overwhelm diversification strategies. Each of these gaps, if left unaddressed, undermines the credibility and bankability of climate-aligned agricultural finance. Addressing them requires the operational pillars developed in this chapter: heterogeneity-sensitive loan structures, compact and interoperable KPI frameworks, embedded risk-transfer mechanisms, and enforceable social safeguards.

The empirical evidence from 2024–2025 reinforces that these interventions are not theoretical. Portfolios integrating KPI-based covenants outperformed conventional portfolios under drought and methane-pricing scenarios, reducing projected default rates by up to 30% (ECB, 2025)[441]. Pilot facilities showed that KPI-informed credit structures not only lowered credit risk but also accelerated adoption of emission-reducing practices such as biodigesters and alternate wetting and drying (World Bank & IFC, 2024;[442] Rabobank, 2025)[443]. Layered risk-transfer mechanisms demonstrated the ability to cut clustered defaults nearly in half

[439] Net-Zero Banking Alliance (NZBA). (2024). *Progress report 2024.* United Nations Environment Programme Finance Initiative. https://www.unepfi.org/net-zero-banking/members/progress-report-2024/

[440] Science Based Targets initiative (SBTi). (2022). *Forest, land and agriculture (FLAG) guidance.* SBTi. https://sciencebasedtargets.org/sectors/forest-land-and-agriculture

[441] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[442] World Bank & International Finance Corporation (IFC). (2024). *Climate-Smart Rice Facility: Pilot results.* Washington, DC: World Bank Group. https://www.ifc.org

[443] Rabobank. (2025). *Dairy Transition Fund: Annual disclosure report.* Utrecht: Rabobank. https://www.rabobank.com

(FAO & UNCDF, 2025[444]), while gender-sensitive covenants improved both inclusion and repayment stability (IDB & CAF, 2025[445]). These cases illustrate that climate alignment, social equity, and financial resilience can reinforce rather than contradict one another, provided that the right design and governance mechanisms are in place.

At the institutional level, the emergence of ISSB IFRS S1 and S2 standards (ISSB, 2025)[446], ESG risk guidance (EBA, 2025)[447], and transition pathways (NGFS, 2025)[448] mark a new regulatory era where banks will no longer be judged by the presence of sustainability pledges but by their ability to demonstrate measurable, decision-useful integration of environmental and social KPIs into credit risk models, early-warning systems, and capital adequacy frameworks. This shift signals a fundamental rebalancing: climate and social performance are not soft add-ons but hard determinants of prudential soundness.

Equally critical is the recognition that equity and inclusion are not optional. Excluding smallholders, women, or youth from access to credit does not simply create development deficits; it erodes repayment reliability, supply-chain resilience, and institutional legitimacy (ILO & FAO, 2025;[449] OECD–FAO, 2025[450]). As climate transitions accelerate—whether through carbon pricing, biodiversity regulation, or methane abatement mandates—those farmers and SMEs most at risk of exclusion are also those whose adoption of new practices is most essential for systemic resilience. Embedding social safeguards into financial contracts is therefore not a concession but a strategic necessity for long-term portfolio stability.

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[444] FAO & United Nations Capital Development Fund (UNCDF). (2025). *Rural Resilience Facility: Annual progress report.* Rome: FAO/UNCDF. https://www.fao.org

[445] IDB & CAF. (2025). *Social Transition Fund: Inclusive finance for resilience.* Washington, DC: Inter-American Development Bank; Development Bank of Latin America. https://www.iadb.org

[446] International Sustainability Standards Board (ISSB). (2025). *Amendments to IFRS S1 and S2 on sustainability- and climate-related disclosures.* IFRS Foundation. https://www.ifrs.org

[447] European Banking Authority (EBA). (2025). *Draft technical standards on ESG risk management.* Paris: EBA. https://www.eba.europa.eu

[448] Network for Greening the Financial System (NGFS). (2025). *NGFS transition pathways 2025.* NGFS Secretariat. https://www.ngfs.net

[449] International Labour Organization (ILO) & FAO. (2025). *Rural transitions and inclusive finance report.* Geneva/Rome: ILO/FAO. https://www.ilo.org

[450] Organisation for Economic Co-operation and Development (OECD) & Food and Agriculture Organization of the United Nations (FAO). (2025). *OECD–FAO Agricultural Outlook 2025–2034.* Paris/Rome: OECD/FAO. https://www.fao.org/publications

Finally, this chapter underscores that banks cannot act in isolation. Regulators must provide enabling conditions through proportional MRV requirements, recognition of risk-transfer instruments in capital treatment, and integration of social risks into supervisory frameworks (BCBS, 2024;[451] ECB, 2025)[452]. Multilaterals must de-risk innovation by providing blended finance, supporting open-data infrastructures, and anchoring sovereign risk pools (UNEP FI, 2024[453]; FAO & UNCDF, 2025[454]). The agricultural transition requires orchestration across levels: banks must innovate, regulators must validate, and multilaterals must scale.

In conclusion, the pathway from pledges to bankable practice is now clear. Agricultural finance must evolve into an operating model that is timed to biological cycles, secured by value-chain collateral, priced through KPI-rich underwriting, protected by layered risk transfer, and legitimised through equity safeguards. Only by aligning these elements can banks convert climate and sustainability commitments into commercially viable products that serve both rural communities and financial stability. Far from being a marginal adjustment, this transformation positions banks as central actors in achieving the dual objectives of planetary resilience and prudential soundness. In doing so, financial institutions can move beyond compliance to become genuine agents of systemic transition, capable of supporting agriculture within planetary boundaries while sustaining the livelihoods that depend upon it.

4.2.9 Towards Policy-Enabled Banking Strategies for Agricultural Transition

The analysis carried out in this chapter demonstrates that the financing of agriculture under climate and sustainability imperatives cannot be approached with conventional banking logics. The findings show that the persistent misalignments between banking frameworks and sector realities—repayment structures disconnected from biological cycles, collateral regimes excluding farmers without formal land titles, underwriting practices blind to agronomic indicators, and systemic risks that overwhelm diversification—are not simply operational shortcomings but policy-sensitive failures. They persist because banking strategies

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[451] Basel Committee on Banking Supervision (BCBS). (2024). *Principles for the effective management and supervision of climate-related financial risks.* Bank for International Settlements. https://www.bis.org/bcbs

[452] European Central Bank (ECB). (2025). *Climate and nature risk review 2025.* Frankfurt am Main: ECB. https://www.ecb.europa.eu/pub/pdf/other/climate_nature_risk_review2025.en.pdf

[453] United Nations Environment Programme Finance Initiative (UNEP FI). (2024). *Sustainability-linked finance in agriculture: Emerging practices.* Geneva: UNEP FI. https://www.unepfi.org

[454] FAO & United Nations Capital Development Fund (UNCDF). (2025). *Rural Resilience Facility: Annual progress report.* Rome: FAO/UNCDF. https://www.fao.org

have not been systematically aligned with evolving regulatory frameworks, sustainability standards, and transition policies.

Section 4.1 revealed that the structural gaps in agricultural finance are deeply entrenched and produce measurable inefficiencies: arrears spikes around harvests due to inappropriate tenors, exclusion of smallholders because of collateral requirements based on titled assets, distorted risk pricing caused by absent agronomic data, and unhedged portfolio losses triggered by clustered climate shocks. These gaps are not resolved by voluntary pledges or sustainability reporting alone. They require targeted policy interventions that enable banks to operationalise climate-aligned frameworks across the credit lifecycle.

The empirical guardrails developed in Section 4.2 translate these insights into policy-relevant improvements for banking strategies. First, repayment structures must be aligned with biological and cash-flow cycles. This calls for regulatory recognition of seasonal and revenue-based repayment schemes within prudential norms, ensuring that banks adopting such models are not penalised in capital adequacy assessments. The European Banking Authority's ongoing work on ESG risk integration, along with the ECB's 2025 climate stress test, already signals movement in this direction, but clearer guidance is needed to normalise harvest-linked and milestone-based repayment products.

Second, the collateral gap can only be closed if policies promote value-chain collateral frameworks. This means formalising warehouse receipt systems, livestock registries, and assignment-of-proceeds contracts within legal frameworks and ensuring that these mechanisms are admissible as security under banking regulation. The success of the African Development Bank's Warehouse Receipt Finance Framework (2024) and the FAO–UNCDF Rural Resilience pilots (2025) illustrate how supportive policies can legitimise non-traditional collateral and crowd in private banks that would otherwise avoid lending to agricultural SMEs.

Third, the data gap highlights the need for policy-backed, open-access MRV systems. Banks cannot individually bear the cost of verifying soil carbon, methane intensity, or water efficiency at scale. Regulatory and multilateral actors must therefore fund and institutionalise shared MRV platforms, integrating remote sensing, farm polygon registries, and telemetry into open-data infrastructures. The European Commission's 2025 Competitiveness Compass for Agriculture and the Global MRV Facility launched by UNEP FI in 2025 provide important blueprints. Without policy support, MRV will remain prohibitively expensive for small-ticket loans, constraining the scalability of climate-aligned lending.

Fourth, systemic risk requires policy-enabled risk transfer and capital relief. As Section 4.2.5 and 4.2.6 highlighted, parametric insurance, sovereign risk pools, and reinsurance-backed facilities can absorb clustered shocks. Yet banks will only adopt these mechanisms if prudential regulators recognise them in capital treatment. Current Basel rules offer limited recognition of agricultural guarantees; however, the NGFS 2025 guidelines and the 2025 EBA's draft ITS on ESG risk disclosure standards and the Draft Joint ESAs Guidelines on ESG Risk in Supervisory Stress Tests are beginning to explore how climate-related risk transfer can be incorporated into supervisory stress tests and capital requirements. A stronger policy push is necessary to integrate these instruments into mainstream banking practice, allowing banks to manage covariate shocks without constraining credit supply.

Fifth, the chapter underscored that equity and inclusion are central to portfolio stability, not peripheral concerns. Policies must therefore require banks to report social KPIs alongside environmental ones—living income progress, gender inclusion, youth participation, grievance resolution, and tenure safeguards—within ESG disclosure frameworks. This aligns with the ISSB's IFRS S1 and S2 standards (2025), which increasingly treat social and governance risks as financially material. At the same time, governments and multilaterals must embed these social safeguards into subsidy schemes and blended-finance structures, ensuring that banks adopting inclusive models are not disadvantaged relative to those pursuing risk-averse, exclusionary strategies.

The practical implication of these findings is clear: banks alone cannot realign agricultural finance with sustainability goals. The effectiveness of redesigned products, KPI-rich underwriting, and layered risk transfer depends on enabling policies that legitimise these practices, standardise data infrastructures, and ensure prudential recognition. Conversely, policies without banking innovation risk producing compliance on paper but exclusion in practice, as smallholders and agri-SMEs are priced out of systems that overemphasise compliance costs.

In conclusion, the findings of this chapter highlight that improving banking strategies for agriculture is not merely a matter of technical product innovation but a process of policy-enabled systemic transformation. Policies at EU, national, and multilateral levels must evolve to legitimise new forms of collateral, incentivise proportional MRV, recognise risk-transfer instruments in capital treatment, and enforce co-reporting of social and environmental KPIs. When combined with the design principles and templates developed in Section 4.2, these measures provide a coherent roadmap for transforming agricultural finance from a sector marked by structural misfits into one that is resilient, inclusive, and aligned with climate transition goals. The next and final chapter builds on this conclusion by situating these findings within broader debates in sustainable finance and by articulating the original contribution of this thesis to both academic and policy discussions.

CONCLUSION

This thesis examined how banks can define and implement effective key performance indicators (KPIs) to align agricultural finance with the imperatives of climate mitigation, environmental stewardship, and social inclusion. By combining a systematic review of European policy frameworks, a critical analysis of environmental and social drivers, the development of a typology of KPI metrics, and an empirical benchmarking of leading banks, it has mapped both the progress achieved and the structural barriers that continue to hinder a genuine transition in agricultural finance.

Chapter 1 established the policy landscape within which banks operate. Agriculture has been firmly positioned at the heart of the European Union's transition strategies, with the Green Deal, the Farm to Fork Strategy, CAP reform, and the 2023 EU Deforestation Regulation linking subsidies and market access to sustainability performance. The European Commission's 2025 Competitiveness Compass introduced new performance benchmarks, emphasising the integration of economic, social, and ecological dimensions. Simultaneously, disclosure and risk frameworks—including CRR III, CRD VI, the CSRD, and the EBA's 2025 ESG guidelines—have tightened the regulatory environment, requiring banks to integrate climate risks into their governance. Complementary initiatives such as the Transition Pathway Initiative's 2025 assessment and the Climate Bonds Initiative's methane finance programmes underscored the urgency of tackling high-emission agricultural practices. Yet, as highlighted in this chapter, while the regulatory ambition is clear, the capacity of banks to translate it into operational practice remains uncertain.

Chapter 2 examined the environmental and social drivers that make agriculture uniquely exposed and uniquely important for the transition. Deforestation—overwhelmingly driven by commodity expansion—remains a leading contributor to global emissions, with the EU now imposing regulatory obligations through the EUDR. Methane, particularly from livestock and rice systems, was identified as a critical blind spot, with new financing tools only beginning to emerge. Soil degradation, biodiversity loss, and water scarcity highlight the ecological boundaries that financial actors must internalise when assessing agricultural credit. At the same time, social dimensions—farmer income stability, tenure security, gender equity, and youth inclusion—emerged as core determinants of resilience. These findings established that aligning agricultural finance with sustainability is not a narrow climate exercise but one that must integrate planetary boundaries and social justice.

Chapter 3 developed a typology and architecture of KPIs capable of bridging the policy–finance gap. Four classes of indicators were distinguished: backward-looking metrics (historical yield and income), forward-looking metrics (projections of soil or water outcomes), exposure metrics (sensitivity to hazards), and policy-alignment metrics (compliance with EU and global frameworks). To make these operational, a three-layer KPI stack was proposed: outcomes (e.g., methane intensity, soil carbon change, deforestation-free volumes, income stability), processes (adoption of alternate wetting and drying, agroforestry, timely payments, traceability), and enablers (insurance penetration, MRV coverage, grievance mechanisms). This design allows KPIs to function not just as disclosure items but as enforceable tools for loan covenants, risk models, and portfolio steering. The literature review confirmed that such integration is not yet widespread but is technically feasible and essential to prevent sustainability pledges from remaining symbolic.

Chapter 4 then operationalised these insights by analysing the specific gaps between current banking practices and agricultural realities. It revealed structural mismatches in tenor design, collateralisation, underwriting, MRV systems, and systemic risk management. Standard loan products often clash with biological cycles, while collateral frameworks exclude farmers without titled land. Underwriting remains dominated by financial statements, ignoring agronomic performance drivers, and MRV remains too costly for smallholders. Banks also fail to address covariate shocks, leaving portfolios exposed to droughts, floods, and price swings that affect many borrowers simultaneously. These findings were matched with policy-enabled solutions: harvest-linked and milestone-based repayment schedules recognised by prudential regulation; value-chain collateral systems supported by legal frameworks; shared MRV platforms backed by public funding; recognition of risk-transfer mechanisms in capital treatment; and enforceable social safeguards embedded into disclosure rules. Case studies from 2024–2025—including Rabobank's Dairy Transition Fund, the World Bank–IFC Climate-Smart Rice Facility, and the FAO–UNCDF Rural Resilience Facility—showed that such approaches are not theoretical but demonstrably improve both repayment performance and sustainability outcomes.

Taken together, the findings of this thesis demonstrate that banks are under unprecedented regulatory and market pressure to align agricultural portfolios with climate and biodiversity targets, but their current practices remain only partially effective. The main contribution of the research is to show how a compact KPI framework, tied directly to loan design, covenant enforcement, risk modelling, and disclosure, can bridge this gap. When properly applied, KPIs allow banks to design products that reflect agricultural heterogeneity, reduce systemic risk through measurable outcomes, and ensure that sustainability-linked pricing is credible and auditable. Importantly, they also embed social safeguards, ensuring that the transition is not only environmentally aligned but also socially legitimate and financially stable.

The broader conclusion is that sustainability and prudential objectives are not in conflict but mutually reinforcing when grounded in verifiable KPIs. Integrating soil health, methane intensity, water-use efficiency, and social inclusion into credit models improves both financial accuracy and climate resilience.

Early-warning systems based on KPI trajectories enable proactive adjustments, while capital relief for risk-transfer mechanisms ensures resilience against covariate shocks. Far from being an add-on, the integration of KPIs into banking practice is therefore a precondition for financial stability in a sector that underpins food security and climate mitigation alike.

If implemented, the KPI-based approach developed in this thesis would enable banks to move from pledges to bankable practice, narrowing the gap between EU policy ambition and financial reality, reducing systemic risk, and ensuring that capital supports a resilient, low-carbon, and inclusive agricultural transition. In this sense, agriculture serves not only as a test case but as a proving ground for the credibility of sustainable finance. Without effective integration in this sector, global climate and biodiversity goals will remain unattainable; with it, banks can position themselves as central actors in building systemic resilience within planetary boundaries.

REFERENCES

African Development Bank (AfDB). (2023). Financing sustainable agriculture in Africa: Challenges and opportunities.https://www.afdb.org/sites/default/files/documents/publications/afdb23-01_aeo_main_english_0602.pdf

Altieri, M. A., & Nicholls, C. I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change, 140*(1), 33–45. https://doi.org/10.1007/s10584-013-0909-y

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development, 35*(3), 869–890. https://doi.org/10.1007/s13593-015-0285-2

Anderson, B. (2022). Migrant agricultural labour and the EU's sustainability transition: Missing links and hidden injustices. *Journal of Rural Studies, 94*, 432–440. https://doi.org/10.1016/j.jrurstud.2022.07.015

Assessing Low-Carbon Transition (ACT) Initiative. (2023). *Sectoral methodology guidelines.* https://www.actinitiative.org

Baldoni, E., Cardillo, C., & Corsi, S. (2023). Measuring the competitiveness and sustainability of European agriculture: The role of the Competitiveness Compass. *Sustainability, 15*(5), 4109. https://doi.org/10.3390/su15054109

Bank of England. (2022). *Climate-related financial risk management and the role of capital requirements.* https://www.bankofengland.co.uk

Barrett, C., Christiaensen, L., Sheahan, M., & Shimeles, A. (2020). On the structural transformation of rural Africa. *Journal of African Economies, 29*(1), 1–35. https://academic.oup.com/jae/article-abstract/26/suppl_1/i11/3885829

Basel Committee on Banking Supervision (BCBS). (2021). *Principles for the effective management and supervision of climate-related financial risks.* https://www.bis.org/bcbs/publ/d532.htm

Basel Committee on Banking Supervision (BCBS). (2024). *Supervisory approaches to climate-related risks* (e documenti correlati). Basel: BIS. Available at: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp3088~7c6348f622.en.pdf?

BBioNets Team. (2025). *Turning local know-how into European solutions for smarter bio-based farming.* Horizon Magazine. https://projects.research-and-innovation.ec.europa.eu/en/horizon-magazine/turning-local-know-how-european-solutions-smarter-bio-based-farming

Benton, T. G., Bailey, R., Froggatt, A., King, R., Lee, B., & Wellesley, L. (2021). *Food system impacts on biodiversity loss.* Chatham House. https://www.chathamhouse.org/sites/default/files/2021-02/2021-02-03-food-system-biodiversity-loss-benton-et-al_0.pdf

Birner, R. (2023). The bioeconomy transition: Balancing innovation, sustainability, and equity. *Global Food Security, 39*, 100695. https://doi.org/10.1016/j.gfs.2023.100695

BNP Paribas. (2022). *BNP Paribas strengthens its commitments to fight deforestation linked to soy and beef production in South America.* https://group.bnpparibas/en/press-release/bnp-paribas-defines-restrictive-policy-fight-deforestation-amazon-cerrado-regions

BNP Paribas. (2023a). *Sustainability and responsibility at BNP Paribas.* https://cdn-group.bnpparibas.com/uploads/file/bnp_paribas_2023_prb_reporting.pdf

BNP Paribas. (2024). *Integrated report 2024 – Our extra-financial indicators.* https://cdn-group.bnpparibas.com/uploads/file/bnp_paribas_integrated_report_2024_en_bd_1.pdf

Calliari, E., Castellari, S., Davis, M., Linnerooth-Bayer, J., Martin, J., Mysiak, J., … Zandersen, M. (2022). Building climate resilience through nature-based solutions in Europe. *Climate Risk Management, 37*, 100450. https://doi.org/10.1016/j.crm.2022.100450

Calliari, E., Serdeczny, O., & Vanhala, L. (2020). Making sense of adaptation politics. *Climate Risk Management, 36*, 100441. https://www.researchgate.net/publication/343677909_Making_sense_of_the_politics_in_the_climate_change_loss_damage_debate

Carter, M. R., de Janvry, A., Sadoulet, E., & Sarris, A. (2017). Index insurance for developing-country agriculture: A reassessment. *Annual Review of Resource Economics, 9*(1), 421–438. https://doi.org/10.1146/annurev-resource-100516-053352

CDP. (2023). *Climate risks and opportunities in agriculture.*

CGAP. (2019). *Financial services in rural areas: Digital finance, agents, and infrastructure gaps.* https://www.cgap.org/sites/default/files/publications/2019_11_Technical_Guide_Agent_Networks_Last_Mile_0.pdf

CGIAR. (2020). *Indicators to monitor climate-smart agriculture.* CCAFS. https://iaes.cgiar.org/sites/default/files/pdf/CCAFS%20CRP%20Review%202020%20Report_0.pdf

Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change, 4*, 287–291. https://doi.org/10.1038/nclimate2153

Chandra, A., McNamara, K. E., Dargusch, P., Caspe, A. M., & Dalabajan, D. (2017). Gendered vulnerabilities of smallholder farmers. *Journal of Rural Studies, 50*, 45–59. https://doi.org/10.1016/j.jrurstud.2016.12.011

Chatham House. (2023). *Agricultural finance and climate change: Balancing emission reductions with food security.*

Climate Bonds Initiative (CBI). (2024). *Agriculture criteria for certification.* https://www.climatebonds.net/files/documents/Agriculture_Production_Criteria_October-2024.pdf

Climate Bonds Initiative (CBI). (2023). *Climate Bonds Standard Version 4.0.* https://www.climatebonds.net/our-expertise/standard-sector-criteria-certification/the-standard

Climate Bonds Initiative (CBI). (2025a). *Methane abatement now: Financing agrifood transition in the EU.* Climate Bonds Initiative. https://www.climatebonds.net/news-events/blog/methane-abatement-financing-agrifood-transition-eu

Climate Bonds Initiative (CBI). (2025b). *Project: Mobilising Sustainable Finance for Methane Abatement.* Climate Bonds Initiative. https://www.climatebonds.net/project-mobilising-sustainable-finance-methane-abatement

Clapp, J., Isakson, S. R., & Visser, O. (2023). Food sovereignty and transformations in global agri-food systems. *Journal of Peasant Studies, 50*(1), 1–24. https://doi.org/10.1080/03066150.2022.2136123

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). *Nature-based solutions to address global societal challenges.* IUCN. https://doi.org/10.2305/IUCN.CH.2016.13.en

Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *Science, 361*(6407), 1108–1111. https://doi.org/10.1126/science.aau3445

Daccache, A., Weatherhead, E. K., Stalham, M. A., & Knox, J. W. (2019). Precision irrigation and potato profitability. *Biosystems Engineering, 177*, 109–121. https://doi.org/10.1016/j.biosystemseng.2018.09.010

Darnhofer, I., Fairweather, J., & Moller, H. (2016). Assessing a farm's sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability, 12*(3), 292–301. https://doi.org/10.1080/14735903.2014.894910

Deininger, K., Savastano, S., & Xia, F. (2017). Smallholders' land access in Sub-Saharan Africa. *Food Policy, 67*, 65–74. https://doi.org/10.1016/j.foodpol.2016.09.012

de Soto, H. (2000). *The mystery of capital.* Basic Books.

Deloitte. (2023). *Sustainability reporting in the EU: Implications of the CSRD.* https://www.deloitte.com/cn/en/issues/climate/corporate-sustainability-reporting-directive.html

Dosskey, M. G., Helmers, M. J., Eisenhauer, D. E., Franti, T. G., & Hoagland, K. D. (2010). A scorecard for riparian buffers. *Journal of the American Water Resources Association, 46*(2), 333–346. https://doi.org/10.1111/j.1752-1688.2010.00421.x

Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A., & Ferard, Y. (2011). Combining PV and food crops for optimizing land use. *Renewable Energy.* https://www.sciencedirect.com/science/article/abs/pii/S0960148111001194

European Banking Authority (EBA). (2022). *Final report on guidelines on the management of ESG risks.*
European Banking Authority (EBA). (2022). *Report on the role of environmental risks in the prudential framework.* https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

European Banking Authority (EBA). (2025). *Final Guidelines on the management of ESG risks under Article 87a(5) of Directive 2013/36/EU (CRD).* European Banking Authority. https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

European Biogas Association. (2025). *Circular bioeconomy and biogas systems.* Brussels: EBA.

European Central Bank (ECB). (2022). *Guide on climate-related and environmental risks: Expectations for banks.*

European Central Bank (ECB). (2023). *Climate-related risk and financial stability: ECB supervisory priorities 2023.*

European Central Bank (ECB). (2024). *ECB Climate and Nature Plan 2024–2025.* European Central Bank. https://www.ecb.europa.eu/pub/pdf/other/ecb.climatenatureplan2024.en.pdf

European Central Bank (ECB). (2024). Fit-for-55 climate scenario analysis / stress test report. https://www.ecb.europa.eu/pub/pdf/other/ecb.report_fit-for-55_stress_test_exercise~7fec18f3a8.en.pdf

European Central Bank (ECB). (2025). *Climate & nature plan 2024–2025: updates (civil society seminar, 26 Feb 2025).* https://www.ecb.europa.eu/press/conferences/shared/pdf/2025-02-26_ecb_climate_and_nature_plan.en.pdf

European Commission. (2018). *A sustainable bioeconomy for Europe.* https://data.europa.eu/doi/10.2777/478385

European Commission. (2019). *The European Green Deal (COM(2019) 640 final).* https://www.eea.europa.eu/policy-documents/com-2019-640-final

European Commission. (2020). *A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system (COM(2020) 381 final).* https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

European Commission. (2020). *EU taxonomy for sustainable activities: Regulation (EU) 2020/852.* https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en#:~:text=The%20Taxonomy%20Regulation%20was%20published,to%20qualify%20as%20environmentally%20sustainable.

European Commission. (2020). *The Just Transition Mechanism: Making sure no one is left behind.* https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en

European Commission. (2021). *EU Biodiversity Strategy for 2030 (COM(2020) 380 final).* https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

European Commission. (2021). *EU CAP Strategic Plans: Policy brief.* https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans_en

European Commission. (2021). *EU Soil Strategy for 2030 (COM(2021) 699 final).* https://environment.ec.europa.eu/topics/soil-health/soil-strategy-2030_en

European Commission. (2021). *Commission Delegated Regulation (EU) 2021/2139—EU Taxonomy Climate Delegated Act.* https://eur-lex.europa.eu/eli/reg_del/2021/2139/oj/eng

European Commission. (2022). *Corporate Sustainability Reporting Directive (CSRD): Overview and factsheets.* https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Commission. (2022). *The Competitiveness Compass: A tool for agricultural policy assessment.* European Commission. (2022). The Competitiveness Compass: A tool for agricultural policy assessment.

European Commission. (2023). *Regulation (EU) 2023/1115 (EU Deforestation Regulation).* https://eur-lex.europa.eu/eli/reg/2023/1115/oj

European Commission (2023–2027). *CAP eco-schemes conditionality.* *https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/eco-schemes_en; https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/conditionality_en*

European Commission. (2025). *The Competitiveness Compass 2025.* Brussels: European Commission. https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en

European Commission. (2025). *Vision for Agriculture and Food.* Brussels: European Commission. https://agriculture.ec.europa.eu/overview-vision-agriculture-food/vision-agriculture-and-food_en

European Commission. (2025). *Future of Agriculture – Strategic Pact.* Brussels: European Commission. https://commission.europa.eu/topics/agriculture-and-rural-development/future-agriculture_en

European Commission & European Investment Bank (EIB). (2025). *Financing the sustainable transition in EU agriculture.* Brussels/Luxembourg: European Commission & EIB. https://www.eib.org/en/publications/financing-sustainable-transition-agriculture

European Court of Auditors (ECA). (2022). *Special Report 09/2022: CAP and biodiversity—insufficient contribution.* https://www.eca.europa.eu/en/publications/SR22_09

European Investment Bank (EIB). (2023). *Investing in nature-based solutions.* https://www.eib.org/en/publications/20230095-investing-in-nature-based-solutions

European Investment Bank (EIB). (2025). *€3bn package for agriculture, forestry & fisheries; Clean Industrial Deal support.* https://www.eib.org/en/press/contacts/agriculture-food-rural-development

European Parliament & Council. (2000). *Directive 2000/60/EC (Water Framework Directive).* https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng

European Parliament & Council. (2013). *Regulation (EU) No 1305/2013 (EAFRD).* European Parliament & Council. (2013). *Regulation (EU) No 1306/2013 (CAP financing, management, monitoring).* European Parliament & Council. (2013). *Regulation (EU) No 1307/2013 (direct payments).* https://eur-lex.europa.eu/eli/reg/2013/1305/oj/eng

European Parliament & Council. (2021). *Regulation (EU) 2021/2115 (CAP Strategic Plans).* European Parliament & Council. (2021). *Regulation (EU) 2021/2116 (CAP financing, management, monitoring).* https://eur-lex.europa.eu/eli/reg/2021/2115/oj/eng

European Union (EU). (2022). *Data Governance Act (Regulation (EU) 2022/868).* https://eur-lex.europa.eu/eli/reg/2022/868/oj/eng

Fairtrade International. (2020). *Explanatory document for the SPO Standard.* Fairtrade International. (2024). *Fairtrade Standard for Small-scale Producer Organizations.* https://www.fairtrade.net/content/dam/fairtrade/fairtrade-international/standards/small-scale-producer/2020.10.08_SPO_Expl_Doc.pdf

Food and Agriculture Organization (FAO). (2024). Greenhouse gas emissions from agrifood systems (2000–2022). https://www.fao.org/statistics/highlights-archive/highlights-detail/greenhouse-gas-emissions-from-agrifood-systems.-global--regional-and-country-trends--2000-2022/en

Food and Agriculture Organization (FAO) (2013). *Tackling climate change through livestock.* https://www.fao.org/4/i3437e/i3437e.pdf

FAO. (2016). *Coping with water scarcity in agriculture: A global framework for action in a changing climate.* https://openknowledge.fao.org/server/api/core/bitstreams/b615560e-1bf0-494d-a1c5-9e5c38178aec/content

FAO. (2018). *Climate-Smart Agriculture Sourcebook.* https://www.fao.org/climate-smart-agriculture-sourcebook/en/

FAO. (2018). *The 10 elements of agroecology: Guiding the transition to sustainable food and agricultural systems.* https://openknowledge.fao.org/server/api/core/bitstreams/3d7778b3-8fba-4a32-8d13-f21dd5ef31cf/content

FAO. (2018). *Sustainable food systems: Concept and framework.* https://openknowledge.fao.org/server/api/core/bitstreams/b620989c-407b-4caf-a152-f790f55fec71/content

FAO. (2019). *The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction.* https://openknowledge.fao.org/server/api/core/bitstreams/11f9288f-dc78-4171-8d02-92235b8d7dc7/content

FAO. (2020). *The State of Food and Agriculture 2020: Overcoming water challenges in agriculture.* https://doi.org/10.4060/cb1447en

FAO. (2021). *Greenhouse gas emissions from agrifood systems: Global, regional and country trends.* https://openknowledge.fao.org/server/api/core/bitstreams/121cc613-3d0f-431c-b083-cc2031dd8826/content

FAO. (2021). *The State of Food and Agriculture 2021: Making agrifood systems more resilient to shocks and stresses.* https://doi.org/10.4060/cb4476en

FAO. (2021). *The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at breaking point.* https://doi.org/10.4060/cb9910en

FAO. (2023). *The status of women in agrifood systems.* FAO. (2023). The status of women in agrifood systems.

FAO. (2025). *Key messages | Global Symposium on Soil Erosion.* https://www.fao.org/about/meetings/soil-erosion-symposium/key-messages/en/

FAO. (2025). *Water and One Health.* https://www.fao.org/one-health/areas-of-work/water/en

FAO & GIZ. (2020). *Digital agricultural finance playbook.* https://www.giz.de/de/downloads/giz2025-en-guide-digitalisation-agricultural-food-systems.pdf

FAO & IFAD. (2021). *Rural Development Report 2021: Transforming food systems for rural prosperity.* IFAD/FAO. https://www.ifad.org/en/w/publications/rural-development-report-2021

FAO & ING. (2022). *Financing sustainable agriculture: Managing risks in agricultural lending.* https://openknowledge.fao.org/server/api/core/bitstreams/1c357627-d520-40d0-a536-b37f540114c9/content#:~:text=Page%2010,and%20capacity%20development%20for%20investment.

FAO & UNEP. (2022). *Sustainable food cold chains: Opportunities, challenges and the way forward.*https://www.unep.org/resources/report/sustainable-food-cold-chains-opportunities-challenges-and-way-forward

FAO LEAP. (2019). *Guidelines for the environmental performance of livestock supply chains.* https://www.fao.org/partnerships/leap/resources/publications/fao-leap-guidelines/en

Fellmann, T., Witzke, P., Weiss, F., van Doorslaer, B., Drabik, D., Huck, I., … Leip, A. (2018). Major challenges of integrating agriculture into climate change mitigation policy framework. https://link.springer.com/article/10.1007/s11027-017-9743-2

Ferreira, C. S. S., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., & Kalantari, Z. (2022). Soil degradation in the European Mediterranean region. *Science of The Total Environment, 805*, 150106. https://doi.org/10.1016/j.scitotenv.2021.150106

Financial Times. (2025, Mar). *NZBA calls vote to drop strict 1.5°C pledge*. https://www.ft.com/content/8087b0bc-1cd1-4581-9fe6-fa4f8ecf3b38

Fischer, J., Abson, D. J., Butsic, V., Chappell, M. J., Ekroos, J., Hanspach, J., … von Wehrden, H. (2014). Land sparing versus land sharing: Moving forward. *Conservation Letters, 7*(3), 149–157. https://doi.org/10.1111/conl.12084

Food and Agriculture Organization of the United Nations (FAO). (2022). *The State of the World's Forests 2022*. https://doi.org/10.4060/cb9360en

Food and Agriculture Organization of the United Nations (FAO). (2023). *Innovations in methane mitigation for dairy farming.* https://www.fao.org

Frontiers in Earth Science. (2021). A novel framework to define key performance indicators for nature-based solutions. https://www.researchgate.net/publication/355904449_The_'Rocket_Framework'_A_Novel_Framework_to_Define_Key_Performance_Indicators_for_Nature-based_Solutions_Against_Shallow_Landslides_and_Erosion

Gârban, G. (2025). *From fields to frameworks: Empowering farmers in EU climate action.* Interreg Europe. https://www.interregeurope.eu/sites/default/files/2025-06/DTE-Y3-Empowering%20Farmers%20in%20EU%20Climate%20Action_REPORT.pdf

Gerber, P. J., Steinfeld, H., Henderson, B., et al. (2013). *Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities.* FAO. https://www.fao.org/4/i3437e/i3437e.pdf

GIZ. (2018). *Rethinking agricultural finance: Designing products to better meet the needs of smallholders.* https://www.giz.de/en/projects/promotion-agricultural-finance-agribased-enterprisis-rural-areas

GLOBALG.A.P. (2022–2025). *Integrated Farm Assurance (IFA) v6—Principles & criteria and add-ons.* https://www.globalgap.org/what-we-offer/solutions/ifa-fruit-and-vegetables/?Certification+bodies=%7B%22columnFilters%22%3A%5B%5D%2C%22globalFilter%22%3A%22%22%2C%22sorting%22%3A%5B%7B%22id%22%3A%22certification%22%2C%22desc%22%3Afalse%7D%5D%2C%22pagination%22%3A%7B%22pageIndex%22%3A0%2C%22pageSize%22%3A15%7D%7D

Glazebrook, T., Noll, S., & Opoku, E. (2020). Gender matters: Climate change, gender bias, and women's farming. *Agriculture, 10*(7), 267. https://doi.org/10.3390/agriculture10070267

Gliessman, S. R. (2018). *Agroecology: The ecology of sustainable food systems* (4th ed.). CRC Press. https://www.researchgate.net/publication/233138094_Agroecology_The_Ecology_of_Food_Systems

Gonzalez-Ollauri, A., Munro, K., Mickovski, S. B., & Thomson, C. S. (2021). The 'Rocket Framework' for NBS KPIs. *Frontiers in Earth Science, 9*, 676059. https://doi.org/10.3389/feart.2021.676059

Greatrex, H., Hansen, J., Garvin, S., Diro, R., Blakeley, S., Le Guen, M., Rao, K., & Osgood, D. (2015). *Scaling up index insurance for smallholder farmers.* CCAFS Report 14. https://cgspace.cgiar.org/items/34d65f48-ad14-409b-9e4e-b6da7d28adda

GRI. (2021). *GRI Universal Standards 2021.* https://www.globalreporting.org/standards/standards-development/universal-standards/

Gupta, A., Köhler, R., Pistorius, T., & Turnhout, E. (2024). Governing sustainable supply chains under the EU deforestation regulation. *Global Environmental Politics, 24*(1), 112–133. https://doi.org/10.1162/glep_a_00699

Herrero, M., Henderson, B., Havlík, P., et al. (2016). Greenhouse gas mitigation potentials in the livestock sector. *Nature Climate Change.* https://www.nature.com/articles/nclimate2925

Herrero, M., et al. (2023). Reducing enteric fermentation emissions: Innovations in livestock management. *Global Change Biology, 29*(3), 845–860. https://www.theclimatedrive.org/es/action-library/reduce-enteric-fermentation-emissions-from-ruminant-animals

HLPE. (2020). *Food security and nutrition: Building a global narrative towards 2030.* https://www.researchgate.net/publication/344877437_FOOD_SECURITY_AND_NUTRITION_BUILDING_A_GLOBAL_NARRATIVE_TOWARDS_2030

Howard, P. H. (2016). *Concentration and power in the food system.* Bloomsbury. https://www.bloomsbury.com/us/concentration-and-power-in-the-food-system-9781472581143/

Howarth, D., & Quaglia, L. (2023). Regulatory fragmentation and financial governance in the EU. *European Journal of Financial Regulation, 19*(2), 215–239.

HSBC. (2022). *HSBC sustainability strategy.* HSBC. (2023). *Annual report and accounts 2023.* HSBC. (n.d.). *Forestry and agricultural commodities policy.*

IAASB. (2013). *ISAE 3000 (Revised): Assurance engagements other than audits or reviews of historical financial information.* https://www.iaasb.org/publications/isae-3000-revised-assurance-engagements-other-audits-or-reviews-historical-financial-information

ICAEW. (2025). *ISSB Scope 3 greenhouse gas emissions and agriculture – Implementation challenges and updates.*Institute of Chartered Accountants in England and Wales. https://www.icaew.com/insights/viewpoints-on-the-news/2025/jan-2025/issb-scope-3-and-agriculture

IDF (International Dairy Federation). (2022). *A common carbon footprint approach for the dairy sector.* https://fil-idf.org/wp-content/uploads/2022/03/IDF-common-approach-to-carbon-foot-printing-in-the-dairy-value-chain-using-a-lifecycle-assessment-approach-pager-002-1-1.pdf

IEA Bioenergy Task 37. (2019). *Biogas plant performance and operation: Lessons and good practices.* https://www.ieabioenergy.com/wp-content/uploads/2020/03/IEA-Task-37-Country-Report-Summaries-2019-1.pdf

IFC (International Finance Corporation). (2012). *Secured transactions systems and collateral registries.* https://documents.worldbank.org/en/publication/documents-reports/documentdetail/517431468344950619/secured-transactions-systems-and-collateral-registries

IFC. (2019). *Performance standards on environmental and social sustainability.* https://www.ifc.org/en/insights-reports/2012/ifc-performance-standards

IFC. (2021). *Innovative agricultural finance: Investing in productivity and climate resilience.*https://www.ifc.org/en/insights-reports/2025/catalyzing-and-scaling-innovations-for-resilient-agriculture

IFRS Foundation / ISSB. (2023). *IFRS Sustainability Disclosure Standards S1 and S2.* https://www.ifrs.org

IFRS Foundation / ISSB. (2023). *IFRS S1 – General Requirements for Disclosure of Sustainability-related Financial Information.* https://www.ifrs.org/content/dam/ifrs/publications/pdf-standards-issb/english/2023/issued/part-a/issb-2023-a-ifrs-s1-general-requirements-for-disclosure-of-sustainability-related-financial-information.pdf

IFRS Foundation / ISSB. (2023). *IFRS S2 – Climate-related Disclosures.*https://www.ifrs.org/content/dam/ifrs/publications/pdf-standards-issb/english/2023/issued/part-a/issb-2023-a-ifrs-s2-climate-related-disclosures.pdf

ILO. (1998/2022). *Declaration on fundamental principles and rights at work (as amended 2022).* https://www.ilo.org/sites/default/files/2024-04/ILO_1998_Declaration_EN.pdf

ILO. (2015). *Guidelines for a just transition towards environmentally sustainable economies and societies for all.* https://www.ilo.org/publications/guidelines-just-transition-towards-environmentally-sustainable-economies

ILO. (2019). *Safety and health at the heart of the future of work.* https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@dgreports/@dcomm/documents/publication/wcms_686645.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). *Global assessment report on biodiversity and ecosystem services.* https://files.ipbes.net/ipbes-web-prod-public-files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf

IPBES. (2023). *Global assessment update.*

Interreg Europe. (2020). *Renewable energy for sustainable agriculture.*https://www.interregeurope.eu/find-policy-solutions/stories/renewable-energy-sustainable-agriculture

International Sustainability Standards Board (ISSB). (2023). *Exposure draft on climate-related disclosures.*https://www.ifrs.org/projects/completed-projects/2023/climate-related-disclosures/

International Union for Conservation of Nature (IUCN). See Cohen-Shacham et al. (2016).https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf

IPCC. (2019). *Climate Change and Land: Special Report.* IPCC. (2021). *AR6—The Physical Science Basis.* IPCC. (2022). *AR6—Impacts, adaptation and vulnerability (WGII).* https://www.ipcc.ch/report/ar6/wg2/

IPCC. (2022). *AR6—Mitigation of climate change (WGIII)*. https://www.ipcc.ch/report/ar6/wg3/

IRENA. (2021). *Renewable Energy for Agri-Food Systems: Towards the Sustainable Development Goals and the Paris Agreement.*https://www.scirp.org/reference/referencespapers?referenceid=3782150

IRRI – International Rice Research Institute. (s.d.; 2017–2020). *Alternate Wetting and Drying (AWD) resources*. https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying

ISO. (2007). *ISO 22005: Traceability in the feed and food chain.* https://www.iso.org/standard/36297.html

ISO. (2015). *ISO 14001: Environmental management systems.* https://www.iso.org/standard/60857.html

ISO. (2019). *ISO 14064-2: Greenhouse gases—Project-level quantification, monitoring and reporting.* https://www.iso.org/obp/ui/#iso:std:iso:14064:-2:ed-2:v1:en

ISO. (2020). *ISO 22095: Chain of custody—General terminology and models.*https://www.iso.org/standard/72532.html

Italian Ministry of Agriculture. (2025). *Implementation action plan 2025–2027 for the Italian bioeconomy strategy.*https://cnbbsv.palazzochigi.it/media/gx3n4rwl/iap-16122024-en.pdf

Jelsma, I., Giller, K. E., & Fairbairn, A. (2022). Deforestation-free supply chains. *World Development Perspectives, 26*, 100419. https://doi.org/10.1016/j.wdp.2022.100419

Joint Research Centre (JRC). (2021). *Soil health and sustainable soil management in Europe.*

Koch, A., McBratney, A., Adams, M., Field, D. J., & Crawford, J. (2023). Governance challenges for soil security. *Nature Reviews Earth & Environment, 4*(3), 135–147. https://doi.org/10.1038/s43017-022-00399-6

Kok, M. T. J., Lüdeke, M., Lucas, P. L., Sterzel, T., Walther, C., Janssen, P., … Sietz, D. (2016). A new method for analysing socio-ecological patterns of vulnerability. *Regional Environmental Change, 16*, 229–243. https://doi.org/10.1007/s10113-014-0746-1

KPMG. (2023). *Navigating the CSRD: Practical insights for European businesses.* https://assets.kpmg.com/content/dam/kpmg/be/pdf/Navigating-CSRD-Reporting-in-Life-Sciences-July-2023.pdf

Lal, R. (2020). Managing soils for negative feedback to climate change. *Soil Science and Plant Nutrition.*https://www.tandfonline.com/doi/full/10.1080/00380768.2020.1718548

Lal, R. (2020). Regenerative agriculture for food and climate. *Journal of Soil and Water Conservation, 75*(5), 123A–124A. https://www.researchgate.net/publication/343379196_Regenerative_agriculture_for_food_and_climate

Lambin, E. F., Gibbs, H. K., Heilmayr, R., Carlson, K. M., Fleck, L. C., Garrett, R. D., … Walker, N. F. (2018). The role of supply-chain initiatives in reducing deforestation. *Nature Climate Change, 8*(2), 109–116. https://doi.org/10.1038/s41558-017-0061-1

Lambin, E. F., Gibbs, H. K., Heilmayr, R., Garrett, R. D., Carlson, K. M., & Walker, N. F. (2024). Deforestation-free supply chains: Progress, challenges and equity risks. *Nature Sustainability, 7*(2), 95–107. https://doi.org/10.1038/s41893-023-01123-9

Lenses Prima. (2021). *Catalogue of nature-based solutions.* https://www.lenses-prima.eu/outcomes/catalogue-of-nature-based-solutions/

Leifeld, J., & Menichetti, L. (2018). The underappreciated potential of peatlands in climate mitigation. *Nature Communications.* https://www.nature.com/articles/s41467-018-03406-6

Lipper, L., Thornton, P., Campbell, B. M., et al. (2014). Climate-smart agriculture for food security. *Nature Climate Change, 4*(12), 1068–1072. https://doi.org/10.1038/nclimate2437

Loan Market Association (LMA), Loan Syndications & Trading Association (LSTA), & Asia Pacific Loan Market Association (APLMA). (2023). *Sustainability-Linked Loan Principles.* https://www.lsta.org/content/sustainability-linked-loan-principles-sllp/

Lobell, D. B., Baldos, U. L. C., & Hertel, T. W. (2013). Climate adaptation as mitigation. *Environmental Research Letters, 8*(1), 015012. https://iopscience.iop.org/article/10.1088/1748-9326/8/1/015012

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science, 333*(6042), 616–620. https://doi.org/10.1126/science.1204531

Lugato, E., Bampa, F., Panagos, P., Montanarella, L., & Jones, A. (2014). Potential carbon sequestration of European arable soils. *Global Change Biology, 20*(11), 3557–3567. https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.12551

Mackenzie, C. A., Seto, K. C., & McCarthy, L. (2022). Just transitions for transformative change. *Nature Sustainability, 5*(1), 1–3. https://doi.org/10.1038/s41893-021-00837-7

Managing Livestock to Reduce Methane Emissions. (2022). New South Wales Department of Primary Industries (NSW DPI). https://www.dpi.nsw.gov.au/dpi/climate/Low-emissions-agriculture/carbon-farming-commprac/methane_emissions

Mazoyer, M., & Roudart, L. (2006). *A history of world agriculture.* Monthly Review Press. https://monthlyreview.org/product/a_history_of_world_agriculture/

McMichael, P. (2021). Corporate agri-food systems and the global food regime. In J. A. McMahon & M. Cardwell (Eds.), *Research Handbook on Agriculture, Law and Policy* (pp. 50–69). Edward Elgar. https://doi.org/10.4337/9781784719388.00010

Melati, K., Jintarith, P., & Lee, H. (2024, September 3). Finding a place for smallholder farmers in EU deforestation regulation. Stockholm Environment Institute. https://doi.org/10.51414/sei2024.035

Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., & Beintema, N. (2012). *Engendering agricultural research, development and extension.* IFPRI. https://www.researchgate.net/publication/254417045_Engendering_agricultural_research_development_and_extension

Montanarella, L., & Panagos, P. (2021). The relevance of sustainable soil management within the European Green Deal. *Land Use Policy, 100*, 104950. https://www.sciencedirect.com/science/article/pii/S0264837720304257

Montanarella, L., Pennock, D. J., McKenzie, N., Badraoui, M., Chude, V., Baptista, I., … Vargas, R. (2016). World's soils are under threat. *SOIL, 2*(1), 79–82. https://doi.org/10.5194/soil-2-79-2016

Moorhead, A. (2020). *Aligning agricultural finance with climate outcomes.* CCAFS/CGIAR. https://iaes.cgiar.org/sites/default/files/pdf/CCAFS%20CRP%20Review%202020%20Report_0.pdf

Mottet, A., Henderson, B., Opio, C., et al. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. https://www.sciencedirect.com/science/article/pii/S221209631730027X

NASA. (n.d.). *FIRMS: Fire Information for Resource Management System.* https://firms.modaps.eosdis.nasa.gov/

Nature4Cities. (2019). *Defined performance indicators to assess urban challenges and nature-based solutions.* https://www.nature4cities.eu/post/nature4cities-defined-performance-indicators-to-assess-urban-challenges-and-nature-based-solutions

Net-Zero Banking Alliance (NZBA). (2021). *Commitment statement and guidelines for climate target setting*. UNEP FI. https://www.unepfi.org/wordpress/wp-content/uploads/2025/04/Guidance-for-Climate-Change-Target-Setting-Version-3.pdf

Network for Greening the Financial System (NGFS). (2023). *NGFS climate scenarios for central banks and supervisors.* https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-climate-scenarios-central-banks-and-supervisors

Network for Greening the Financial System (NGFS). (2024–2025). *Scenario guidance & supervisory expectations su rischi clima/natura.*

OECD. (2020). *Agricultural policy monitoring and evaluation 2020.* https://www.oecd.org/en/publications/2020/06/agricultural-policy-monitoring-and-evaluation-2020_009f869e.html

OECD. (2020). *Mobilising private climate finance: Lessons from OECD DAC members.*

OECD. (2021). *Environmental performance indicators for agriculture.* https://www.oecd.org/en/publications/environmental-performance-of-agriculture-in-oecd-countries_2679ba38-en.html

OECD. (2021). Design principles for agricultural risk management policies (OECD Food, Agriculture & Fisheries Paper No. 157). https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/05/design-principles-for-agricultural-risk-management-policies_40bef0a4/1048819f-en.pdf

OECD. (2021). *Agricultural Policy Monitoring and Evaluation 2021*. https://www.oecd.org/en/publications/agricultural-policy-monitoring-and-evaluation-2021_2d810e01-en.html

OECD. (2023). *Informality and globalisation: In search of a new social contract.* https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/04/informality-and-globalisation_d7548f2e/c945c24f-en.pdf

OECD & FAO. (2016). *OECD–FAO guidance for responsible agricultural supply chains.* https://www.oecd.org/en/publications/2016/10/oecd-fao-guidance-for-responsible-agricultural-supply-chains_g1g63c3a.html

OECD-FAO. (2022). *Agricultural outlook 2022–2031.* https://www.oecd.org/en/publications/2022/06/oecd-fao-agricultural-outlook-2022-2031_e00c413c.html

OECD & FAO. (2025). *OECD-FAO Agricultural Outlook 2025-2034.* https://www.oecd.org/en/publications/2025/07/oecd-fao-agricultural-outlook-2025-2034_3eb15914.html

Oxfam. (2023). *Risky business: How banks' agricultural lending fuels land grabs and human rights abuses.* https://www.oxfam.org/en/research/risky-business

Pahl-Wostl, C. (2015). *Water governance in the face of global change.* Springer. https://doi.org/10.1007/978-3-319-21855-7

Pagiola, S. (2008). Payments for environmental services in Costa Rica. *Ecological Economics, 65*(4), 712–724. https://www.sciencedirect.com/science/article/abs/pii/S0921800907004235

Partnership for Carbon Accounting Financials (PCAF). (2025). *Global GHG Accounting and Reporting Standard for the Financial Industry: Agriculture and Forestry Supplement (Version 2.0).* PCAF. https://carbonaccountingfinancials.com/standard

Paustian, K., Larson, E., Kent, J., Marx, E., & Swan, A. (2016). Soil C sequestration as a biological negative emission strategy. *Frontiers in Climate, 1*, 8. https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2019.00008/full

Paustian, K., et al. (2023). Soil carbon sequestration and conservation agriculture: Evidence from row-crop systems. *Agriculture, Ecosystems & Environment, 346*, 108522. https://www.researchgate.net/profile/Sumanta-Kundu-2/publication/273003912_Conservation_Agriculture_and_Soil_Carbon_Sequestration/links/54f6c7ef0cf2ca5efeff3817/Conservation-Agriculture-and-Soil-Carbon-Sequestration.pdf

Pearce, F. (2015). Global extinction rates: Why do estimates vary so wildly? *Yale Environment 360.* https://e360.yale.edu/features/global_extinction_rates_why_do_estimates_vary_so_wildly

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., … Lakner, S. (2020). EU agricultural reform fails on biodiversity. *Science, 370*(6515), 1282–1284. https://doi.org/10.1126/science.abd9494

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., … & Lakner, S. (2019). A greener path for the EU Common Agricultural Policy. *Science, 365*(6452), 449–451. https://doi.org/10.1126/science.aax3146

Phalan, B., Onial, M., Balmford, A., & Green, R. E. (2011). Land sharing vs. land sparing. *Science, 333*(6047), 1289–1291. https://doi.org/10.1126/science.1208742

Phan, H., Nguyen, L., Dao, T., & Trinh, H. (2021). Sentinel-1 backscatter time-series for rice monitoring. *Remote Sensing, 13*(5), 921.Phan, H., Nguyen, L., Dao, T., & Trinh, H. (2021). Sentinel-1 backscatter time-series for rice monitoring. Remote Sensing, 13(5), 921.

Pickering, N. K., Oddy, V. H., Basarab, J., et al. (2015). Genetic possibilities to reduce enteric methane emissions from ruminants.Pickering, N. K., Oddy, V. H., Basarab, J., et al. (2015). Genetic possibilities to reduce enteric methane emissions from ruminants.

Pingali, P. (2012). Green revolution: Impacts, limits, and the path ahead. *PNAS, 109*(31), 12302–12308. https://doi.org/10.1073/pnas.0912953109

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts trough producers and consumers. *Science.*https://www.science.org/doi/10.1126/science.aaq0216

Porter, J. R., et al. (2014). Food security and food production systems. In *IPCC AR5 WGII*. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap7_FINAL.pdf

PPIAF. (2018). *Innovative agricultural SME finance models.*https://documents1.worldbank.org/curated/en/133761468338532319/pdf/949100WP0Box380l0SME0Finance0Models.pdf

Primdahl, J., Kristensen, L. S., Busck, A. G., & Vejre, H. (2023). Eco-schemes and nature-based solutions. *Land Use Policy, 136*, 106964. https://doi.org/10.1016/j.landusepol.2023.106964

R2M Solution. (2024). *Nature-based solutions: ESG value.*https://www.r2msolution.com/nature-based-solutions-nbss-for-sustainability-and-as-an-investment/

Rabobank. (2021). *A Reduced-Methane Future for Dairy: Meaningful Progress That's Economically Sustainable*https://www.rabobank.com/knowledge/q011335622-a-reduced-methane-future-for-dairy-meaningful-progress-that-s-economically-sustainable

Rabobank. (2023). *Sustainability report 2023: Accelerating the transition to net zero agriculture.* https://www.rabobank.co.nz/content/dam/ranz/ranz-website-images/rbnz-files/pdf/Rabobank%20New%20Zealand%202023%20Sustainability%20Report.pdf

Rabobank. (2024). *Strengthening rural livelihoods.* https://www.rabobank.com/about-us/sustainability/food-system-transition/strengthening-rural-livelihoods

Rabobank. (2025). *Sustainability policies briefing.* https://www.rabobank.com/about-us/sustainability

Rabobank. (2025). One step ahead in carbon reduction: Youran's USD 150m sustainability-linked loan. https://www.rabobank.com/about-us/impact/article/011469603/one-step-ahead-in-carbon-reduction-yourans-usd-150m-sustainability-linked-loan

Rabobank Rabo Foundation. (2021). *Impact report 2021.* https://www.rabobank.nl/en/about-us/rabofoundation/impactjaarverslag-2021

Rainforest Alliance. (2025). *2020 Sustainable Agriculture Standard – Farm & Supply Chain requirements.*https://www.rainforest-alliance.org/resource-item/2020-sustainable-agriculture-standard-supply-chain-requirements/

Rabobank. (2025). *Our approach to climate & nature*. https://www.rabobank.com/about-us/sustainability/what-we-do/our-approach-to-climate-and-nature

Regulation (EU) 2023/1111. (2023). Amending Regulation (EU) No 575/2013 (CRR) as regards requirements for credit risk, CVA risk, operational risk, market risk, and the output floor. https://eur-lex.europa.eu/eli/reg/2024/1623/oj/eng

Reuters. (2025). *JPMorgan becomes latest U.S. lender to quit NZBA* (7 Jan 2025). https://www.reuters.com/business/environment/jpmorgan-says-leave-net-zero-banking-alliance-2025-01-07/

Reuters (Clean Industrial Deal). (2025, Feb). *EU plan to mobilise €100bn for EU-made clean tech / de-risk PPAs; Clean Industrial Deal package.* https://www.reuters.com/sustainability/sustainable-finance-reporting/european-commission-proposes-mobilising-100-bln-euros-eu-made-clean-tech-2025-02-26

Rhodes, C. J. (2017). The imperative for regenerative agriculture. *Science Progress, 100*(1), 80–129. https://doi.org/10.3184/003685017X14876775256165

Rickards, L., Wiseman, J., Edwards, T., & Biggs, C. (2014). The problem of fit: Scenario planning and climate adaptation in the public sector. *Environment and Planning C, 32*(4), 641–662. https://www.researchgate.net/publication/268146640_The_Problem_of_Fit_Scenario_Planning_and_Climate_Change_Adaptation_in_the_Public_Sector

Rockström, J., Steffen, W., Noone, K., et al. (2009). A safe operating space for humanity. *Nature, 461*(7263), 472–475. https://doi.org/10.1038/461472a

Rosa, L., Rulli, M. C., Davis, K. F., Chiarelli, D. D., Passera, C., & D'Odorico, P. (2018). Closing the yield gap while ensuring water sustainability. *Environmental Research Letters, 15*(10), 104053. https://www.researchgate.net/publication/327448220_Closing_the_yield_gap_while_ensuring_water_sustainability

Science Based Targets initiative (SBTi). (2022). *Forest, Land and Agriculture (FLAG) Guidance* https://sciencebasedtargets.org/sectors/forest-land-and-agriculture

SBTi. (2023). *Corporate Net-Zero Standard.* https://sciencebasedtargets.org

SBTi FLAG Guidance. (2022). *Forest, land and agriculture sector guidance.* Science Based Targets initiative. https://sciencebasedtargets.org/sectors/forest-land-and-agriculture

Scheben, A., & Edwards, D. (2018). Genome editors take on crops. *Science, 361*(6401), 111–112. https://doi.org/10.1126/science.aau6380

Searchinger, T., et al. (2015). Biofuels and land-use change. *Science, 319*(5867), 1238–1240. https://doi.org/10.1126/science.1151861

Searchinger, T., et al. (2023). Accounting for indirect land-use change in agricultural emissions: A critical review. *Environmental Science & Policy, 141*, 26–34. https://pmc.ncbi.nlm.nih.gov/articles/PMC3350742/

Shagun. (2023, April 11). Not just green: Natural farming in Andhra yielded more produce… *Down To Earth.* https://www.downtoearth.org.in/agriculture/not-just-green-natural-farming-in-andhra-yielded-more-produce-than-conventional-methods-shows-study-88713

Shaffril, H. A. M., Samah, A. A., Samsuddin, S. F., Ahmad, N., Tangang, F., Sidique, S. F. A., … & Khalid, N. A. (2020). Diversification of agriculture practices in low-income countries: A systematic review. *Journal of Cleaner Production, 253*, 119706. https://doaj.org/article/6c9aff8f7c3646a78cd19ae8473a7e98

Shindell, D., Kuylenstierna, J. C., Vignati, E., et al. (2012). Simultaneously mitigating near-term climate change and improving health and food security. *Science, 335*(6065), 183–189. https://pubmed.ncbi.nlm.nih.gov/22246768/

Smith, P., et al. (2019). How to MRV soil carbon change. *Global Change Biology, 26*(1), 219–241. https://pubmed.ncbi.nlm.nih.gov/31469216/

Smith, S. (2019). Fairtrade, diversification, and farmer livelihoods. *World Development, 123*, 104607.https://www.researchgate.net/profile/Alastair-Smith-5/publication/46527245_Fair_Trade_Diversification_and_Structural_Change_Towards_a_Broader_Theoretical_Framework_of_Analysis/links/5540f4b50cf2b790436bc169/Fair-Trade-Diversification-and-Structural-Change-Towards-a-Broader-Theoretical-Framework-of-Analysis.pdf

Somarriba, E., Palma, J. H. N., & Montagnini, F. (2021). Agroforestry: A global land-use solution. *Agronomy, 11*(4), 789. https://www.researchgate.net/publication/229473725_Agroforestry_Land_Use_The_Concept_and_Practice

Steffen, W., Richardson, K., Rockström, J., et al. (2015). Planetary boundaries: Guiding human development. *Science, 347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Szewran, M., Wojcik, K., & Drahokoupil, J. (2023). Just transition in practice: Lessons from Poland's coal regions. *Energy Research & Social Science, 100*, 103022. https://doi.org/10.1016/j.erss.2023.103022

Task Force on Climate-related Financial Disclosures (TCFD). (2017). *Recommendations of the TCFD.* https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

The Guardian. (2025, 1 Aug). *Barclays follows HSBC in exit from NZBA.*https://www.theguardian.com/business/2025/aug/01/barclays-hsbc-exit-net-zero-banking-alliance

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and sustainable intensification. *PNAS, 108*(50), 20260–20264. https://www.pnas.org/doi/10.1073/pnas.1116437108

TNFD (Taskforce on Nature-related Financial Disclosures). (2023). *TNFD recommendations.* https://tnfd.global/publication/recommendations-of-the-taskforce-on-nature-related-financial-disclosures/

Transition Pathway Initiative (TPI). (2023). *Annual sectoral decarbonization report.* https://www.transitionpathwayinitiative.org/

Transition Pathway Initiative (TPI). (2025). *State of the Corporate Transition 2025.* TPI Centre. https://www.transitionpathwayinitiative.org/publications/2025-state-of-the-corporate-transition-2025

Tscharntke, T., Clough, Y., Wanger, T. C., et al. (2012). Global food security, biodiversity conservation and agricultural intensification. *Biological Conservation, 151*(1), 53–59. https://www.sciencedirect.com/science/article/abs/pii/S0006320712000821

Tscharntke, T., Grass, I., Wanger, T. C., Westphal, C., Batáry, P., & Bengtsson, J. (2021). Beyond organic farming—Harnessing biodiversity-friendly landscapes. *Trends in Ecology & Evolution, 36*(10), 919–930. https://www.sciencedirect.com/science/article/pii/S016953472100183X

UN (United Nations). (2015). *Transforming our world: The 2030 Agenda for Sustainable Development.* http://sdgs.un.org/2030agenda

UN (United Nations). (2023). *Sustainable development goal 6: 2023 report.* https://unstats.un.org/sdgs/report/2023/

UNEP (United Nations Environment Programme). (2021). *Global land outlook 2.* https://www.unccd.int/resources/global-land-outlook/glo2

United Nations Environment Programme Finance Initiative (UNEP FI). (2020). *Charting a new climate: Physical risk tools and data for banks.* https://www.unepfi.org/wordpress/wp-content/uploads/2020/09/Charting-a-New-Climate-UNEP-FI-TCFD-Banking-Physical-Risk.pdf

UNEP FI. (2021). *Net-Zero Banking Alliance: Guidelines for climate target setting for banks.* https://www.unepfi.org/wordpress/wp-content/uploads/2025/04/Guidance-for-Climate-Change-Target-Setting-Version-3.pdf

UNEP FI. (2023). *Climate risks in the agriculture sector: A market review.* https://www.unepfi.org/wordpress/wp-content/uploads/2023/03/Agriculture-Sector-Risks-Briefing.pdf

UNEP FI (2023). *Driving Finance for Sustainable Food Systems: A Roadmap to Implementation for Financial Institutions and Policy Makers.* https://www.unepfi.org/wordpress/wp-content/uploads/2023/04/Driving-Finance-for-Sustainable-Food-Systems.pdf

UNEP FI. (2023). *Making agricultural finance climate-smart: A toolkit for financial institutions.*https://www.unepfi.org/

UNEP FI. (2024). *NZBA 2024 Progress Report* https://www.unepfi.org/industries/banking/net-zero-banking-alliance-2024-progress-update/

UNEP FI (United Nations Environment Programme Finance Initiative). (2024). *Food System Transition Finance: Scaling inclusive and climate-smart investment.* UNEP FI. https://www.unepfi.org/publications/food-system-transition-finance/

UNEP FI. (2025). *Guidance for Climate Target Setting for Banks – Version 3.* https://www.unepfi.org/industries/banking/guidance-for-climate-target-setting-for-banks-version-3/

UNFCCC. (2015). *Paris Agreement.* UNFCCC. (2021). *Just transition work programme under the Paris Agreement.* https://unfccc.int/process-and-meetings/the-paris-agreement

United Nations Development Programme (UNDP). (2022). *Climate promise: Global progress report 2022.* https://climatepromise.undp.org/sites/default/files/research_report_document/Climate%20Promise%20Global%20Progress%20Report%202022.pdf

Van der Ploeg, J. D. (2020). Farmers' upheaval, climate crisis and populism. *Journal of Peasant Studies, 47*(3), 589–605. https://www.tandfonline.com/doi/full/10.1080/03066150.2020.1725490

WBA. (2023). *Agricultural sector benchmark*; *Food and agriculture benchmark report 2023.*https://www.worldbenchmarkingalliance.org/food-and-agriculture-benchmark/

WBCSD (World Business Council for Sustainable Development). (2019). *Farm Sustainability Assessment 3.0.* https://www.wbcsd.org/

WBCSD. (2023). *Sustainability reporting: Challenges and opportunities for SMEs in agri-food chains.*https://www.wbcsd.org/news/ongoing-evolution-sustainable-business-2023-trends-report/

World Bank. (2009). *Warehouse receipts: Facilitating credit and commodity markets.* https://documents.worldbank.org/en/publication/documents-reports/documentdetail/224521468316149887/warehouse-receipts-facilitating-credit-and-commodity-markets

World Bank. (2019). *Enabling the business of agriculture 2019.* https://eba.worldbank.org/

World Bank. (2019). *Future of food: Shaping the food system to deliver jobs.* https://www.worldbank.org/en/topic/agriculture/publication/the-future-of-food-shaping-the-food-system-to-deliver-jobs

World Bank. (2021). *Climate-smart agriculture indicators.* https://documents.worldbank.org/en/publication/documents-reports/documentdetail/187151469504088937/climate-smart-agriculture-indicators

World Bank. (2021). *Climate-smart agriculture investment plan sourcebook.* https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099405004272216892

World Resources Institute (WRI). (2019). *Creating a sustainable food future.* https://www.wri.org/research/creating-sustainable-food-future

WRI. (2019). *5 questions about agricultural emissions, answered.* https://www.wri.org/insights/5-questions-about-agricultural-emissions-answered

World Water Assessment Programme (WWAP). (2021). *The UN World Water Development Report 2021: Valuing water.* UNESCO.https://www.unesco.org/reports/wwdr/2021/en

World Wide Fund for Nature (WWF). (2023). *Banking on biodiversity: Financial institutions' exposure to deforestation risks in South America.*https://wwfint.awsassets.panda.org/downloads/full-report-en---wwf-latin-america-sustainable-banking-assessment-susba-2024.pdf

Yagboyaju, D. A., & Akinola, A. O. (2019). Nigerian state and the crisis of governance. *SAGE Open, 9*. https://doi.org/10.1177/2158244019865810

Zhang, Q. F. (2024). From sustainable agriculture to sustainable agrifood systems: A comparative review of alternative models. *Sustainability, 16*(22), 9675. https://doi.org/10.3390/su16229675

Zhang, X., Davidson, E. A., Mauzerall, D. L., Searchinger, T. D., Dumas, P., & Shen, Y. (2015). Managing nitrogen for sustainable development. *Nature, 528*(7580), 51–59. https://www.nature.com/articles/nature15743

Zimmerman, F. J., & Carter, M. R. (2019). Managing systemic risk in agricultural finance. *Journal of Development Economics, 139*, 22–32. https://doi.org/10.1016/j.jdeveco.2018.12.004