INCREASING AMBITION IN NATIONALLY DETERMINED CONTRIBUTIONS THROUGH AGRICULTURE AND FOOD SYSTEMS INNOVATION

Evidence, foundational analysis, and recommendations for NDCs

UNITED NATIONS FOUNDATION

CLIMATE FOCUS

Increasing ambition in Nationally Determined Contributions through agriculture and food systems innovation: *Evidence, foundational analysis, and recommendations for NDCs*

A disquisition commissioned by the Agriculture Innovation Mission for Climate (AIM for Climate) and developed by the United Nations Foundation and Climate Focus

Authors:
Christine Negra, UN Foundation
Sara Minoli, Climate Focus
Haseeb Bakhtary, Climate Focus

We extend our gratitude to the following individuals who generously shared their time and expertise as reviewers. Their insights and support proved invaluable.

- Abdou Tenkouano, International Centre of Insect Physiology and Ecology (icipe)
- Ajay Panchbhai, International Rice Research Institute (IRRI), CGIAR
- Atu Bilaro, Tanzania Agricultural Research Institute (TARI)
- Brent Loken, WWF-International
- Cristina Rumbaitis del Rio, United Nations Foundation
- Franziska Haupt, Climate Focus
- Hellen Keti, Abosi Top Hill Farmers' Cooperative
- Jaime Adams, US Department of Agriculture
- Jean Claude Rubyogo, Pan-Africa Bean Research Alliance (PABRA), Alliance Bioversity & CIAT, CGIAR
- Kelly Witkowski, The Nature Conservancy (TNC)
- Maha al-Zu'bi, International Water Management Institute (IWMI), CGIAR
- Mateete Bekunda, International Institute of Tropical Agriculture (IITA), CGIAR
- Mbaye Diop, Senegalese Institute for Agricultural Research (ISRA)
- Milindi Sibomana, One Acre Fund
- Melaina Dyck, Climate Focus
- Molly McGregor, NDC Partnership
- Moses Odeke, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)
- Oumar Baba Samaké, EcoTech Mali
- Paul Winters, International Commission for Climate Change, Food Security, and Agriculture
- Ryan O'Connor, NDC Partnership
- Sara Wolf, NDC Partnership

We deeply appreciate the support of following individuals in reviewing NDC documents:

- Georg Hahn, Climate Focus
- Jacob Shea, Climate Focus
- Malachy Tierney, Climate Focus
- Pablo Nuñez, Climate Focus
- Maria José Rodezno Ayestas, Climate Focus
- Theda Vetter, Climate Focus

Special thanks for inputs from the UN Foundation Climate and Environment team: Ryan Hobert, Lasse Bruun, Evelin Toth, Carrie Fernandes, and Scarlett Kao.

Design: Elisa Perpignan, Climate Focus

Publication date: September 2024

CONTENTS

1. Executive summary **5**

1.1 Investing in agriculture and food systems innovation 5
1.2 Agriculture and food systems innovation in current NDCs 7
1.3 Recommendations for policymakers 9

2. Setting the scene **14**

3. Methodology **19**

4. Evidence for investing in agriculture and food systems innovation **23**

4.1 Research and development (R&D) systems 23
4.2 Information systems 25
4.3 On-farm production 26
4.4 Post-harvest handling 27
4.5 Markets 28
4.6 Finance 29
4.7 Policy 32

5. Agriculture and food systems innovation in current NDCs **36**

5.1 Inclusion of agriculture and food systems innovation in existing NDCs 36
5.2 Relationship between country characteristics and inclusion of innovation in NDCs 38
5.3 Country requests for support with agriculture and food systems innovation 47

6. Recommendations for policymakers **50**

6.1 High-level recommendations 50
6.2 Policy measures for agriculture and food systems innovation in NDCs 52
6.3 Final reflections 56

Annex 1 – Methodology for NDC review **58**

Annex 2 – Results: Keyword search of NDC documents **63**

Annex 3 – Examples of agriculture and food systems innovation in NDCs **69**

Annex 4 – Complementary findings: country requests for support through the NDC Partnership **74**

Annex 5 – Literature sources **78**

CHAPTER 1

EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY

The world faces unprecedented urgency to make agriculture and food systems more resilient to climate change and to lower the greenhouse gas (GHG) emissions they generate. Formulation of the next round of Nationally Determined Contributions (NDCs), due in 2025 as part of the Paris Agreement cycle, offers a unique opportunity to strengthen investment in and support for the research and innovation that will undergird any serious efforts to transform our agriculture and food systems.

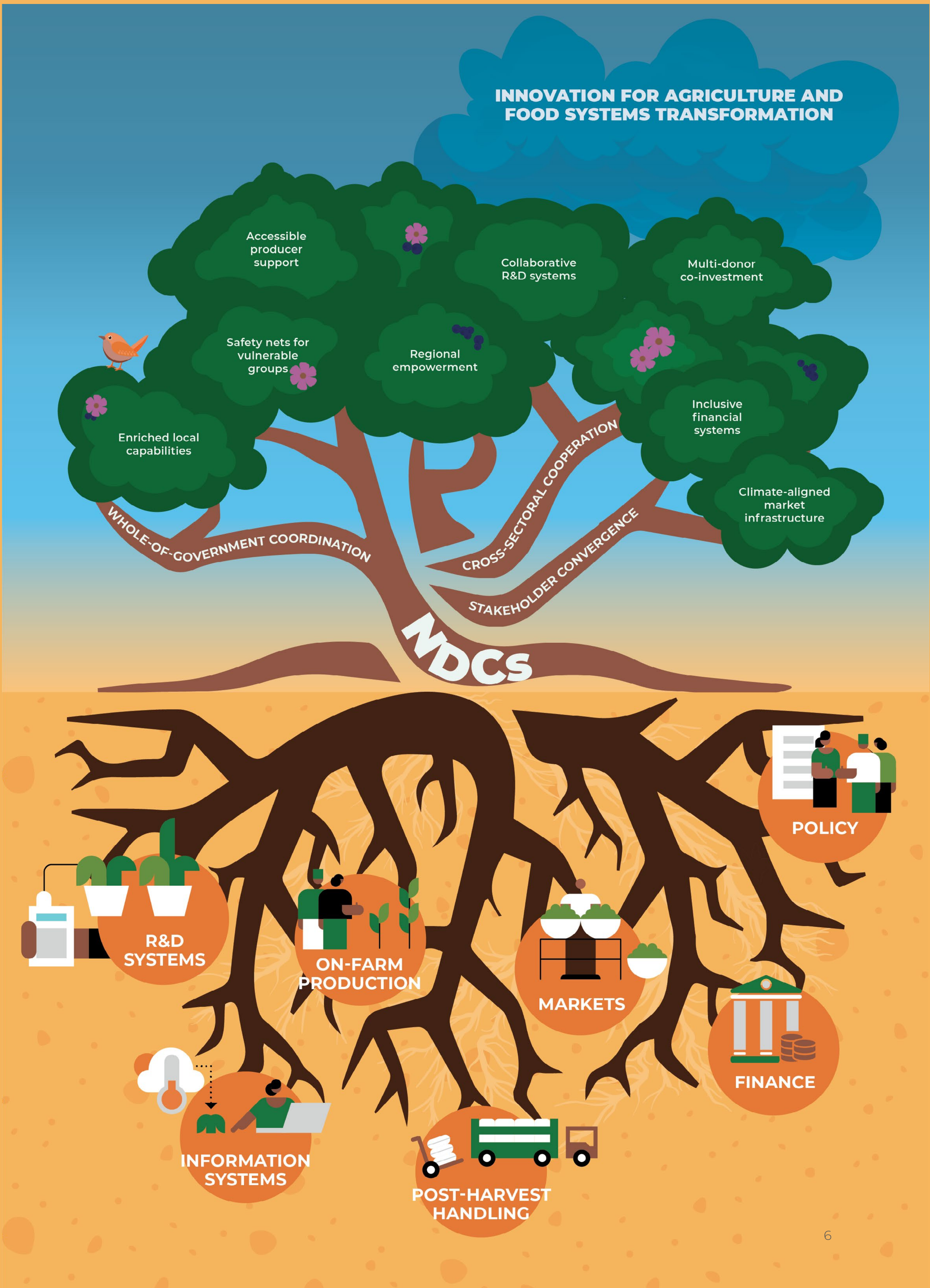
NDCs provide a platform to bring all climate-related national policy priorities together, including to plan and implement agriculture and food systems measures in a holistic manner. **This report explores how robust inclusion of seven major categories of agriculture and food system innovation in NDCs is relevant for all countries seeking to cultivate transformative investments that increase their climate action ambition.**

1.1 Investing in agriculture and food systems innovation

Agriculture and food systems encompass primary production, transport, storage, processing, retail, and consumption and they are shaped by research and information systems, financial flows, and policy contexts. Achieving productivity, sustainability, and resilience in agriculture and food systems requires innovation, in many different forms. Innovation is a multi-scale and iterative process of creating and putting into use practices that are new to a particular context (FAO, 2019a).

We reviewed recent literature to assess the effectiveness of investing in agriculture and food systems innovation for achieving necessary climate and agriculture outcomes. We found strong evidence to support enhancing national commitment to investments in seven major categories of innovation.

- **Research & Development (R&D) systems –** Investments in agricultural research improve productivity and economic growth, however transformative innovation is hampered by inadequate and imbalanced funding and insufficient collaboration across regions and sectors.
- **Information systems –** New types of data gathering and analysis have improved the information landscape for agriculture and food, however equitable access and benefits will depend on improved governance systems that promote trust, data-sharing, and steady funding.
- **On-farm production –** Despite technological progress, climate-aligned productivity gains at scale will require greater support to producers and value chain actors in adopting appropriate technologies and practices.
- **Post-harvest handling –** Tactical deployment of appropriate interventions across complex, multi-level food supply chains can increase efficiency and mitigate food losses and waste that generate GHG emissions and increase vulnerability.


INNOVATION FOR AGRICULTURE AND FOOD SYSTEMS TRANSFORMATION
Accessible producer support
Collaborative R&D systems
Multi-donor co-investment
Safety nets for vulnerable groups
Regional empowerment
Inclusive financial systems
Enriched local capabilities
Climate-aligned market infrastructure
WHOLE-OF-GOVERNMENT COORDINATION
CROSS-SECTORAL COOPERATION
STAKEHOLDER CONVERGENCE
NDCs
POLICY
R&D SYSTEMS
ON-FARM PRODUCTION
MARKETS
FINANCE
INFORMATION SYSTEMS
POST-HARVEST HANDLING

- **Markets –** Improved market price transparency, changes in sectoral subsidies, and other strategies can better enable and incentivize climate-aligned agricultural production.
- **Finance –** To validate new finance models for climate adaptation and mitigation in agriculture and food systems, greater coordination among governments and across sectors can increase fluency with climate-aligned investment needs and opportunities.
- **Policy –** Holistic, transformative national strategies can deploy under-utilized policy tools and promote whole-of-government approaches to more equitably allocate costs and benefits of climate-aligned sectoral transitions.

1.2 Agriculture and food systems innovation in current NDCs

We assessed the prevalence of agriculture and food systems innovation in NDCs submitted by 167 Parties to the Paris Agreement as of May 2024. NDC documents were reviewed for mentions of 130 keywords related to seven categories of agriculture and food systems innovation.

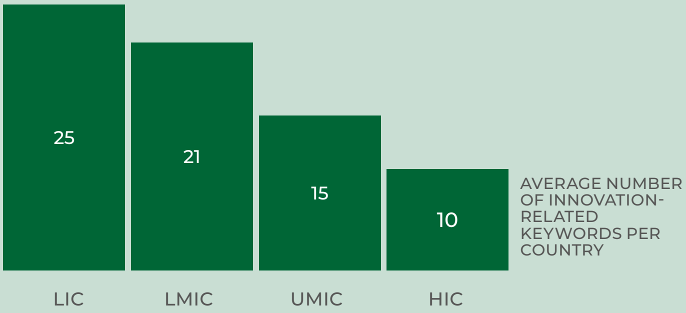
Most countries mention at least one category of agriculture and food systems innovation in their NDCs, however low-income countries include more categories and more keywords overall. More countries refer to innovation in on-farm production in their NDCs than to any other innovation category and, on average, countries mention keywords related to on-farm production more often.

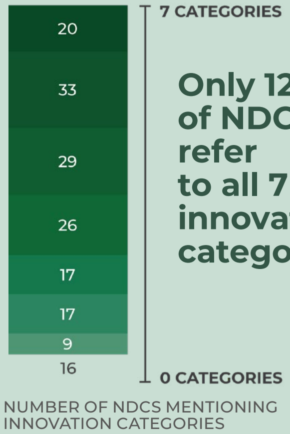
In future NDCs, governments can signal an intention to increase and re-balance investment to more effectively incentivize climate-aligned changes in agriculture and food systems. As countries amplify agriculture and food objectives in their NDCs, the likelihood of achieving these objectives will increase through explicit inclusion of measures that support innovation.

Agriculture and food systems innovation could be included more prominently in many NDCs

A comprehensive review of 167 Nationally Determined Contributions (NDCs) assessed how often Parties to the Paris Agreement mentioned 130 keywords related to seven categories of agriculture and food systems innovation.

Agriculture and food systems innovation is mentioned in NDCs more often by lower-income countries.





Only 12% of NDCs refer to all 7 innovation categories.

Nearly all NDCs refer to innovation in on-farm production. Other innovation categories receive less attention.

SEVEN INNOVATION CATEGORIES

PERCENT OF COUNTRIES REFERRING TO INNOVATION CATEGORIES

R&D systems that effectively integrate national, in-region, and international research capacities

Information systems that equitably deliver actionable resources for management, planning, and policy making

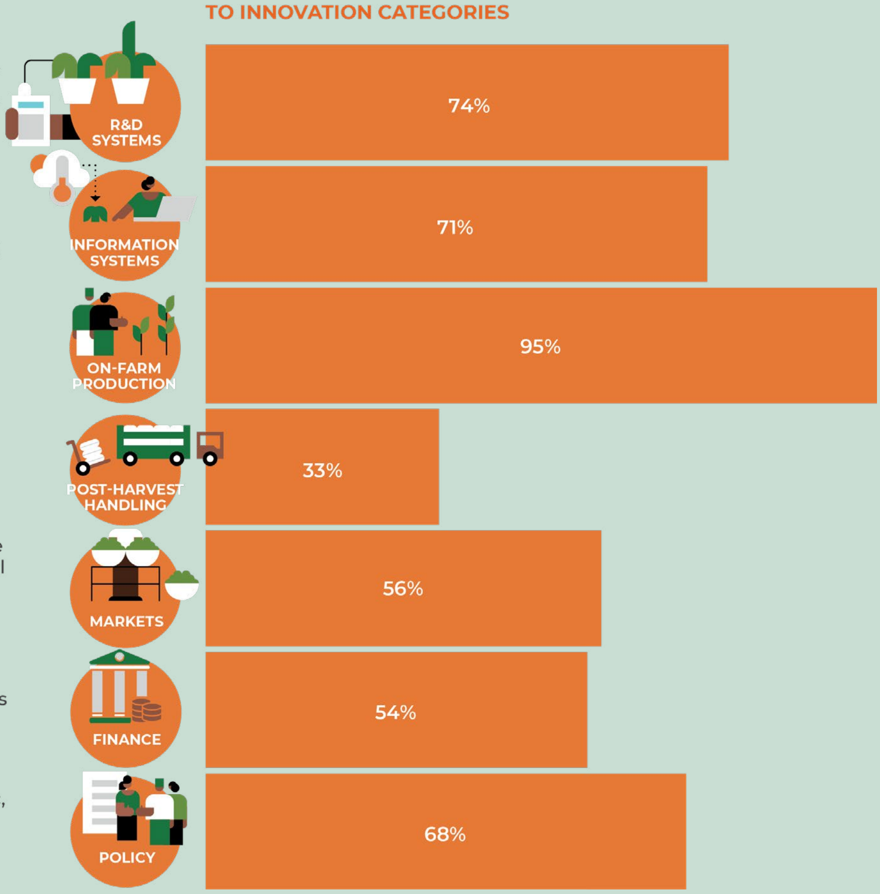
On-farm production that increases resilience and sustainability

Post-harvest handling that adds value and efficiently reduces loss and waste

Markets that expand income opportunities for agricultural producers and value chain actors

Finance that flows toward climate-aligned technologies and practices

Policy that promotes holistic, transformative national strategies

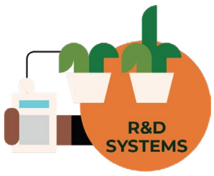


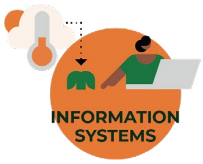
1.3 Recommendations for policymakers

With several categories of agriculture and food systems innovation only modestly included in existing NDCs, the next phase of NDC submissions presents an important opportunity for policymakers to scale up their climate ambition. Review of recent literature and existing NDCs suggests the following overarching strategies are relevant for all countries as they develop NDCs:

- **Take a holistic approach** to climate-aligned agricultural and food systems that re-balances investment across multiple, mutually reinforcing forms of innovation.
- **Cultivate stakeholder convergence** on the importance and feasibility of new policies and investments and **enrich capabilities for locally led innovation** among in-region researchers, producers, extension advisors, agri-entrepreneurs, public officials, and local financial institutions.
- **Pursue national innovation priorities** through targeted, evidence-based investments in existing agricultural value chains, R&D systems, and other **national assets**.
- Achieve long-term climate goals by **co-investing carefully** through negotiated international partnerships that equitably allocate risks and benefits and deliver stable funding for national institutions.

Table 1. Recommendations for including seven categories of agriculture and food systems innovation in NDCs

INNOVATION CATEGORY	RECOMMENDATIONS
	• Maintain and increase base funding for national agricultural research institutions to ensure they can fully deliver on national climate science priorities while effectively working with international institutions and private companies to collaboratively develop new knowledge and to adapt relevant technologies. • Establish goals and guidelines for public-private R&D partnerships to ensure these deliver public value through commercialization of research outputs that are tailored to local biophysical and socio-economic conditions. • Mandate national mechanisms for comprehensive assessment of R&D impacts and gaps focusing on productivity, resilience, and GHG emissions, while also considering socio-economic and biodiversity objectives.

INNOVATION CATEGORY	RECOMMENDATIONS
	• Continue and enhance data-gathering and data-sharing related to agricultural yields, soil and water quality, agrobiodiversity, greenhouse gas emissions, food security, market activity, labor, and other environmental and socio-economic dimensions of agriculture and food systems through national programs and international partnerships and translate these data into meaningful and usable information for producers and value chain actors. • Mandate whole-of-government mechanisms for tracking and assessing the impact of agriculture and food system policies and programs to better understand how these help or hinder climate-aligned sectoral transitions, especially for vulnerable, small-scale production systems. • Participate in international initiatives to integrate long-term national datasets with new measurement and analysis tools to build more accessible and actionable information resources that support agricultural management, market planning, and policy making while establishing robust protocols for data ownership, sharing, and use.
	• Specify national efforts to address gaps in agricultural productivity, resilience, and GHG mitigation through validated technological and socio-economic interventions. • Articulate concrete plans for enhancing demand-led technical and financial support for climate-aligned on-farm innovation by under-served agricultural producers. • Mandate cross-ministry collaboration on needs assessment and program development to anticipate and respond to climate change impacts, GHG emissions, biodiversity loss, and natural resource degradation.
	• Specify planned investments to improve storage, transport, processing, and marketing infrastructure in agricultural value chains. • Identify opportunities to improve utilization of organic waste streams and better meet agricultural fertilization needs. • Mandate relevant agencies to monitor food loss and waste, and associated GHG emissions and resilience impacts, to better inform and implement tailored, cost-effective interventions. • Establish mechanisms for enhanced coordination among input suppliers, producers, and market actors to reduce post-harvest loss through aligned capabilities for meeting production timing, quantity, and quality requirements.

INNOVATION CATEGORY	RECOMMENDATIONS
	• Specify plans to deliver technical and financial support for producers to access climate-aligned agricultural inputs and to effectively participate in agricultural markets. • Build out reliable storage, transport, and energy networks that better enable agricultural producers to access remunerative marketing opportunities. • Establish platforms to enhance agricultural product aggregation through coordination across value chain actors including small-, medium-, and large-scale traders. • Mandate relevant agencies to increase market transparency through domestic initiatives and international partnerships.
	• Specify plans for steering right-sized finance to small- and medium-sized agri-entrepreneurs. • Participate in regional initiatives to improve quantification of opportunities and risks associated with climate-aligned investment in agricultural value chains and to enhance sectoral fluency within local financial systems. • Establish aspirations and guardrails for climate finance and blended finance approaches to filling agriculture and food system funding gaps.
	• Mandate whole-of-government coordination to steer existing public and private capital flows, including sectoral subsidies, toward co-investment in more sustainable, resilient agriculture and food systems. • Identify and deploy specific policy tools to more effectively incentivize climate-aligned transitions in distribution, transport, processing, manufacturing, retail, and food services components of agricultural value chains. • Articulate a national approach for navigating tradeoffs associated with climate-aligned policies including compensation mechanisms for imposed costs and safety nets for vulnerable social groups.

Countries vary in their needs and capabilities for promoting agriculture and food systems innovation. Table 2 proposes strategic, cross-cutting approaches for lower- and higher-income countries.

Table 2. Recommended strategies for lower- and higher-income countries.

LOWER-INCOME COUNTRIES	HIGHER-INCOME COUNTRIES
Emphasize innovation to sustainably increase productivity, shrink yield gaps, and grow the agricultural economy while building biophysical and socio-economic resilience and minimizing GHG emissions.	Emphasize innovation to more effectively achieve GHG mitigation and other sustainability objectives that simultaneously reduce vulnerability to shifting climatic regimes and resource degradation.
Assess national assets (e.g. land, labor, natural resources) that can be more effectively mobilized toward climate-aligned agriculture and food systems transformation through domestic programs and international collaborations.	Assess how national assets (e.g., modern food supply chains; digital capabilities) can better contribute to climate objectives through targeted use of policy incentives, technical support, and rulemaking.
Engage in regional initiatives to harmonize research investments, market development, and financial and policy innovation.	Calculate impacts of current R&D investments for climate-proof agricultural productivity and evaluate risks of knowledge and technology obsolescence without additional investment.
Cultivate long-term, strategic collaborations with global donors and international research partners that are anchored in national objectives and more effectively deploy and safeguard national assets.	Expand research partnerships with lower-income countries based on complementary capacities, shared goals, equitable benefits, and long-term planning.
Solicit public-private partnerships focused on commercialization of national research outputs and other domestic priorities, grounded in quantified investment needs and return on investment (ROI) and incorporating plans for inclusive access.	Monitor cost-effectiveness and benefit allocation from existing and emerging public-private partnerships to continually improve equitable ROI.
Assess and, where possible, mitigate risks that constrain commercial investment in agriculture and food systems, while working with domestic financial system leaders to build sectoral fluency.	Publicly subsize lending programs to incentive climate transitions in domestic agriculture and food systems.
	Contribute to international efforts to steer climate finance toward agriculture and food systems and infuse climate objectives into humanitarian aid programs.

CHAPTER 2

SETTING THE SCENE

2. SETTING THE SCENE

The world cannot address global climate and food crises without transforming our agriculture and food systems.

The world faces unprecedented urgency to make agriculture and food systems more resilient to climate change and to lower the greenhouse gas (GHG) emissions they generate. Climate change is already affecting food security through higher temperatures, changing precipitation patterns, and more frequent extreme weather events (IPCC, 2023). The global agriculture and food system accounts for one-third of the world's net greenhouse gas (GHG) emissions and, on its own, could push us past the 1.5°C target in the next 40 years (Clark et al., 2020; Tubiello et al., 2021).

The development of Nationally Determined Contributions (NDCs), due in 2025 as part of the Paris Agreement cycle, offers a unique opportunity to strengthen investment in and support for the research and innovation that will undergird any serious efforts to transform our agriculture and food systems. NDCs provide a platform to bring all climate-related national policy priorities together, including to plan and implement agriculture and food systems measures in a holistic manner. This report explores how robust inclusion of seven major categories of agriculture and food system innovation in NDCs is relevant for all countries seeking to cultivate transformative investments that increase their climate ambition.

Robust and context-specific innovation capacity is essential to transition to sustainable, resilient agriculture and food systems.

As environmental and economic disruptions proliferate, global prosperity and food security rely fundamentally on sustainable, resilient agriculture and food systems. Achieving productivity, sustainability, and resilience requires innovation in many different forms, led by a constellation of agriculture and food systems actors (Hellin et al., 2024). When in-region institutions and local stakeholders have access to relevant knowledge, technologies, and resources, they can lead resilience-oriented innovation (Tenkouano et al., 2023). When socio-technical and policy barriers are lowered for cost-effective mitigation measures, producers and value chain actors can take steps to reduce GHG emissions (Roe et al., 2021).

However, agricultural production systems and value chains across the world vary enormously (Romero-Silva et al., 2024). A wide range of biophysical and socio-economic factors shape the size, connectivity, and profitability of farms and agriculture and food businesses (Giller et al., 2021a). National food system policies are similarly heterogeneous, reflecting specific country circumstances and capabilities (Lowder et al., 2022). This profound diversity necessitates context-specific innovation, and every country has distinct knowledge and technology needs (Conti et al., 2024; FOLU, 2023; Cassman & Grassini, 2020; WWF, 2023).

> **AGRICULTURAL INNOVATION** *has been defined as "a multi-scale process of creating and putting into use agricultural practices, new to a particular environment" (Gildemacher et al. 2015). Given the tremendous diversity across the world's agriculture and food systems, this definition encompasses climate-aligned technologies and production practices, capacity building, information systems, development of markets and value chain infrastructure, and supportive business models and policies (Reardon et al., 2019).*

Currently, innovation is hampered by investment and implementation barriers.

Imbalanced investment across categories of innovation and across regions has hampered sustainable transformation of agriculture and food systems. For many years, 'upstream' research and technology development have been the major recipients of global investment in agricultural innovation (Hellin et al., 2024). While inventing and updating these upstream climate-smart technologies have been a major driver of food security gains, much-needed improvement in agricultural productivity, sustainability, and resilience cannot be achieved without complementary investments in 'downstream' innovation in markets, infrastructure, financial systems, and policies (Reardon et al., 2019).

Global public spending patterns for overall research and development (R&D) have been dynamic in recent decades, with rising expenditures by middle-income countries and the private sector and falling expenditures by higher-income and lower-income countries (Dehmer et al., 2019). In the realm of agricultural R&D, middle-income countries now out-spend and out-produce higher-income countries (Baldos, 2023; Fuglie, 2018). National governments are major investors in agricultural R&D (Dalberg Asia, 2021), but for a growing number of lower-income countries, crushing sovereign debt payments are seriously constraining domestic R&D budgets (Kadirgamar et al., 2024; Zucker-Marqes et al., 2024). Private sector R&D investment is geographically concentrated, representing two-thirds of all R&D spending in high- and upper middle-income countries and only one-third and one-fifth in lower middle- and low-income countries respectively (Dehmer et al., 2019).

In the context of climate change, agricultural knowledge and technologies may become rapidly obsolete in countries with inadequate or declining R&D investment (Fuglie, 2018). Without continual renewal of underlying science, stagnating agricultural productivity diminishes food security and socio-economic well-being (Dehmer et al., 2019; CGIAR, 2023; Stads et al., 2022). Countries vary widely in their capacity to fund and conduct agriculture and food systems research and many lower-income countries are unable to mobilize sufficient resources to meet their knowledge and technology needs (Okem et al., 2024; Fuglie, 2018). This gap is especially problematic as climate change increases production risks for the 500 million small-scale farmers who supply one-third of the world's food and who are dramatically under-served by R&D investments (CGIAR, 2023; Nature, 2020). The most resource-constrained small producers are further marginalized by their inability to access or afford essential inputs (Chikowo et al., 2022).

While estimates are very high for the overall return on investment (ROI) in agricultural R&D, ex ante ROI estimates for technology development can be elusive, especially in smallholder-dominated agricultural systems (Alston et al., 2020). Once validated in research trials, new technologies and management practices can be shared with agricultural producers through extension systems, agri-company networks, development projects, and other dissemination mechanisms. Recent studies have revealed that adoption by small-scale producers can be quite low (Ishtiaque et al., 2024; Stevenson & Vlek, 2018) with potential barriers ranging from inadequate technological feasibility and needs assessment to insufficient delivery mechanisms and technical support (Freyer et al., 2024).

The investment gap for agriculture and food systems R&D is large and the capacity of donor governments to fill this gap is constrained by competing demands related to humanitarian crises and geopolitical conflicts (Perera et al. 2024). In recent years, donor governments have slowed their support for R&D in low-income countries despite spill-over benefits to their own agricultural systems (Dalberg Asia, 2021; Westendorg, 2019). Just over seven percent of overseas development assistance goes toward research and innovation to improve food and nutritional security (CGIAR, 2023). Donor-supported agricultural R&D projects typically receive short-duration funding targeted to technology development and dissemination and other narrowly focused objectives (Conti et al., 2024; TEC-UNFCCC, 2022). Funding opportunities strongly reflect donor priorities and limited participation of intended beneficiaries in research design minimizes opportunities to enhance the feasibility and utility of research outputs (Hellin et al., 2024; FAO, 2022).

NDCs are an important mechanism to guide investment toward climate-aligned agriculture and food systems innovation and implementation.

NDCs are at the heart of the Paris Agreement and the achievement of global climate goals. They embody efforts by each country to reduce national GHG emissions and adapt and build resilience to the impacts of climate change. Each Party to the Paris Agreement is required to prepare, communicate, and maintain successive NDCs that it intends to achieve.

In the context of the 1.5-degree target, 2025 is a particularly important moment as countries continue to revise and enhance their NDCs in alignment with the mechanism to rachet up efforts agreed under the Global Stocktake at UNFCCC COP28. NDC submissions in 2025 will be informed by the New Collective Quantified Goal for mobilizing climate finance for developing countries, which is set to be finalized at COP29. Updated NDCs are officially due in February 2025 and, in practice, will be submitted throughout 2025.

For all countries, and especially those that committed to advance climate-smart agriculture under AIM for Climate and the COP28 Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action (UAE Declaration), the time is now to build capacity for more robust representation of the agriculture and food systems, including research and innovation plans, in their NDCs. The need for support in this process is likely to be greatest for low- and middle-income countries (LMICs) where agriculture and food systems are dominated by smallholder farmers, who have distinct opportunities and challenges.

The overall objective of this report is to support policymakers, especially in low and middle income governments, to integrate agriculture and food systems innovation within their NDCs.

Compared to other sectors, the visibility of agriculture and food systems in NDCs has been low and numerous efforts are underway to increase the representation of this critical sector in future NDC submissions. In this study, we focus specifically on how agriculture and food system innovation has been included in existing NDCs to establish a baseline and to identify untapped opportunities for consideration by governments.

To support policymakers, this report:

- Summarizes available evidence related to effectiveness of investments in agriculture and food systems innovation for achieving climate and agriculture outcomes.
- Presents results from a review of existing NDCs submitted by countries with a specific focus on the inclusion of agriculture and food systems innovation as part of their climate change mitigation and adaptation measures.
- Offers actionable recommendations for policymakers to enhance their NDC ambition and implementation toward sustainable and resilient agriculture and food systems by considering and integrating agriculture and food systems innovation.

CHAPTER 3

METHODOLOGY

3. METHODOLOGY

Categorizing agriculture and food systems innovation

Agriculture and food systems encompass primary production, transport, storage, processing, retail, and consumption and they are shaped by R&D and information systems, financial flows, and policy contexts (Lowder et al., 2022). Drawing on literature review, we developed seven categories to represent the multiple essential components of innovation processes in agriculture and food systems (Table 4). Each of these categories of innovation are discussed in greater detail in Section 4. These innovation categories are used to guide findings, analysis, and recommendations throughout the report.

Table 3. Categories of agriculture and food systems innovation.

INNOVATION CATEGORY	MAJOR COMPONENTS
Research & development (R&D) systems	Enhanced R&D systems that effectively integrate national, in-region, and international research capacities
Information systems	Information access and utilization
On-farm production	Enhanced productivity, resilience, and sustainability through improved management of soils, water, crops, livestock, labor, and energy
Post-harvest handling	Increased storage and processing efficiency and product value addition that reduces loss and waste
Markets	Expanded income opportunities for producers and value chain actors through market development, support to market actors and demand-side measures
Finance	Capital steered toward improved technologies and practices through financial support and planning
Policy	Supportive policies (e.g. regulations; institutions; programs; economic incentives)

Reviewing existing NDCs

We used a semi-automated scan, keyword search, and manual document review to assess inclusion of agriculture and food systems innovation in existing NDCs (see details in Annex 1). We extracted and reviewed NDC text related to agriculture and food systems innovation to determine the prevalence of agriculture and food systems innovation in NDCs. Findings are presented in Section 5.

Characterizing country contexts

To account for different capacities to invest in agriculture and food systems innovation, we differentiated findings from the NDC review using the World Bank's country groupings, specifically: low-income countries (LIC); low middle-income countries (LMIC); upper middle-income countries (UMIC); and high-income countries (HIC). Additionally, we compared country-level findings for the prevalence of agriculture and food systems innovation in NDCs with country characteristics that influence capacity for investment and implementation (see Table 3). We selected variables related to multiple categories of innovation and datasets that provide indicators at the country level if they had near or full global coverage (i.e., we prioritized datasets that included a larger number of countries and/or were more easily interpreted).

Table 4. Data sources for country characteristics related to agricultural and food system innovation.

VARIABLES	DATA SOURCE DESCRIPTIONS
Climate vulnerability ND-GAIN Vulnerability Index (ND-GAIN, 2023)	• The ND-GAIN Country Index summarizes a country's vulnerability to climate change in combination with its readiness to improve resilience. A country's ND-GAIN index score is composed of a Vulnerability score and a Readiness score. • The Vulnerability Index measures a country's exposure, sensitivity, and ability to adapt to the negative impact of climate change across six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. • The Vulnerability Index ranges from 0 (low vulnerability) to 1 (high vulnerability), meaning that countries with a lower score are less vulnerable than those with higher score.
Percent of smallholder farmers (Lowder et al., 2021)	• Estimate of the number of farms per country worldwide, their distribution per farm size class, using the most recent agricultural censuses available, in combination with survey data where needed. • The percent of small farms is calculated as the number of farms that are less than 2 hectares in size divided by the total number of farms per country.
Gross Domestic Product (GDP) per capita (World Bank, 2022)	• GDP and GDP per capita for the year 2022 in current USD. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. GDP per capita is gross domestic product divided by midyear population.
International finance flows to the agricultural sector OECD-CRS (OECDStat, 2024)	• The CRS Aid Activity database provides a set of granular data that enables analysis on where aid goes, what purposes it serves and what policies it aims to implement, on a comparable basis for all providers who report their activity-level statistics to the Organisation for Economic Co-operation and Development (OECD). Data are collected on individual projects and programmes, with a range of attributes for each activity. • For this report, we extracted the average financial flows (USD Disbursed) for the agricultural sector ("III.1.a. Agriculture") per recipient country based on individual projects recorded in the creditor reporting system (CRS) for the period 2018-2022.
GHG emissions from food production and post-production EDGAR-FOOD (Crippa et al., 2021)	• The EDGAR-FOOD database is a global emission inventory of GHGs from the global food systems. It represents the first database consistently covering each stage of the food chain for all countries with yearly frequency for the period 1990-2015. • For this report, we calculated the share of GHG emissions from agriculture production and post-production over the total emissions from agriculture and food systems per country for the year 2018. • Production refers to the sum of emissions from LULUC (land use, land-use change) and production (primary production of food commodities). • Post-production refers to the sum of emissions from transport, processing, packaging, and retail.

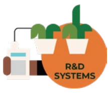
VARIABLES	DATA SOURCE DESCRIPTIONS
Governance Worldwide Governance Indicators (WGI) (World Bank, 2024)	• The WGI are intended for general cross-country comparisons and for evaluating broad trends over time. The WGI feature six aggregate governance indicators (range 0-100) for over 200 countries and territories over the period 1996–2022: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption. • For this report, we calculated the average of the six indicators per country for the year 2022.

CHAPTER 4

EVIDENCE FOR INVESTING IN AGRICULTURE AND FOOD SYSTEMS INNOVATION

4. EVIDENCE FOR INVESTING IN AGRICULTURE AND FOOD SYSTEMS INNOVATION

There is a growing body of evidence to support investment in research and innovation for sustainable, resilient agriculture and food systems. In this section, we review available evidence for the benefits and cost-effectiveness of enhanced national commitments to investment in seven categories of agriculture and food systems innovation.



4.1 Research and development (R&D) systems

Agricultural R&D drives productivity, economic growth, and sustainability.

R&D is the foundation for increased productivity and economic growth in agriculture and food systems. A meta-analysis by Rao et al. (2019) found that “the contemporary returns to agricultural R&D investments appear as high as ever,” noting median annual economic returns of 41 percent and 34 percent in developing and developed countries, respectively. For example, a two-fold increase in public investment in US agricultural research from 2025 to 2035 is projected to deliver meaningful productivity growth and economic benefits through 2050 (Baldos, 2023). In globalized agriculture and food systems, yield and economic benefits from R&D investments are not restricted by national borders. Knowledge and technology spillovers contribute substantially to return on R&D investments (Baldos, 2023) and benefits can accrue to both developed countries and developing countries (Westendorg, 2019).

Agriculture and other land-based sectors play a critical role in climate change mitigation, especially in the near-term, but this is hampered by low investment in implementation and innovation. As estimated by Roe et al (2021), implementation of 20 land-based activities during 2020 to 2050 could deliver cost-effective GHG mitigation of between 8 and 14 gigatons CO_2eq per year, of which 35 percent would emerge from the agriculture sector. Reducing GHG emissions from agriculture and food systems is strongly linked to research-driven increases in agricultural productivity. More efficient use of land, water, and fertilizers can reduce GHG footprints embedded in these inputs and potentially reduce GHG emissions associated with agricultural land expansion (Baldos, 2023). Mitigation-focused research has validated numerous technologies and practices including improvements in crop traits, livestock feed additives, fertilizer formulations, and water management in rice production that can reduce emission (WRI, 2019).

Agricultural research institutions have proven their worth but are facing new pressures.

For many decades, agricultural research institutions in HICs have been publicly supported to deliver knowledge and technologies that serve domestic priorities (Nin-Pratt, 2021). Crop and livestock yields in developed countries have steadily increased as researchers develop and improve technologies and management practices that are transferred into on-farm practice (WRI, 2019). The 1960s ushered in an era of international investment by HICs that established both national agricultural research systems (NARS) and international agricultural research centers (IARCs) to mobilize science toward agriculture and food systems challenges in developing countries (Conti et al., 2024; Fuglie & Echeverria, 2024; Alston et al., 2020). IARCs and NARS were intended to generate international scientific public goods and to adapt these to local production systems in tandem, and the interactions between them has taken many forms and evolved over time. Recent years have seen a push for locally led development and re-balancing of R&D investment across national and international institutions (Jayne et al., 2024).

Over seven decades, the impact of CGIAR and other IARCs has broadened from strong productivity gains in wheat and rice in Asia to benefits in Africa and Latin America, improvements in a larger set of crops, and development of management technologies for pests and natural resources (Fuglie & Echeverria, 2024). The CGIAR continues to be a mainstay for adaptive crop breeding across the developing world (Gollin et al., 2021). Impact estimates for investments in IARCs reflect the scope and data sources of individual studies. Alston et al. (2020) determined that, over multiple decades, CGIAR research has generally delivered a 10-to-1 ROI. Fuglie & Echeverria (2024) estimated that CGIAR-related crop research from 1961 to 2020 provided USD 1.3 billion in cumulative economic impacts based on direct productivity impacts from farmer adoption on more than 221 million hectares across 92 developing countries (Fuglie & Echeverria, 2024). Including demographic shifts and macroeconomic growth over a 45-year period in their calculations, Gollin et al. (2021) estimated trillions of dollars of annual benefits across developing nations from crop improvement by IARCs.

However, climate change, biodiversity loss, and socio-economic crises are imposing new imperatives on agricultural research institutions, which are adjusting their internal structures and external collaborations to meet these new realities. As they do so, these institutions are weighing the relative importance of technological and sociological forms of innovation, while also responding to their geographic contexts and investment signals by traditional and new funders (Conti et al., 2024; Hellin et al., 2024; TEC-UNFCCC, 2022).

The socio-political context and the specific mix of R&D organizations operating in any given agricultural region will shape how research is mobilized. While institutional objectives and the interests of local constituencies are often at odds, local agriculture and food system needs and opportunities can be better served when multi-stakeholder processes are in place to foster compromise and collaboration (Conti et al., 2024; WFO, 2023).

Private sector R&D is globally important for commercially viable investment.

Globally, private companies are major players in agriculture and food system R&D. Depending on the size and nature of their business, companies may undertake shorter-term, targeted projects (e.g., adapting technologies to regional value chains, testing new service delivery models) or longer-term scientific discovery (e.g., developing novel technologies). These efforts are driven by the potential for commercial returns, which vary significantly based on market and policy conditions (Ishtiaque et al., 2024). Therefore, the private sector is commonly constrained to R&D activities associated with large or rapid ROI such as may be achieved within well-defined markets or with proprietary technologies (WRI, 2019). Revenue models for private sector R&D can encompass less profitable areas when agricultural research organizations share their scientific expertise in exchange for a clearer path to commercialization for research outputs. Such partnerships must navigate tensions between public good and commercial mandates (Conti et al., 2024).

4.2 Information systems

Data-gathering in agriculture and food has expanded, but critical data and information gaps persist.

Initially concentrated on yield and other aspects of agricultural production, data-gathering in agriculture and food systems has expanded over the years to encompass food security, market activity, labor, and other socio-economic factors. As their fundamental significance becomes more widely appreciated, soil and water quality, agrobiodiversity, GHG emissions, and other environmental and natural resources dimensions of agriculture and food systems are increasingly measured, enabling improved quantification of negative externalities (FAO, 2023).

Similarly, traditional data-gathering through decadal national censuses and periodic large-scale surveys (which are the basis for long-term global datasets such as FAOSTAT) has been more recently complemented by remote sensing, *in situ* sensor measurements, and machine learning (enabling new global, crop- and livestock-specific datasets) (Kabede et al., 2024). Assessment of technology adoption has been aided by recent advances in information-gathering ranging from better tracking of seed sales to plant DNA sampling (Fuglie & Echeverria, 2024). While tracking of agriculture and food system policies has improved, assessments of implementation and impact are not yet sufficiently aggregated (Lowder et al., 2022). Estimated GHG mitigation potential in agriculture and food systems has also advanced although challenges in aggregating sectoral estimates and accounting for land competition risk double-counting (Roe et al., 2021).

In many parts of the world, existing data and information systems are insufficient to support effective farm management (e.g., variety selection; planting timing; stocking rates), market planning (e.g. yield forecasting), policy making (e.g. land use planning), and sustainability improvement (e.g. life cycle assessment). Inadequate spatial and temporal resolution, methodological variation across jurisdictions and across time, sparsely monitored areas and production types, and aging datasets all obscure meaningful heterogeneity within crop and livestock systems (Kabede et al., 2024). Data and information systems for agriculture and food lack mechanisms for coordinated governance and long-term funding. Misaligned institutional incentives, low capacity to adopt innovative methods, data privacy concerns, and weak data-sharing among public, private, and research organizations all result in inefficient, duplicative, and fragmented information systems (Kabede et al., 2024).

Access to weather and climate information, early warning systems, and complementary advisory services, can support producers to better select crops and varieties, time planting and harvesting, and benefit from validated conservation practices (IPCC, 2019. WMO, 2023). Unequal access to information resources reflects and reinforces socio-economic inequalities among different groups of producers and value chain actors with women very commonly disenfranchised despite their substantial roles in agriculture and food systems (Ishtiaque et al., 2024).

Public policy is an essential driver toward sustainable, resilient agriculture and food systems, however estimation methods for quantifying and comparing the costs of alternative policy options remain under-developed (FAO, 2023). Sustainability assessments of food systems have been focused on higher-income countries, leaving lower-income countries less prepared to anticipate and respond to climate change and other threats (Fourat et al., 2024). Implementation of national strategies for achieving productive, sustainable, and resilient agricultural systems will rely on baseline and ongoing technical assessments, however mandates and funding for sectoral data-gathering are commonly inadequate (Okem et al., 2024; WRI, 2019). Many regions require greater investment in demographic and socio-economic data-gathering to inform agriculture and food policies

(NISR, 2019). Developing regions also commonly lack information about the functioning of national organizations leading agricultural research, development, and extension (Jayne et al., 2024).

4.3 On-farm production

Increased sustainability has been documented for many different agricultural technologies and on-farm practices in many different production contexts, although specific productivity, resilience, and GHG mitigation outcomes will depend on numerous contextual factors (WWF and Climate Focus 2024; IPCC, 2019).

Investment flows toward improved technologies and practices, but adoption varies.

Agriculture is an inherently complex and knowledge-intensive endeavor. In controlled research trials, scientists test new technologies and practices against many different field conditions while optimizing for a discrete set of outcome variables (Cassman & Grassini, 2020). In real-world farm contexts, producers make use of incomplete information to continuously balance dozens of biophysical, socio-cultural, and market factors that operate at multiple temporal spatial scales, while optimizing their inputs and labor to maximize yield and profit (Giller et al., 2021b; Waldman et al., 2020).

Despite decades of R&D focused on productivity, crop and livestock yield gaps persist in many agricultural systems and may worsen due to climatic changes if validated climate-smart technologies and practices are not integrated into farming systems (Agnew & Hendery, 2023). Improved crop seeds and livestock breeds have long received public and private investment as important technologies for increasing yield and building climate resilience. Their effective development and adoption can be enhanced through demand-led approaches such as creating product profiles that reflect preferences of producers (e.g., drought and disease resistance) and markets (e.g. cooking times; flavor) (Tenkouano et al., 2023).

More recently, investment has flowed to novel technologies. For example, biofertilizers, in a range of application formats, utilize bacteria or fungi to improve plant nutrition or defense against pathogens. Demand for biofertilizer technologies is growing in some agricultural regions, although their use remains limited in many parts of the world where they may not be well adapted to local growing conditions, value chains, or policy contexts (Freyer et al., 2024). While riskier than incremental scientific advances, novel technologies can deliver new benefits when they are compatible with local policies and value chains, although these benefits tend to accrue to better resourced producers (Cassman & Grassini, 2020).

As R&D organizations generate new knowledge and validate new technologies and practices, high ROI depends on robust adoption by producers and other value chain actors. Low adoption and dis-adoption are associated with financial barriers (e.g., high upfront costs; subsidized support of existing technologies), delayed or episodic benefits (e.g., only during drought years), and ineffective roll-out strategies (e.g., low use of peer networks, technical support, and post-adoption reinforcement) (Ishtiaque et al., 2024). In recent global consultation, producers highlighted inadequate financial resources and insecure land tenure as key obstacles to adopting climate-aligned practices (WFO, 2023).

Adoption of improved technologies and practices is low in small-scale agricultural systems.

Small-scale producers provide 70–80 percent of the world's food and play an important role in biodiversity preservation and climate mitigation and adaptation (Ricciardi et al., 2018), however, they are typically more vulnerable to crop failure, livestock loss, and other challenges (Iese et al., 2020). In agricultural systems dominated by small-scale production, adoption rates for new technologies and practices are typically low (Stevenson & Vlek, 2018). There are many potential explanations for this ranging from inappropriate technology 'push' approaches to inadequate incentives, service delivery, and technical support (Nature, 2020; Albuquerque et al., 2023). Appetite for adopting risky new technologies is often low for many small-scale producers and agri-entrepreneurs, who operate within fragmented value chains that provide few opportunities for empowered market participation or accessing appropriate inputs and advisory services (Nature, 2020). For producers operating on a subsistence basis or participating in informal local markets, capacity to innovate will depend on well-targeted, integrated support that addresses the full range of resource constraints (Chikowo et al., 2022).

Originally driven by food security goals, domestic and international efforts to enhance innovation capacity among small-scale producers are intensifying in response to climate change, biodiversity loss, and natural resource degradation (CGIAR, 2023). Pressure has mounted for R&D investments to generate impact at scale and recent studies point to several promising strategies. Early-stage assessment of producers' needs and local value chains can provide valuable information to research teams about the bundles of technologies and practices that specific agricultural systems would realistically adopt and, importantly, what supportive infrastructure would be required (Tenkouano et al., 2023). When national agencies and research institutions approve or sponsor new technologies and practices, the potential for widespread, sustained adoption increases (TEC-UNFCCC, 2022; Fuglie, 2018).

Agricultural diversification is widely regarded as a winning strategy.

While some monoculture farms can be profitably managed in their specific biophysical, market, and policy contexts, single crop and livestock-only operations encounter numerous challenges (e.g., decreased soil fertility; pest and disease burden; commodity market volatility) and do not capitalize on the potential agronomic and market benefits of diversification (Kibaara, 2023; Chikowo, 2022). For example, integrated crop-livestock systems have been shown to achieve higher and more stable yields and other positive outcomes (e.g., carbon sequestration; enhanced agrobiodiversity), although they may elevate labor and management requirements (Delandmeter et al., 2024).

4.4 Post-harvest handling

Large amounts of food are lost and wasted across all agriculture and food systems.

Food lost in supply chains and wasted in retail and consumption settings adds greatly to global food insecurity. For example, under-developed storage, transport, and processing infrastructure in sub-Saharan Africa contributes to post-harvest food losses that exceed the value of food aid by a factor of ten (Kibaara, 2023). In the U.S. each year, food wasted in household, retail, and food service contexts is estimated at 159 kilograms per capita (UNEP, 2024).

On-farm food loss has been estimated at 1.2 billion tons annually with a carbon footprint of 2.2. gigatons CO_2eq (WWF, 2021). Associated with over 8 percent of global GHG emissions, wasted food has been valued at over USD 1 trillion annually (UNEP, 2024). Nearly a third (29%) of global food system GHGs emissions are associated with food distribution, consumption, and waste disposal (Crippa et al., 2021). Loss and waste at this scale represent grossly inefficient use of the land, inputs, labor, energy, and other valuable resources used to produce food (IPCC, 2019).

Increased efficiency can reduce emissions and build resilience in agriculture and food value chains.

Mitigation potential varies meaningfully by region, food type, and food chain stage, requiring careful assessment to ensure that interventions can feasibly reduce loss and waste within complex, multi-level food supply chains (FAO, 2019b). Interventions range from technological improvements (e.g., new storage and processing methods) to policy measures (e.g., extended shelf-life dates) (WWF and Climate Focus, 2024). Investments in decentralized food processing can reduce post-harvest food loss while helping to meet local food demand (Kinkpe & Grethe, 2023). Organic waste recycling systems can be an appropriate complement to food waste and loss reduction efforts. For example, composting systems could boost fertilizer supply in some African production systems, but this would require policy support (e.g., subsidies) and investment in decentralized infrastructure for segregated waste collection, quality control, and compost processing and distribution (Freyer et al., 2024). Investments that optimize local food supply chains and cold chain infrastructure could reduce food loss and associated GHG emissions, especially when focused on regions, food types, and food chain stages with greatest quantified mitigation potential (Friedman-Heiman & Miller, 2024).

BUSINESS-AS-USUAL IN AGRICULTURE AND FOOD SYSTEMS IS EXPENSIVE.

Recent large-scale, global studies have estimated that the costs imposed by agriculture and food systems on societies and ecosystems around the world exceed 10 percent of global GDP. Falling in the range of USD 10-18 trillion per year, estimated costs of current practices encompass GHG emissions, resource degradation, and environmental pollution as well as poverty, malnutrition, and diet-driven productivity loss. In low-income countries, poverty, undernourishment, and other hidden costs equate to more than a quarter of GDP. Unhealthy diets impose the greatest costs in higher-income countries. Although they bear a proportionally greater cost burden, LIC and LMIC countries are the source of only a quarter of global agrifood system costs. Interventions in agricultural production would be instrumental in reducing environmental costs while societal costs can be addressed through poverty reduction and dietary interventions.

Sources: FAO, 2023; Ruggeri Laderchi et al. 2024

4.5 Markets

Producers need technical and financial support to effectively participate in agricultural markets.

Agricultural producers' capacity to innovate in pursuit of productivity, sustainability, resilience, and profitability is strongly influenced by their access to inputs, working capital, and remunerative markets (Reardon et al., 2019). Producers typically access seeds, livestock genetics, nursery stock, agrochemicals, machinery, and other inputs from agri-companies or agro-dealers. In higher-income countries, input supply chains are formal and largely managed through established commercial mechanisms (Marshall et al., 2021). In lower-income countries, input supply chains are typically a mix of formal and informal channels that offer producers unreliable access to inputs and limited financing options (Marshall et al., 2021). The level and type of direct and indirect public sector support for input supply varies across countries (Gautam et al., 2020). In all countries, existing input supply chains do not adequately promote climate-smart technologies and practices (Agnew & Hendery, 2023).

The global food supply originates on millions of farms around the world and moves through labyrinthine networks that encompass a wide array of transport, storage, processing, packaging, and retail facilities (Giller et al., 2021; Ricciardi et al., 2018). Market prices for agricultural products are the dominant mechanism for signaling shifting demands (e.g., product type and timing; quality expectations; environmental footprint) to producers (Russell, 2023). It is challenging to incentivize and empower producers to innovate when market prices and infrastructure are unpredictable (Malabo Montpellier Panel. 2022). Building out reliable storage, transport, and energy networks can steer the flow of agricultural products and re-shape incentives received by producers and agri-entrepreneurs (van Gaal et al., 2023; Liverpool-Tasie et al., 2020).

While price volatility affects all agricultural operations, smaller-scale producers often wrestle with low price transparency and limited choice of buyers (Haddad, 2020; Oyinbo et al., 2021). If small-scale producers are supported to improve their connectivity and agility within market networks, they could increase their income-earning potential and capacity to invest in resilience-building strategies (Schoneveld, 2022; Nandi el al., 2021). In less formal markets, agri-SMEs play an essential role in connecting small-scale producers to inputs, services, and buyers (Liverpool-Tasie, 2020).

4.6 Finance

Funding patterns for agricultural research have been shifting across countries and sectors.

Historically, HICs have been major research investors, although, by the 2010s, their expenditures represented less than 50 percent of global spending on all forms of R&D (Dehmer et al., 2019). Funded primarily by donor governments, philanthropies, and multi-lateral development agencies, the world's largest IARC network, CGIAR, has seen a 25 percent decline in investment since a 2014 high of USD 1 billion (Conti et al., 2024; Fuglie & Echeverria, 2024).

Agricultural R&D budgets have expanded in several middle-income countries, most notably in China, while remaining stagnant in many food-insecure regions, which rely heavily on IARC-led science for improved crop technologies (Fuglie & Echeverria, 2024; Dalberg Asia, 2021; WRI, 2019). In many African nations, for example, under-funding of NARS results from budget constraints as well as minimal budget-sharing from CGIAR (Jayne et al., 2024). Agricultural research related to climate change mitigation has received minimal funding despite nearly 15 years of multilateral cooperation through the Global Research Alliance for Agricultural Greenhouse Gas Mitigation (WRI, 2019). Agricultural R&D investments of USD 70 billion are projected to reduce GHG emissions by 15 gigatons of CO_2eq a year (CGIAR, 2023).

While some R&D investments lead to profitable commercialization, some amount of public or philanthropic funding will be required on an ongoing basis to ensure institutional continuity and baseline scientific capacity (Tenkouano et al., 2023). Similarly, continuous support for agriculture-related education systems builds a pipeline of qualified researchers and sectoral professionals (Jayne et al., 2024; Amarante et al., 2022; Pardey et al., 2017).

International aid for agriculture and food is over-extended and climate finance is under-delivered.

Annual overseas development assistance (ODA) for agriculture and food security hovers around USD 12-15 billion in grants and USD 10 billion in concessional loans (Perera et al. 2024). For comparison, nearly USD 400 billion is invested in climate adaptation annually by small-scale producers in lower-income regions (Hou & Jones, 2023). The 2010s saw bilateral funding drop by nearly USD 1 billion (Dalberg Asia, 2021) and emergency food aid increase by 77 percent (Perera et al. 2024). In 2021, ODA to agriculture in Africa dropped by USD 1.3 billion (AU, 2024). In the last seven years, nearly one-third of global development funding has flowed to countries experiencing food security crises (GNAFC, 2024).

Climate finance is widely viewed as crucial for fueling progress toward the Paris Agreement goals (Caldwell et al., 2022). Donor governments have articulated major commitments to deliver climate finance, including for agriculture and food systems, but follow-through has been slow (Perera et al. 2024; OXFAM, 2022). Only three percent of public climate finance and under five percent of international development budgets are allocated to agriculture and food (Díaz-Bonilla, 2023). Effective implementation of donor-funded research and innovation depends on efficient, predictable disbursement of allocated funds, however, unstable donor funding and bureaucratic rules can result in budget cuts and disbursement delays that degrade project impacts (Jayne et al., 2024; Savvidou et al., 2021; Nature Plants. 2020).

Although the volume and impact of private adaptation finance are not widely reported, the last decade has seen over USD 5 billion invested in adaptation-related tools and services that can benefit small-scale producers (e.g., agricultural marketplaces; farm management) (Burwood-Taylor et al., 2024). In the absence of efficient mechanisms for providing appropriate types of capital to highly decentralized farmers and value chain actors, climate finance flows into the agriculture sector have been small and slow (CBI, 2024).

The world can afford necessary investments, but not every country has the resources.

To achieve Sustainable Development Goal (SDG) 2 (Zero Hunger) by 2030, new global public investment of USD 33 to 50 billion would be required annually, including additional donor contributions of USD 14 billion (Perera et al. 2024). If achieved at global scale, agriculture and food systems transformation promises very significant socio-economic and environmental benefits in return for investments under 0.4 percent of global GDP (Ruggeri Laderchi et al. 2024). Estimated investment needs for agriculture and food system transformation are in the order of USD 400-500 billion annually, including USD 3 billion for public agricultural R&D (World Bank, 2021). Current finance flows within the agriculture and food sector are large relative to estimates of new financing required (CBI, 2024).

The costs of agriculture and food systems transformation exceed the financing capacity of lower-income countries for which these would represent nearly 2 percent of GDP (Ruggeri Laderchi et al. 2024). Punishingly high debt service payments to external creditors are pushing the national budgets of dozens of lower-income countries into critical territory (Kadirgamar et al., 2024).

Despite offering a third of global mitigation potential to meet the Paris Agreement targets, agriculture and food systems receive only 4.3 percent (USD 28.5 billion) of total climate finance (CPI, 2023a). Similarly, private sector investment in climate solutions in the agriculture and food systems has been strikingly low with only one in 10 dollars (USD 2.3 billion) of venture capital for agriculture and food technology directed towards companies focused on climate solutions (CPI, 2023a). This is while estimated USD 300 to 350 billion is needed every year through 2030 to support the transition to sustainable and climate-resilient food systems (GAFF, 2022b).

Smaller agri-entrepreneurs fall through the cracks.

While agricultural value chain companies in HICs can generally access subsidized and commercial credit, their counterparts in lower-income countries operate under significant credit constraints (Okem et al., 2024). Small- and medium-size enterprises (SMEs) are essential input suppliers and service providers that, due to their size, face higher business risks and fall through the cracks between micro-finance and commercial lending (CSAF, 2023). Some agri-companies have few or no suitable formal credit opportunities and others successfully access early-stage credit, but encounter continuity gaps when they seek financing to scale their business (Koh, 2024).

Agriculture and food system investment gaps in lower-income countries are exacerbated by perceived economic and political risks, as well as low appetite to offer credit terms that align with the needs of agri-SMEs and other potential investees (Koh, 2024; CSAF, 2023). An annual agri-SME financing gap exceeding USD 100 billion across sub-Saharan Africa and South-East Asia could be reduced by boosting the financial literacy of agri-SMEs, better quantifying credit risks to empower domestic lenders, and bundling loans and insurance (Perera et al. 2024).

While the global volume of private capital is massive, only limited private sector investment has flowed into agriculture and food systems in low- and middle-income countries (Ruggeri Laderchi et al. 2024). Many banks lack the necessary experience to serve as effective intermediaries for sustainble finance directed into agricultural value chains (CBI, 2024).

Blended finance aspirations are slow to materialize.

Blended finance is a relatively new approach to filling agriculture and food system funding gaps by de-risking commercial investments with concessional finance from donor countries and philanthropies (Convergence, 2023). To accelerate private funding toward agriculture and food system adaptation, blended finance will be an important strategy (Burwood-Taylor et al., 2024). Before blended finance aspirations will materialize in agriculture and food systems, new approaches are needed to reduce transaction costs, improve technical assistance to funding recipients, and enhance multi-donor co-investment through better demonstration of development additionality (Perera et al. 2024).

With many potential configurations, efforts to fill investment gaps through blended finance could generate deals that combine capital from private financiers, banks, development finance institutions, sovereign wealth funds, development agencies, multi-donor funds, impact investors, and insurance companies (Perera et al. 2024). Impact investors have mobilized mission-oriented capital at impressive scale, although the imperatives of capital markets constrain their reach into higher-risk components of agriculture and food systems (Koh, 2024; I&P, 2023).

4.7 Policy

Some policy levers are pulled more often than others.

A wide range of public policies and international arrangements directly and indirectly influences the functioning of agriculture and food systems and, in turn, shapes their environmental and social sustainability (Nicolini et al., 2023).

Table 5. Common agriculture and food system policy levers (adapted from Lowder et al, 2022).

POLICY LEVERS	EXAMPLES
Subsidies	For producers: • Market price controls and information systems • Payments for conservation, natural resource management, or carbon sequestration • Low-cost credit, insurance, equipment, or agricultural inputs For consumers: • Food coupons • School feeding and food pantries
Trade policy	• Export promotion and restrictions • Preferential trade agreements • Import tariffs and non-tariff barriers • Phytosanitary standards
Regulations	• Land use and tenure policies • Water usage policies • Rules on product formulation, food safety, and procurement
Information	• Dietary guidelines • Public information campaigns
Taxes	• On agricultural products or producers' income • On pollution emissions • On sale of unhealthy foods or beverage containers
Public goods	• Processing and post-production facilities • Rural roads and transport infrastructure

The great majority of countries direct subsidies to agricultural producers and consumers and three-quarters use trade policies and regulations (Lowder et al., 2022). Recent analysis spotlights the significant potential – and complexity – of financing agriculture and food systems transformation through targeted repurposing of public subsidies including current forms of support to agriculture (Ruggeri Laderchi et al. 2024; Fan et al., 2022). These studies highlight tradeoffs between environmental and social objectives associated with removing or redirecting subsidies (e.g., reduced GHG emissions that correspond with increased poverty) (Gautam et al., 2022).

Public policies can accelerate transfer of research outputs to marginalized agricultural value chain actors (Ruggeri Laderchi et al. 2024). This may require policies that incentivize agri-companies to more deliberately promote climate-smart technologies while also increasing their affordability for producers (e.g., subsidizing their purchase or bundling with insurance) (Ishtiaque et al., 2024). Productivity growth can help to drive investment into agricultural value chains and open up employment opportunities for marginalized groups, such as women and youth, when paired with complementary support (Jayne et al., 2024). About a quarter of countries have policies in place related to distribution of seeds and machinery to producers (Lowder et al., 2022).

Achieving agricultural GHG emissions mitigation aligned with the Paris Agreement will require over USD 10 billion in additional annual investments in agricultural R&D and climate-smart technologies (Rosegrant et al., 2022). Economic, institutional, and technological constraints to investment in agriculture and food system GHG mitigation have proven to be formidable, requiring efforts to improve governance, to elevate economic conditions, and to shift perceptions and incentives (Roe et al., 2021).

Safeguards are important when incentivizing private sector investment.

Public policies that strengthen intellectual property rights are commonly proposed as a way to encourage new types of private sector investment in agriculture and food systems innovation as well as technology spillovers (Jayne et al., 2024). To ensure that incentives for private sector investment align with public sector objectives, policymakers can utilize safeguards including maintaining control of national assets (TEC-UNFCCC. 2022). Governments can also establish data privacy and governance policies that appropriately balance public and private benefits (Kabede et al., 2024). Similar considerations arise with efforts to engage private companies in the pursuit of national R&D priorities. For example, effective partnerships between NARS and agri-companies will need to deliver research outputs suitable for under-served producer groups that have a viable path to commercialization (Jayne et al., 2024).

An integrated approach helps in navigating tradeoffs.

Divergent perspectives about the correct direction of agriculture and food system innovation create inevitable friction for agriculture and food system transformation (Resnick & Swinnen, 2023. UNDP, 2024). In many countries, capturing agricultural GHG mitigation potential will require socio-economic transformation (e.g., redirecting industrial and land use policies), policy innovation, and mechanisms for navigating significant localized tradeoffs (Roe et al., 2021). Pursuing transformative change shifts the allocation of costs and benefits across agriculture and food system stakeholders, potentially creating new winners and losers and generating resistance from established institutions and empowered constituencies (Ruggeri Laderchi et al. 2024). For example, the activities of most national ministries align with their historical sectoral mandate and tend to remain siloed from other parts of government (Lowder et al., 2022; WRI, 2019). Direct engagement among diverse local stakeholders can help to reduce conflict among competing interests and balance how benefits are allocated (Conti et al., 2024; Birachi et al., 2023).

Clear policy signals and whole-of-government coordination can steer existing public and private capital flows toward co-investment in more sustainable, resilient agriculture and food systems (Tenkouano et al., 2023). For example, less than a third of governments apply policy levers to the middle of agricultural value chains (i.e. distribution and transport;

processing and manufacturing; retail and food services) suggesting this is a potential area for increased policy focus (Lowder et al., 2022).

Policy coherence and effective governance are important for navigating tradeoffs and promoting equitable outcomes (WWF and Climate Focus, 2024). Long-term national strategies can facilitate cross-sectoral coordination, clarify incentives for agricultural value chain innovation, and establish mechanisms for transparency and accountability (Ruggeri Laderchi et al. 2024; Freyer et al., 2024; AUDA-NEPAD. 2023). New or reinforced safety nets (e.g. cash transfers) can compensate for policy shifts that increase vulnerabilities for social groups (Ruggeri Laderchi et al. 2024).

CHAPTER 5

AGRICULTURE AND FOOD SYSTEMS INNOVATION IN CURRENT NDCS

5. AGRICULTURE AND FOOD SYSTEMS INNOVATION IN CURRENT NDCS

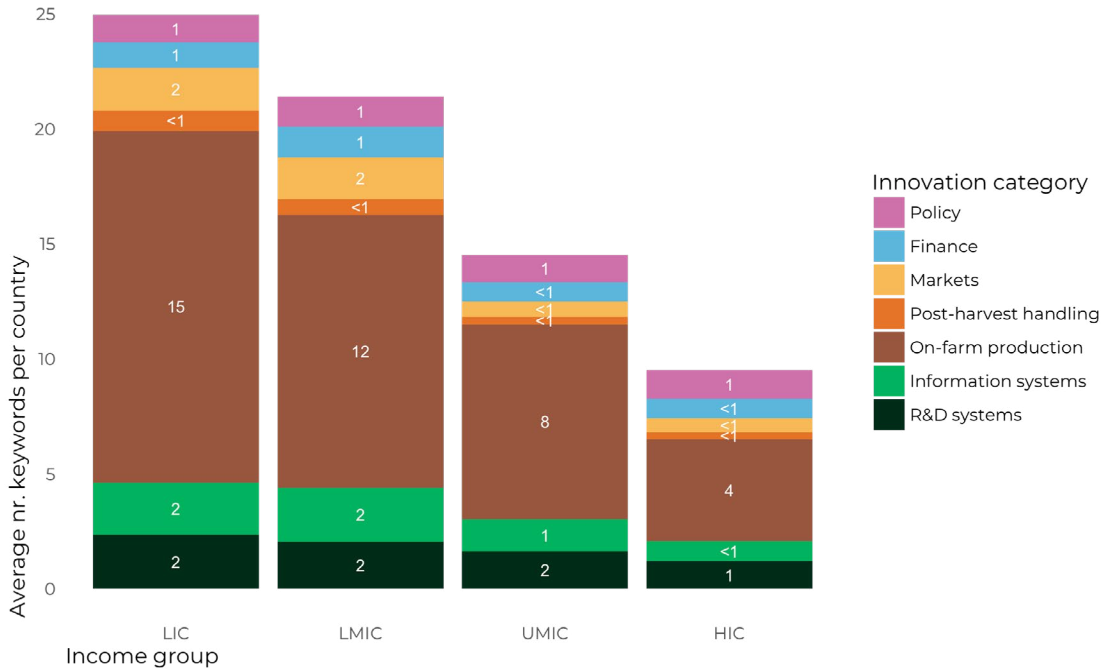
In this section, we assess the extent to which countries have signaled intentions to promote agriculture and food systems innovation as part of their national climate agenda (see tabulated results in Annex 2).

5.1 Inclusion of agriculture and food systems innovation in existing NDCs

Lower-income countries consider agriculture and food systems innovation more comprehensively in their NDCs than other country groupings.

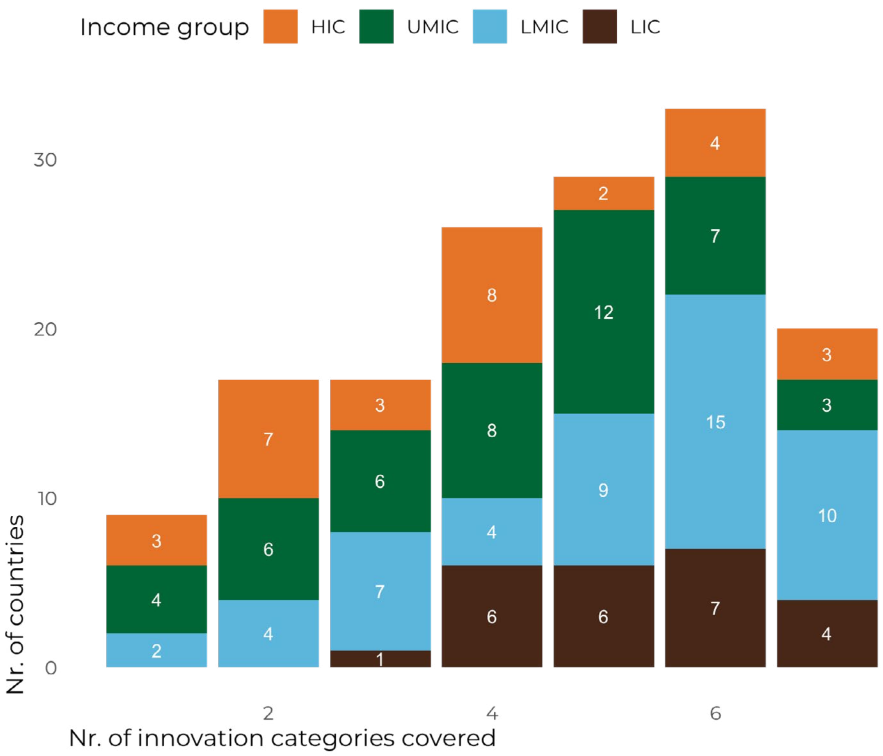
Of the 167 NDCs reviewed, 151 (90%) included at least one keyword related to agriculture and food system innovation. Of these 151 countries, 24 are LICs, 51 are LMICs, 46 are UMICs, and 30 are HICs. On average, NDCs of LICs include 25 unique mentions of keywords related to agriculture and food systems innovation, which is more than twice the number of mentions in NDCs of HICs (Figure 1).

Figure 1. Average number of keywords related to agriculture and food systems innovation per NDC by country groups. The number of keywords is a unique count, meaning that if the same keyword is mentioned multiple times within an individual NDC, it is counted only once (see Annex 1 for details).



Almost all LICs's NDCs have keywords related to at least four of the seven innovation categories while only half of HICs' NDCs have keywords related to at least four of seven innovation categories (Figure 2).

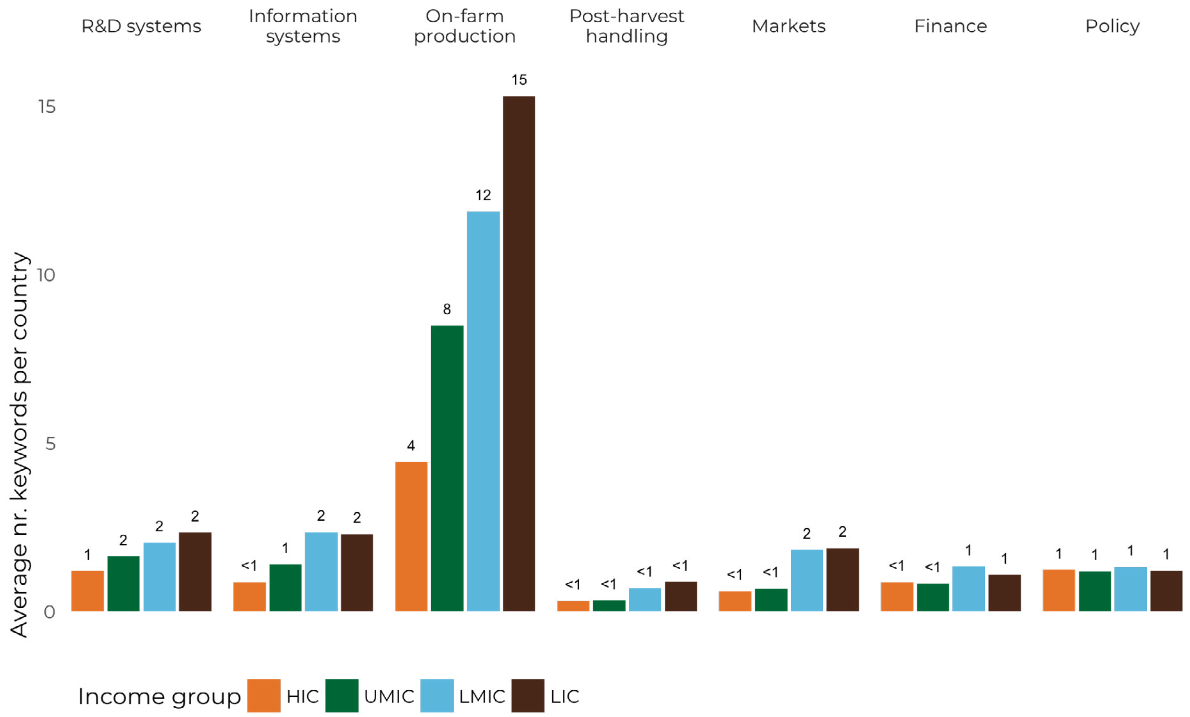
Figure 2. Number of countries mentioning 1 to 7 innovation categories in their NDCs, by country income group.



Across the seven agriculture and food systems innovation categories, keywords related to on-farm production feature most widely across NDCs.

On average, NDCs include 10 unique keywords related to on-farm production, but fewer than 3 keywords related to any other innovation category. LICs's NDCs include more keywords (more than 15 per NDC on average) related to on-farm production than other country groups (Figure 3).

Figure 3. Average number of keywords mentioned for each category of agriculture and food systems innovation, by country income group.



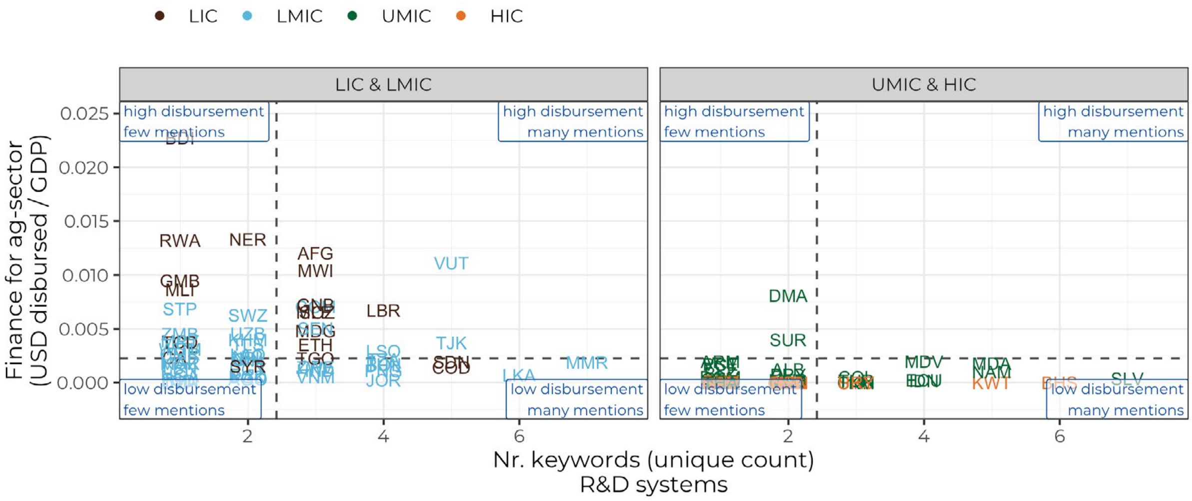
5.2 Relationship between country characteristics and inclusion of innovation in NDCs

It seems reasonable that inclusion of agriculture and food systems innovation in NDCs would reflect variation in countries' needs and capabilities. To explore potential patterns, we plotted keyword mentions against relevant national characteristics of climate vulnerability, governance, and sectoral status including farm size, economic activity, financial flows, and GHG emissions (see Table 3). While few correlations were detected between national characteristics and keyword mentions, we present several of these plots to illustrate observed patterns. Additional analysis can be found in the supplementary material. This section also presents examples from 22 countries that illustrate how they have included measures related to agriculture and food systems innovation in their NDCs.

R&D systems and international financial flows

Of 151 NDCs that have keywords related to agriculture and food system innovation, 112 (74%) include keywords related to R&D systems. 84% of LICs' and LMICs' NDCs have an average of 2 R&D-related keywords while 64% of UMICs' and HICs' NDCs have an average of less than 1.5 R&D-related keywords (Figure 3). LICs are typically more vulnerable to climate change impacts than HICs and tend to have less capacity to invest in R&D systems that can support building agriculture and food system resilience. Among LICs and LMICs, countries receiving lower international financial flows into their agriculture sector appear to include R&D more extensively in their NDCs (Figure 4).

Figure 4. Inclusion of R&D systems in NDCs and international climate finance flows to agriculture. Finance flows are based on OECD Creditor Reporting System corrected for GDP of countries. The vertical and horizontal dashed lines that divide the figures in four quadrants represent the average number of keywords and average finance flows across all plotted countries, respectively.



As discussed in section 4, R&D systems are essential for an inclusive transition to sustainable and resilient agricultural and food systems. Despite high ROI, investment in R&D systems has been insufficient to support the full range of climate-aligned innovation needs.

EXAMPLES OF NDC MEASURES RELATED TO INNOVATION IN R&D SYSTEMS

Sri Lanka

In highlighting the need for capacity and means of implementing their climate mitigation plans, Sri Lanka's NDC calls for R&D and knowledge transfer in all sectors including for precision agriculture, genetic improvement of livestock, development of new crop cultivars, and enhanced productivity and agrotechnology.

Cambodia

Cambodia's NDC includes plans for increased research capacities related to animal genetics, breeding, and feed to strengthen climate change adaptation.

Sierra Leone

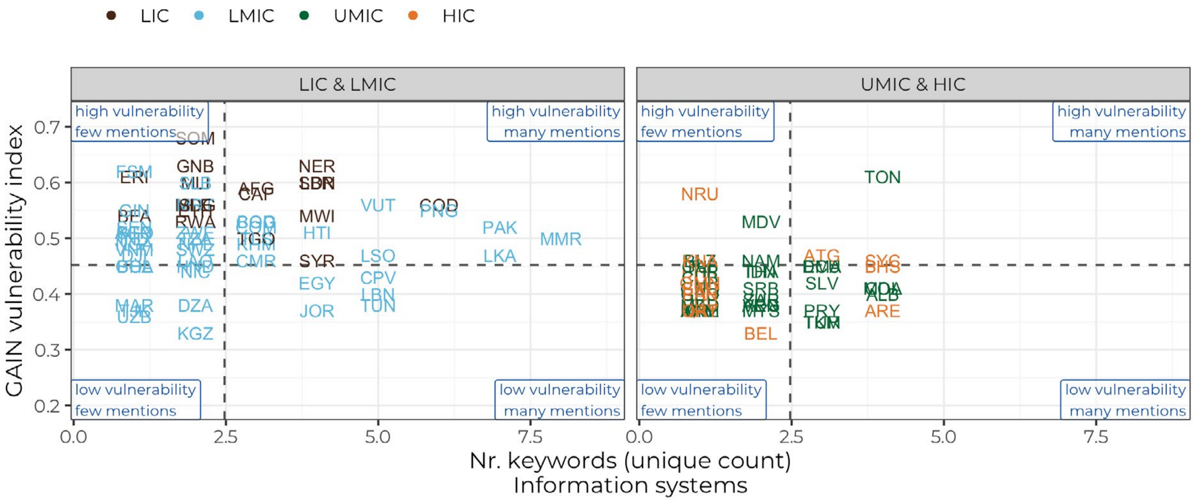
Sierra Leone's NDC outlines several R&D measures including establishment of weather stations to provide reliable and adequate weather data and tailored climate services to farmers around the country as well as providing adequate support to the Sierra Leone Agricultural Research Institute and Njala University to develop appropriate crop varieties and production practices that will enhance resilience to adverse weather conditions.

Information systems and climate vulnerability

Of 151 NDCs that have keywords related to agriculture and food system innovation, 107 (71%) include keywords related to information systems. Similar to R&D-related keywords, LICs and LMICs mention information systems at the highest rate with about 84% of their NDCs referencing information systems an average of 2 times while 58% of UMICs and HICs reference information systems just about 1 time per NDC (Figure 3).

Climate vulnerability tends to be higher in lower-income countries where agriculture and food systems typically have lower resilience and adaptation capacity (Okem et al., 2024). Access to more and better information—including through capacity building, trainings, extension or advisory services, farmers or producers associations, digital and data tools, and early warning and weather forecast systems—can enable agricultural producers and value chain actors to adapt and address climate challenges (UN Climate Change News, 2022; IPCC, 2019). On average, LICs and LMICs refer to information systems more than UMICs and HICs, however, Figure 5 shows that many LICs and LMICs with high vulnerability to climate impacts mention information systems only sparingly in their NDCs.

Figure 5. Inclusion of information systems in NDCs and vulnerability to climate change based on the GAIN index (a higher score corresponds to higher vulnerability).



EXAMPLES OF NDC MEASURES RELATED TO INNOVATION IN INFORMATION SYSTEMS

El Salvador

To build up the resilience of its agriculture and food system, El Salvador's NDC references establishment and development of an agroclimatic information system to reduce vulnerability of farmers to climate change impacts by improving knowledge of sensitive hydro-meteorological variables for production chains and enabling forecasting, timely decision-making, and continuous learning by producers about resilience and adaptation measures for the specific production systems of each zone, community, and family.

Thailand

To address climate change impacts, Thailand's NDC includes plans for building and improving their climate information systems including increasing capacity of responsible agencies to develop climate information services and to enhance early warning systems for disaster management in agriculture and other sectors.

Ecuador

Ecuador's NDC references developing research and generating information systems to strengthen climate change management in the agricultural sector.

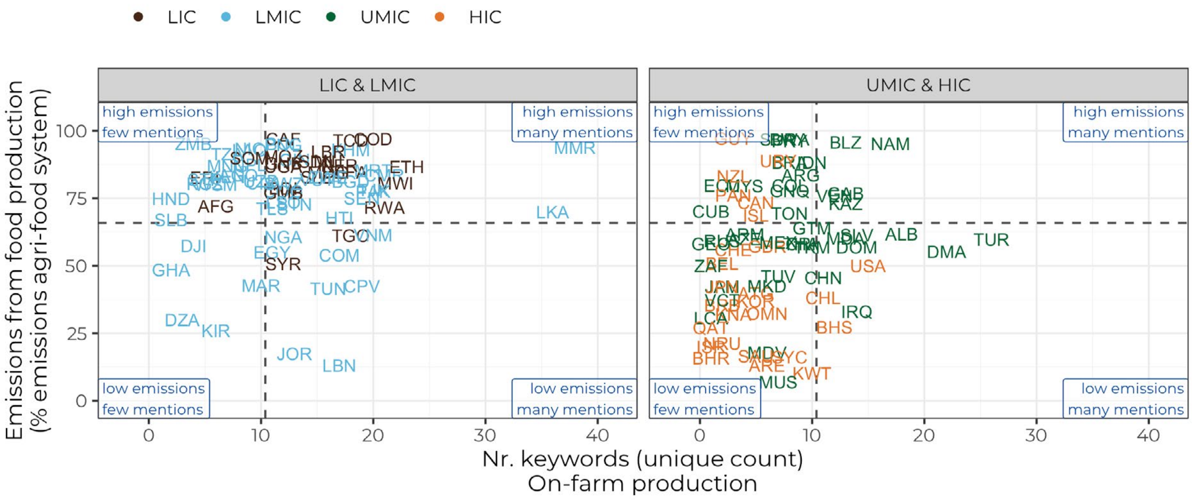
Cambodia

To increase resilience of crop production to climate change and extreme weather events, Cambodia's NDC references support services, capacity building, research, field trials, and up-scaling of climate-smart farming systems.

Sustainable on-farm production and GHG emissions from food production

Of 151 NDCs that have keywords related to agriculture and food system innovation, 144 (95%) include keywords related to on-farm production. LICs and LMICs include more keywords (about 14 per NDC on average) related to on-farm production than UMICs and HICs (about 6 per NDC on average) (Figure 3). In many LICs and LMICs, food production represents a high share of total GHG emissions from their agriculture and food systems (see Figure 6). Sustainable agricultural practices can contribute to climate change mitigation by reducing emissions from crop and livestock production, sequestering carbon in soils and biomass, and decreasing emissions intensity of production systems.

Figure 6. Inclusion of on-farm production in NDCs and share of emissions of agriculture production over total emissions from agriculture and food systems per country. Source: Crippa et al, 2021.



Most mentions of sustainable on-farm production in lower-income countries' NDCs relate to livestock and crop systems including use of fertilizers and pest and disease control measures. More than half of these countries's NDCs also mention integrated production strategies such as agroforestry and agroecology.

EXAMPLES OF NDC MEASURES RELATED TO INNOVATION IN ON-FARM PRODUCTION

Cameroon

Cameroon's NDC includes plans for implementing a range of sustainable production practices: intermittent irrigation of rice fields to reduce methane emissions; use of nitrification inhibitors by 5 percent of farmers by 2030; supplementing fat in ruminant feed by 12 percent; establishing 12,500 food plantations; adopting anti-erosion farming practices and organic farming; establishing composting units with a daily production capacity of 50-100 tons in all regions of the country to scale up the use of biofertilizers; using pyrolysis of agricultural residues for on-farm energy use (biochar, biogas, biofuel); and introducing methanization of manure. The NDC notes that implementation is conditional upon international technological support.

Malawi

Malawi's NDC sets out plans to mitigate GHG emissions from food production through conservation agriculture, conservation tillage, promotion of efficient fertilizer use and manure management, and improved rice management practices. To promote agroforestry, the country's NDC sets a targets of planting 25 trees per hectare on 155,000 hectares of crop fields—an area equivalent to 20 percent of Malawi's total arable land— as well as on 31,784 hectares of village forest areas. By expanding fruit tree production on 27,000 hectares, Malawi intends to achieve at least a 10% tree cover.

Rwanda

To control soil erosion, reduce carbon dioxide and nitrous oxide emissions, and enhance carbon sequestration, Rwanda's NDC presents plans to establish crop rotation on up to 600,000 hectares, terracing structures on 165,000 hectares of sloped arable land, and multi-cropping of coffee and bananas on up to 40,000 hectares as well as intentions to minimize tillage, increase the amount of crop residue left on the soil surface, and expand agroforestry.

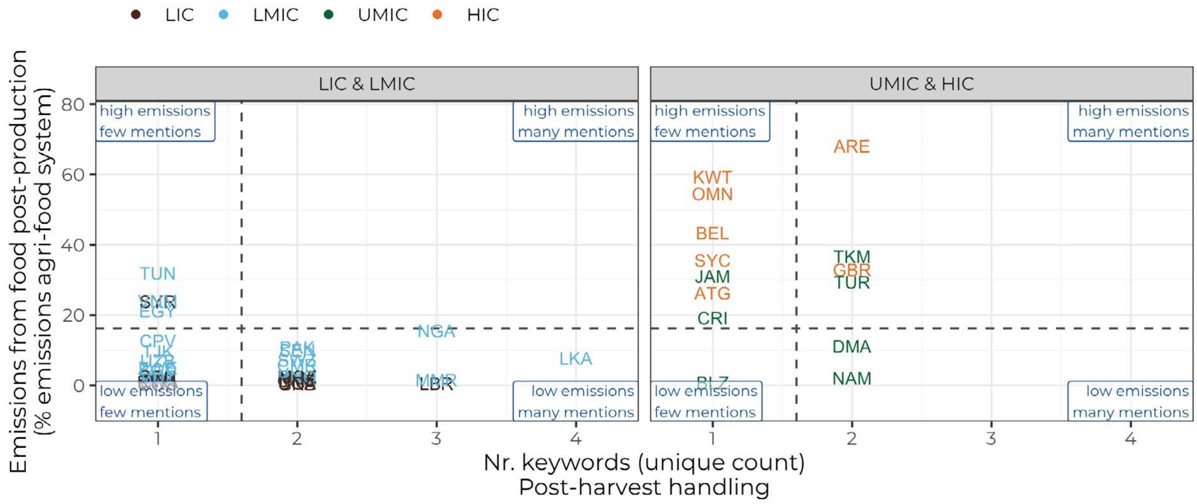
South Sudan

The climate mitigation and adaptation strategies for the agriculture and livestock sectors outlined in South Sudan's NDC provide for crop rotation, reduced tillage, modern grazing practices (e.g., common grazing, rotational grazing, or zero grazing), agroforestry, construction and rehabilitation of rainwater harvesting and storage infrastructures, and expanded use of leguminous fodder shrubs. These measures are intended to reduce fertilizer use and associated water pollution, decrease soil GHG emissions and soil erosion, reduce the vulnerability of cattle keepers and pastoralist communities in water-scarce regions, improve livestock feed quality, and slash livestock methane emissions.

Post-harvest handling and post-production GHG emissions

Only 50 countries' NDCs have keywords related to post-harvest handling in agricultural value chains with only one or two unique mentions in each of these 50 NDCs (Figure 3). A wide range of technological, operational, financial and policy options are available to boost efficiency in post-harvest handling and reduce food loss and waste—but these options are not widely mentioned in NDCs.

Figure 7. Inclusion of post-harvest handling in NDCs and percentage contribution of food post-production to total GHG emissions from agriculture and food systems. Source: Crippa et al. (2021)



In higher-income countries, a greater percentage of total agriculture and food system GHG emissions tends to be associated with post-production stages of agricultural value chains, including processing, packaging, transportation, and retail than in lower-income countries (Figure 7). However, mentions of post-harvest handling are not particularly common among higher-income countries.

EXAMPLES OF NDC MEASURES RELATED TO INNOVATION IN POST-HARVEST HANDLING

The Gambia

The Gambia's NDC includes plans to reduce food losses through improved harvesting techniques; adequate storage using hermetic bags or metal silos to limit exposure to moisture, heat, and pest infestation; deploying mobile processing units, solar dryers, graters, and pressers; contractual and aggregation points that help bring agricultural products to market; warehouse receipt systems to reduce losses during storage; and improved transport conditions and cold storage capacity.

Zimbabwe

Zimbabwe's NDC mentions value addition to agricultural products as a means to strengthen the position and resilience of women in food systems and the agriculture industry.

Senegal

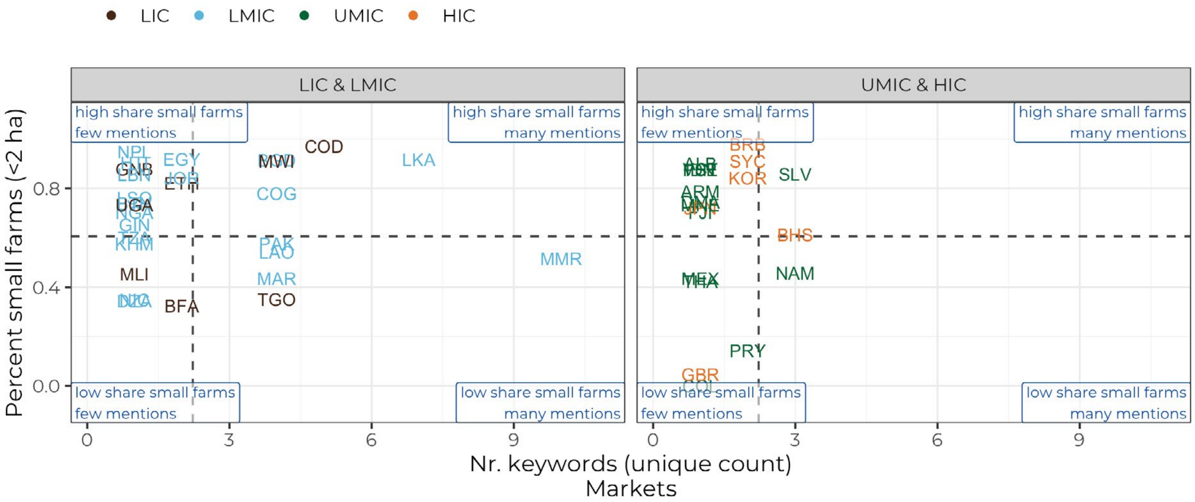
Senegal's NDC prioritizes adaptation measures including employing techniques such as storage or drying in post-harvest management of foods as well as processing and value addition for agricultural products.

Markets and small-scale agriculture

Although only 84 countries include keywords related to agricultural markets in their NDCs, a majority (69%) of LICs and LMICs do so, with fewer than 2 keywords related to markets per NDC on average. Only 42 percent of UMICs' and HICs' NDCs refer to markets, including, on average, less than 1 keyword per NDC (Figure 3). The most commonly mentioned market-related keywords are value chains, transportation, and smallholder farmers.

Small-scale producers are particularly vulnerable to the adverse effects of climate change and often lack equitable access to agricultural inputs and markets (FAO, 2023). Better linkages to remunerative markets can allow smallholders to build resilience, increase productivity, and contribute to improved domestic food supply (Russell, 2023). Figure 8 suggests that many countries with high percentages of small-scale producers in their agricultural sectors have not yet sufficiently included market-related measures in their NDCs.

Figure 8. Inclusion of market-related innovation in NDCs and percentage of small farms (<2 hectares) within national agricultural systems. Source: Lowder et al. 2021.



EXAMPLES OF NDC MEASURES RELATED TO MARKET INNOVATION

South Sudan

South Sudan's NDC includes plans to develop and adopt digital solutions to help farmers stay informed about agricultural markets, including their locations and market prices.

Papua New Guinea

To give smallholder farmers better access to markets and strengthen their food safety, security, and nutrition, Papua New Guinea's NDC indicates plans to scale up and replicate infrastructure, technology, training, and knowledge management for climate-smart agriculture.

Democratic Republic of the Congo

Adaptation measures in the Democratic Republic of the Congo's NDC include organization of commercialization channels and a policy of remunerative prices for farmers selling agricultural products.

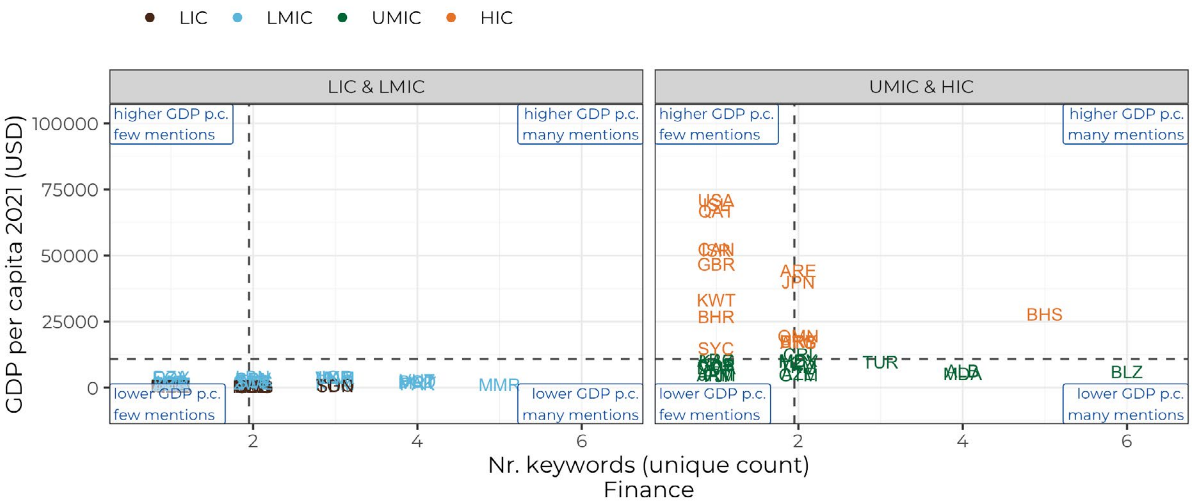
Niger

Niger's NDC includes plans to improve commercialization systems for local agricultural products to benefit vulnerable producers.

Finance and GDP

Only 81 countries' NDCs include keywords related to finance for agriculture and food systems innovation. Finance-related keywords are included in 61 percent of LICs' and LMICs' NDCs and 46 percent of UMICs' and HICs' NDCs, with unique finance-related keywords mentioned about 1 time per NDC on average across all country groups (Figure 3). The most mentioned keywords in these NDCs include insurance, Article 6 of the Paris Agreement, investment, public-private partnerships, subsidies, and credit access. Figure 9 shows that finance is sparingly mentioned by the highest income countries, perhaps because they are much less likely than lower-income countries to use their NDCs to solicit international financial support.

Figure 9. Inclusion of finance-related innovation in NDCs and GDP per capita. Source: World Bank



EXAMPLES OF NDC MEASURES RELATED TO FINANCIAL INNOVATION

The Democratic Republic of the Congo

The DRC's NDC includes plans to provide subsidies to smallholders for adoption of new agroecological practices to sustain their farms.

Vanuatu

Vanuatu's NDC refers to providing subsidies and exploring small grant and soft loan options to build more resilient livelihoods for small-scale producers in agriculture, livestock, forestry, and fisheries. Vanuatu also aspires to increase access of farmers and enterprises to agricultural and climate financing including risk-sharing and insurance services such as affordable micro-insurance and 'climate insurance' models that provide additional safety nets for crop damage and associated loss of income. Vanuatu seeks to explore these options through partnerships with the private sector, international organizations, development partners, and non-governmental organizations.

South Sudan

In its NDC, South Sudan indicates that it will introduce an index-based livestock insurance system to protect livestock keepers and pastoralists in drought-prone and arid regions as a way to provide monetary support for livestock losses in times of drought and severe shortages of fodder.

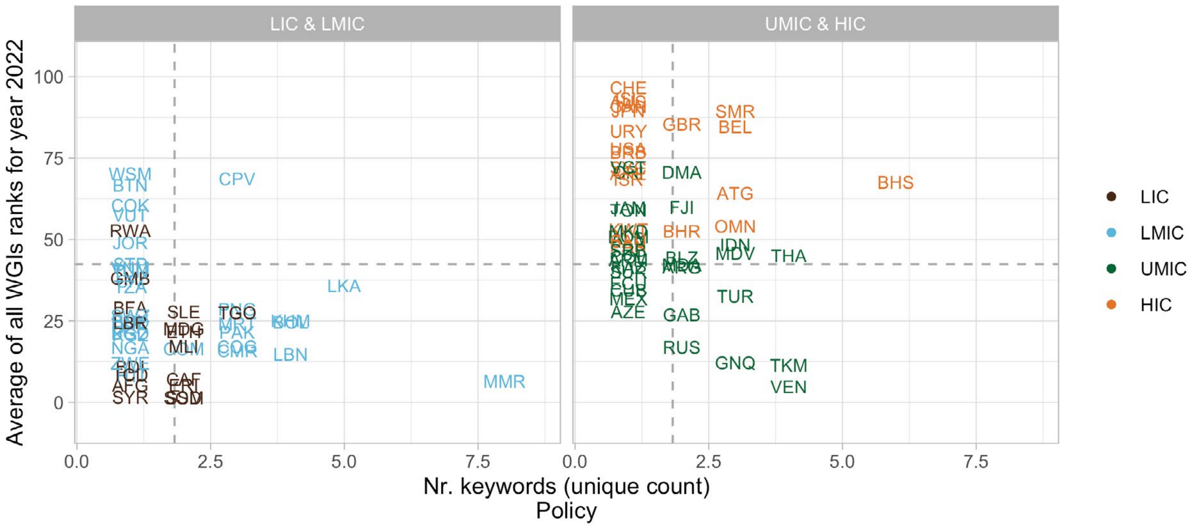
Belize

To build resilience to climate change, Belize's NDC indicates that it will facilitate public-private initiatives to implement cost-effective measures for crop development, livestock production, and soil quality improvement. Belize also seeks to establish a financing facility for investments in climate-smart agriculture through local financial institutions.

Policy and governance

Policy-related keywords are included in 103 NDCs and at similar rates across country groupings, with 67 percent of LICs and LMICs and 70 percent of UMICs and HICs mentioning policy-related keywords on average just above 1 time per NDC (Figure 3). The most common keywords mentioned include land-use planning and regulations.

Figure 10. Inclusion of policy innovation in NDCs and the average rank per country of the six Worldwide Governance Indicators (WGI), i.e., Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption for the year 2022. Source: World Bank - WGI).



A conducive policy environment for investment in agriculture and food systems innovation will include effective overall national governance including political stability, accountability, rule of law, regulatory quality, government effectiveness, and control of corruption. LICs, which generally have a lower ranking in governance indicators, might be expected to include more measures related to policy innovation, however, Figure 10 does not appear to show this.

EXAMPLES OF NDC MEASURES RELATED TO POLICY INNOVATION

Turkmenistan

Turkmenistan's NDC acknowledges that innovation in food production requires the development and adoption of new laws and other regulations, noting that these policies should define the responsibility of state organizations in the innovative development of the agricultural sector as well as measures of state support for investments into agricultural innovation.

Timor-Leste

Timor-Leste's NDC includes plans to capitalize on mitigation and adaptation co-benefits of activities that expand and protect carbon sinks such as carbon farming, ecosystem restoration, agroforestry, or blue carbon management. Timor-Leste will accelerate existing and new land tenure reform efforts through 2030 to improve the enabling environment for nature-based solutions in the land use sector and allow its population to benefit from opportunities arising through Article 6 of the Paris Agreement and emerging global carbon markets.

Pakistan

Pakistan's NDC proposes legal reforms that will enable female farmers to buy or sell land, sell their goods at farmers markets, access loans and finance, and ensure that governmental incentives explicitly target women farmers.

Bolivia

Bolivia's NDC sets out to achieve full titling of all agrarian land by 2030, with at least 43 percent of land ownership rights going to women. Through enabling technology transfer, Bolivia wants to increase production of strategic crops—cereals, stimulants, fruits, vegetables, oilseeds, industrial crops, tubers, roots, fodder—by 70 percent by 2030.

5.3 Country requests for support with agriculture and food systems innovation

Member countries of the NDC Partnership (see Annex 4) assist each other to turn their NDCs into actionable policies, programs, and projects. Countries can submit requests through the Partnership for technical and financial support to enhance and/or implement their NDCs. To date, only nine percent of all submitted requests relate to agriculture and food systems innovation. In total, 567 requests related to agriculture and food systems have been submitted to the NDC Partnership by 60 countries, more than half of which are in sub-Saharan Africa. With 57 percent of these requests already fully or partially supported, governments are still seeking to attract support for the remaining 43 percent.

The three most common activity types mentioned in requests related to agriculture and food system innovation are: developing bankable projects and pipelines, capacity development, and ceveloping or updating monitoring, reporting and verification (MRV) or monitoring and evaluation (M&E) systems and collecting data. The largest support gap exists for requests to support activities related to enacting and revising national strategies and plans and capacity development.

EXAMPLES OF COUNTRY REQUESTS FOR SUPPORT RELATED TO AGRICULTURE AND FOOD SYSTEMS INNOVATION

Liberia *requested support to reduce GHG emissions from crop and livestock production by promoting and adopting low-carbon technologies and practices, including conservation agriculture, no/low tillage, agro-pastoral systems, improved lowland rice cultivation, multi-cropping, and organic fertilizer. Support data for this request is currently unavailable.*

Belize *requested support to improve resilience in the agricultural sector by piloting an agriculture insurance scheme. This request was partially supported by Germany.*

Jordan *requested support to train recent university graduates and unemployed individuals in establishing hydroponics and aquaponics incubators. This request was supported by the Netherlands.*

Cambodia *requested support to improve animal breeding technology through artificial intelligence and to strengthen research capacities on animal genetics, breeding, and feed. Both requests remain unsupported.*

(See additional examples in Annex 4.)

CHAPTER 6

RECOMMENDATIONS FOR POLICYMAKERS

6. RECOMMENDATIONS FOR POLICYMAKERS

Our analysis is intended to support enhanced inclusion of agriculture and food systems innovation in NDCs. In particular, this work aims to support lower-income countries in using NDCs to build resilience and sustainability of small-scale farms and agricultural value chains. With several categories of agriculture and food systems innovation only modestly included in existing NDCs, the next phase of NDC submissions presents an important opportunity. For governments seeking to increase their climate ambition for this important sector, NDCs can signal national priorities to international partners and investors.

With an eye toward real-world barriers and context-specific opportunities, our recommendations emphasize pragmatic considerations including the interconnection of policy ambition with funding commitments. NDCs are an important mechanism for strengthening investment in and support for climate-aligned agriculture and food systems innovation, especially when they are harmonized with other national planning tools such as National Adaptation Plans (NAPs) and National Biodiversity Strategies and Action Plans (NBSAPs). NDCs also present a key opportunity for identifying the financial resources required to tackle climate change through agriculture and food systems and for mobilizing finance and support at the necessary scale.

6.1 High-level recommendations

Every country has distinct opportunities for increasing productivity, enhancing resilience, and mitigating GHG emissions that require context-specific, locally led agriculture and food systems innovation. However, the strategies presented below are relevant for all countries as they develop their NDCs.

Take a holistic approach to agriculture and food systems innovation.

Achieving productivity, sustainability, and resilience requires innovation in many different forms. The seven innovation categories described in this report can be mutually reinforcing when pursued in a holistic way. Current NDCs refer extensively to innovation in on-farm production while other critical innovation categories receive less attention. In future NDCs, governments can signal an intention to increase and re-balance investment to more effectively incentivize climate-aligned changes in agriculture and food systems. By more equally investing across technology development, capacity building, sectoral support systems, market infrastructure, financial systems, and other arenas of innovation, countries are more likely to achieve their climate objectives.

Cultivate stakeholder convergence and enrich local capabilities.

There is wide variation across agricultural systems, political economies, and other important drivers of NDC development. Inclusion of NDC text related to agriculture and food systems innovation – and, most importantly, actual implementation – will depend on convergence among domestic stakeholders on the importance and feasibility of new policies and investments across sectors through multi-stakeholder mechanisms. Climate-aligned transitions in agriculture and food systems will emerge through locally led approaches, implemented by a constellation of agriculture and food systems actors (WWF, 2023). Continuous engagement and support can ensure that in-country and in-region researchers, producers, extension advisors, agri-entrepreneurs, public officials, and local financial institutions are capable of building the sustainability and resilience of agriculture and food systems.

Use national assets to pursue national innovation priorities.

While financial constraints can limit national action, agriculture and food systems in all countries have assets that can be mobilized toward sustainability transitions. Even where they are informal and fragmented, local agricultural value chains convert land, labor, and inputs into food supply and financial flows. Even under-invested R&D systems retain essential knowledge and scientific capabilities. Targeted, evidence-based investments can elevate how existing systems and sectoral actors leverage traditional and emerging knowledge and technology toward climate-aligned transitions.

National priorities for agriculture and foods systems innovation will reflect specific circumstances. In lower-income countries, the most pressing arena for innovation is likely to be sustainably increasing productivity to shrink yield gaps and grow the agricultural economy while building biophysical and socio-economic resilience. In higher-income countries, innovation may be most needed for seizing GHG mitigation and other sustainability objectives that simultaneously reduce vulnerability to shifting climatic regimes and resource degradation.

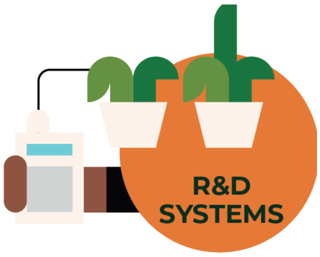
Co-invest carefully to achieve long-term goals.

Navigating climate challenges requires both urgent action and long-term planning. Stable funding commitments to national institutions are central to ensuring that international partnerships deliver context-specific, locally led research and technical support that directly benefit domestic constituencies. Robust national strategies for enhancing agriculture and food systems innovation create a foundation for collaborations with global donors and private sector partners that meaningfully contribute to achieving long-term national goals.

When governments have realistic expectations about the roles that international partners can play in co-investments, they can negotiate allocation of risks and benefits accordingly. Blended finance deals and public-private partnerships will work best when they recognize that commercial imperatives govern the contributions of private companies and financial institutions. To make effective use of the knowledge assets and networks built through short-duration, donor-funded R&D projects, national research institutions can cultivate networks to facilitate transfers to new partners.

6.2 Policy measures for agriculture and food systems innovation in NDCs

While every country has distinct capacities and needs , most countries have meaningful opportunities to increase support to all categories of agriculture and food systems innovation. Based on our review of available evidence and existing NDCs, we offer the following recommendations to policymakers and other stakeholders for integrating agriculture and food systems innovation in their NDCs.

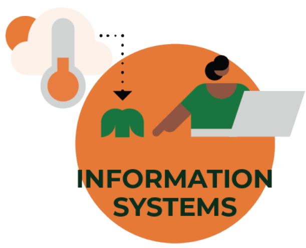


Research and development (R&D)

Evidence. Investments in agricultural research and development lead to improved productivity and economic growth – essential underpinnings of viable climate action – within and across national borders. Much of the work of national and international research institutions is aligned with climate objectives, however transformative innovation is hampered by inadequate and imbalanced funding and insufficient collaboration across regions and sectors. Private sector R&D can make important contributions where large or rapid ROI is in reach.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 74 percent refer to R&D systems, suggesting that governments already recognize their essential role in advancing climate-aligned transformation. In future NDCs, governments can consider including measures to:

- Maintain and increase base funding for national agricultural research institutions to ensure they can fully deliver on national climate science priorities while effectively working with international institutions and private companies to collaboratively develop new knowledge and to adapt relevant technologies.
- Establish goals and guidelines for public-private R&D partnerships to ensure these deliver public value through commercialization of research outputs that are tailored to local biophysical and socio-economic conditions.
- Mandate national mechanisms for comprehensive assessment of R&D impacts and gaps focusing on productivity, resilience, and GHG emissions, while also considering socio-economic and biodiversity objectives.



Information systems

Evidence. New types of data gathering and analysis have improved the information landscape in agriculture and food systems, however access and benefits are not yet equally shared. Meaningful progress will rely on improved governance systems that build trust, facilitate equitable data-sharing, and garner steady funding streams.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 71 percent refer to information systems, indicating broad awareness of their potential to gather and disseminate knowledge that empowers new approaches by producers and value chain actors. In future NDCs, governments can consider including measures to:

- Continue and enhance data-gathering and data-sharing related to agricultural yields, soil and water quality, agrobiodiversity, greenhouse gas emissions, food security, market activity, labor, and other environmental and socio-economic dimensions of agriculture and food systems through national programs and international partnerships and translate these data into meaningful and usable information for producers and value chain actors.
- Mandate whole-of-government mechanisms for tracking and assessing the impact of agriculture and food system policies and programs to better understand how these help or hinder climate-aligned sectoral transitions, especially for vulnerable, small-scale production systems.
- Participate in international initiatives to integrate long-term national datasets with new measurement and analysis tools to build more accessible and actionable information resources that support sustainable agricultural management, market planning, and policy making while establishing robust protocols for data ownership, sharing, and use.

On-farm production

Evidence. Incremental and breakthrough technological progress has not yet been sufficient to shrink yield gaps, increase agricultural resilience, or reduce GHG emissions. Climate-aligned productivity gains will depend on enhanced, sustained, and demand-led investment in supporting producers and value chain actors to adopt appropriate technologies and practices.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 95 percent refer to innovation in on-farm production, reflecting the historical focus on sustainability shifts by crop and livestock producers. In future NDCs, governments can consider including measures to:

- Specify national efforts to address gaps in agricultural productivity, resilience, and GHG mitigation through validated technological and socio-economic interventions.
- Articulate concrete plans for enhancing demand-led technical and financial support for climate-aligned on-farm innovation by under-served agricultural producers including women and youth.
- Mandate cross-ministry collaboration on needs assessment and program development to anticipate and respond to climate change impacts, GHG emissions, biodiversity loss, and natural resource degradation.

Post-harvest handling

Evidence. Due to prevailing inefficiencies across complex, multi-level food supply chains, food loss and waste generate GHG emissions and increase vulnerability at large scale. With encouragement by innovative national policies, food loss and waste could be significantly reduced through careful assessment and tactical deployment of appropriate interventions that cost-effectively increase efficiency and augment domestic food supply.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 33 percent refer to post-harvest handling, suggesting that many countries have not yet developed national strategies for capturing this large mitigation and resilience-building opportunity. In future NDCs, governments can consider including measures to:

- Specify planned investments to improve storage, transport, processing, and marketing infrastructure in agricultural value chains.
- Identify opportunities to improve utilization of organic waste streams and better meet agricultural fertilization needs.
- Mandate relevant agencies to monitor and quantify food loss and waste, and associated GHG emissions and resilience impacts, to better inform and implement tailored, cost-effective interventions.
- Establish mechanisms for enhanced coordination among input suppliers, producers, and market actors to reduce post-harvest loss through aligned capabilities for meeting production timing, quantity, and quality requirements.

Markets

Evidence. Most input supply chains do little to facilitate climate-aligned agricultural production and few market signals sufficiently incentivize producers to adopt new approaches. Changes in sectoral subsidies and improved market price transparency are critical to re-orienting agricultural value chains.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 56 percent refer to agricultural markets, reflecting the growing awareness of the powerful influence of market infrastructures and incentives on decisions by producers and other value chain actors. In future NDCs, governments can consider including measures to:

- Specify plans to deliver technical and financial support for producers to access climate-aligned agricultural inputs and to effectively participate in agricultural markets.

- Build out reliable storage, transport, and energy networks that better enable agricultural producers to access remunerative marketing opportunities.
- Establish platforms to enhance agricultural product aggregation through coordination across value chain actors including small-, medium-, and large-scale traders.
- Mandate relevant agencies to increase market transparency through domestic initiatives and international partnerships.

Finance

Evidence. Painful constraints on donor and government budgets and limited private sector activity are slowing the flow of investment needed to test and validate new finance models for climate adaptation and mitigation in agriculture and food systems. Greater coordination among governments and across sectors can increase financial fluency with climate-aligned investment needs and opportunities.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 54 percent refer to finance, suggesting growing awareness among governments that tailored financial strategies are necessary for catalyzing climate-aligned sectoral transitions. In future NDCs, governments can consider including measures to:

- Specify plans for steering right-sized finance to small- and medium-sized agri-entrepreneurs.
- Participate in regional initiatives to improve quantification of opportunities and risks associated with climate-aligned investment in agricultural value chains and to enhance sectoral fluency within local financial systems.
- Establish aspirations and guardrails for climate finance and blended finance approaches to filling agriculture and food system funding gaps.

Policy

Evidence. Of the wide range of policy tools available, many are underutilized for steering toward sustainable, resilient, and equitable agriculture and food systems. Holistic, transformative national policies struggle to emerge in the context of siloed ministries and stakeholders' divergent visions. While some policies can deliver 'win-win' outcomes, many will require navigating tradeoffs and reallocating costs and benefits.

Recommendations. Of the 151 NDCs that mention agriculture and food systems innovation, 68 percent refer to policy, indicating a majority of governments recognize their lead role in steering holistic sectoral transformation. In future NDCs, governments can consider including measures to:[1]

- Mandate whole-of-government coordination to steer existing public and private capital flows, including sectoral subsidies, toward co-investment in more sustainable, resilient agriculture and food systems.
- Identify and deploy specific policy tools to more effectively incentivize climate-aligned transitions in distribution, transport, processing, manufacturing, retail, and food services components of agricultural value chains.
- Articulate a national approach for navigating tradeoffs associated with climate-aligned policies including compensation mechanisms for imposed costs and safety nets for vulnerable social groups.

6.3 Final reflections

Policies and investments that enable innovation by agricultural producers and value chain actors are urgently needed to promote agriculture and food systems transformation in line with the Paris Agreement's 1.5°C target and the Sustainable Development Goals (FAO, 2024; GAFF, 2022a). The likelihood of achieving food and agriculture objectives increases if countries explicitly include measures that support innovation in their NDCs.

At research centers, in the field, and in the market, stakeholders are continuously learning how to invest strategically and equitably. Yet, there is already extensive evidence that investing in research and innovation cost-effectively accelerates sustainability and resilience in agriculture and food systems. While this report highlights positive examples from selected NDCs, most existing NDCs only partially integrate these significant opportunities.

National governments can use NDCs to steer domestic resources and international climate finance toward priority actions. NDCs can best facilitate agriculture and food systems transformation when they include concrete finance requirements for activities that reduce climate vulnerability and lower GHG emissions, while delivering benefits for food security, human health, and biodiversity.

While the process of enhancing and implementing NDCs will reflect specific national circumstances, every country will benefit from undertaking a range of actions to bolster innovation that promotes transformation of agriculture and food systems. This study indicates that inclusion of specific commitments and co-investment pathways that address all major categories of agriculture and food systems innovation will strengthen NDCs as a mechanism for enhancing climate ambition.

---

[1] In developing their NDCs, policymakers can use the NDC 3.0 Navigator.

ANNEX

ANNEX 1 – METHODOLOGY FOR NDC REVIEW

Source of NDC documents

All available NDC documents were downloaded from the official repository maintained by the UNFCCC. This repository is a centralized source for all submitted NDCs, ensuring the completeness and authenticity of the data. To ensure accurate coverage of information, the relevant sections to revise across NDCs were identified (see Table S1 and Figure S4 in Supplementary Materials).

Initial keywords list

Based on literature review undertaken in 2023, an initial, comprehensive list of words and phrases (Table 6) associated with categories of agriculture and food systems innovation was developed and modified to construct a final list of 130 keyword search terms. It must be noted that some of these keywords were not spelled out fully to account for any variations in their usage (e.g., "tech" to capture both "technology" and "technologies"). Furthermore, in some cases, both American and British variations of words were used to account for the diversity of countries and their language preferences (e.g., "Mechanization" and "Mechanisation").

Table 6. Keyword search terms in seven innovation categories, organized by sub-categories.

SUB-CATEGORY	KEYWORDS
RESEARCH & DEVELOPMENT (R&D)	
Enhanced R&D systems	Research R&D Scien Technol Knowledge Universit Local-validation Regional-validation
INFORMATION SYSTEMS	
Information access / utility	Capacity Extension Services Data Digitalization Farmers-Association Early Alert Weather-forecast
ON-FARM PRODUCTION	
Soil management	Soil Erosion Salinization Compaction Tillage Restoration Rehabilitation Carbon-sequestration Fertil Manure Residues Biochar Compost Green-manure Cover-crop Organic-inputs Mulching
Crop management	Crop Cropping Sowing Seeding Planting Cultivar Crop-Variety Rotation Multicropping Multi-cropping Intercropping Inter-cropping Agroforestry Cereal Pulses Rice Wheat Maize Soybean Agro-chemicals Herbicide Pesticide
Water management	Water Irrigation Alternate Wetting-and-Drying AWD
Livestock management	Livestock Animal Enteric-fermentation Feed Grazing Pasture Grassland Savannah Range-land

SUB-CATEGORY	KEYWORDS
Energy management	Biogas Bio-gas Solar-energy
Productivity increase	Agricultural-intensification Productivity Profitability Breeding System of Rice Intensification SRI
Enhanced resilience	Agro-ecology Regenerative-agriculture Integrated-crop-livestock-systems Silvopastoral-systems Agro-biodiversity Soil-carbon Soil-Fertility Risk-management
POST-HARVEST HANDLING	
Increased efficiency	Post-harvest-processing Storage Food-loss Agriculture-waste
Value addition	Value-chain Co-ownership Cooperative Inclusive-agriculture
MARKETS	
Market development	Market-infrastucture Market-integration Local-market Demand Commercialization Transportation Roads Logistics Supply-chain Treaceability
Support to market actors	Agri-business Small-holders
Demand-side measures	Packaging Food-labels Sustainable-diet Healthy-diet Procurement
FINANCE	
Financial support	Producer-incentives Offtake-guarantees Subsidies De-risking Credit-access Investments Local-financial-institution Blended-finance Financial-inclusion Micro-credit Insurance
Financial planning	Financial-analysis Financial-planning Article-6 Art-6
POLICY	
Supportive policies	Reforms Regulat Legal Polic Land-tenure Land-use-planning

Keywords search and recording

The keywords search and recording phase of this study was designed to ensure comprehensive identification and systematic recording of relevant keywords within the NDCs.

Adobe Reader's advanced search function was employed to maximize the coverage of keyword identification across different sections of the NDC documents. This tool allowed for a comprehensive search of text, ensuring that no relevant occurrences of the keywords were missed. The advanced search function facilitated the identification of keywords within paragraphs, tables, and figures, providing a thorough analysis of the documents. Microsoft Excel was then used for recording the keywords and relevant text excerpts. The spreadsheet was structured to capture various details systematically:

- General Information: Country name, ISO code and reviewer name;
- NDC Excerpts: Relevant paragraphs where keywords were found;
- Context Category: Categorization of the text based on its context (e.g., mitigation, adaptation, means of implementation, governance processes, methodology, annex and others);

- Keywords: A column for each identified keyword; and
- Reviewer Notes: Additional notes or observations by the reviewer.

Each NDC document was subjected to a keyword search using Adobe Reader's advanced search option. When a keyword was found within a context or paragraph that referred to agriculture, AFOLU (Agriculture, Forestry, and Other Land Use), and food systems, the entire paragraph was recorded in Excel. This ensured that the keyword was captured within the appropriate context. If a keyword was found but did not relate to the context of agriculture, AFOLU, or food systems, it was skipped to maintain the relevance of the data collected.

The search process also included a review of tables and figures within the NDCs to ensure comprehensive coverage of the keywords. In instances where multiple keywords were found within the same text, the text was recorded only once to avoid double counting. If new keywords were found, they were added to the list and incorporated into the ongoing search and recording process.

Automated screening of NDC documents for combinations of keywords was complemented by manual review to confirm relevance of search matches and to include document formats that are unsuited to automated search. In particular, if a paragraph was found to be relevant but no keyword from the original list was found, reviewers recorded also the new relevant keywords. For NDCs where the file format did not enable text search, a short text screening was applied manually. Reviewers scanned the documents for relevant sections, ensuring that no critical information was overlooked. This applied to five NDCs. It must be noted that all keywords were translated into Spanish and French to accommodate NDCs not available in English. These translations were reviewed and validated by native speakers to ensure accuracy. This step was crucial to ensure that the analysis was inclusive and comprehensive across different languages.

Data cleaning

Before conducting the analysis, the dataset was preprocessed to ensure its quality and integrity. The dataset underwent several transformations, including:

- Identifying and correcting any inaccuracies, inconsistencies, or missing values in the data. Any obvious errors in the dataset, such as incorrect data entries or misclassified information, were corrected based on the available information and observations made by the reviewers;
- Identifying new keywords not included in the original list and classifying it according to the pre-established intervention areas;
- Harmonizing keywords variations. For example, "biotechnology", "bio-technology" and "bio-technologies" were harmonized and recorded as "bio-technologies"; and
- Converting data into a standard format for script-based processing.

Extended keywords list

See supplementary material.

Quantification methods

Keyword mentions as 'unique count': Different approaches can be used for counting keywords per NDC, such as counting absolute number of keyword mentions, including their repetitions, or counting unique number of keywords, removing repetitions so that if a keyword was found multiple times within an NDC, it is counted only once. In this report we have used the latter, which we call "unique count" approach and applied it to the list of "harmonized keywords" (see Data cleaning and Extended keywords list sections). The same approach has been used for counting keyword mentions per country NDC and innovation category.

Average keyword mentions per NDC: To enable comparison of keyword mentions across country income groups, we calculated the average keyword mentions by summing the number of keyword mentions for all countries within each income group, and then dividing by the number of countries within each income group, considering only countries that have submitted NDC and that had at least one keyword mentioned.

Number of innovation categories covered per NDC: The definition of agriculture and food systems innovation used in this report encompasses a wide range of practices and interventions that we have grouped into seven agriculture and food systems innovation categories. To provide a measure of the breadth by which each country and income group cover the extent of these innovation categories, we have:

- Grouped individual keywords under the seven categories (i.e., each keyword belong to only one innovation category);
- Counting the number of keywords per category and NDC; and
- Counting the number of categories per NDC as unique counts (i.e., in a similar fashion as for the keyword mentions unique count explained above).

Previous work using similar methodologies

Similar methodologies using keywords to research food systems have been used in previous reports by the Climate Policy Initiative (CPI, 2023b) and the World Wildlife Fund (WWF, 2022) collaborating with Climate Focus.

To determine the amount of climate finance to small-scale agriculture and food systems, CPI used a methodology based on keyword searches to screen project-level data for relevant financial flows. To identify small-scale agriculture and food-relevant projects, CPI established a list of keywords that reporting organizations and funders typically use when describing projects targeting smallholders, communities, or other actors in the supply chains. CPI's search allowed for the use of various combinations of keywords and a set of exclusion rules to maximize the chances of capturing relevant projects while avoiding false positive matches. After applying the keyword search to the data, CPI then conducted manual reviews covering at least 80% of financial flows captured through the automated keyword search to confirm the relevance of marked projects.

For the analysis of adaptation measures in NDCs and NAPs of African countries, Climate Focus developed an assessment framework based on literature review of best practices in food system adaptation globally. This framework was then piloted and refined by applying it to three countries' NDCs and NAPs. The framework included 45 categories of measures relevant for food systems adaptation as identified in the literature. These measures were grouped under four themes reflecting the food value chain: pre-production and production; post-harvest (e.g., storage, transport, and distribution); and consumption; and cross-cutting issues (including governance and financial enablers, gender and IPLC equity considerations, just transition, and food security considerations). In the next step, Climate Focus used the framework for a keyword search and qualitative assessment of if, and to what extent, food system measures are considered in the 53 NDCs and 12 NAPs of African countries submitted by June 2022.

Limitations of the methodology

The methodology developed for the purpose of this work employed a mixed-methods approach, integrating both qualitative and quantitative approaches to assess NDCs. The key quantitative aspect involved the recording of metadata (e.g., number of pages of NDCs); the categorization and counting of keyword mentions to enable extracting descriptive statistics; and the identification of trends across country groups (i.e., country income groups, other country characteristics).

Limitations to the methodology include:

- The comprehensiveness of keywords choice is limited by a degree of subjectivity as the choice of which keywords to search for cannot be fully systematized. To enhance comprehensiveness, we allowed reviewers to expand the initial list with new relevant keywords found while screening the text.
- The different number of keywords included in each innovation category, which introduce some bias when comparing the number of keywords found across different categories.
- The different level of standardization of keywords listed under different categories. Because on-farm agricultural practices have well-defined terms, information can be easily categorized and summarized using a specific set of keywords. For instance, when talking about “organic farming,” everyone understands what practices are included under this term. In contrast, for other categories (e.g., R&D and policies), the lack of standardized terminology means that more descriptive and narrative explanations are needed to convey the meaning. This makes it harder to encapsulate the information under a concise set of keywords. For example, “policy enabling environment” might include a wide range of activities and conditions that vary by country, requiring more detailed descriptions.

ANNEX 2 – RESULTS: KEYWORD SEARCH OF NDC DOCUMENTS

For the 151 countries that mention keywords related to agriculture and food systems innovation in their submitted NDCs, the table below presents the number of unique keyword counts, for each innovation category and in total.

Table 7. Frequency of keyword mentions in NDCs for seven innovation categories.

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
Afghanistan	AFG	LIC	3	3	6				1	13
Angola	AGO	LMIC	2	1	8			1		12
Albania	ALB	UMIC	2	4	18		1	4	1	30
Andorra	AND	HIC			1		1			2
United Arab Emirates	ARE	HIC	1	4	6	2	3	2	1	19
Argentina	ARG	UMIC	2	2	9			1	2	16
Armenia	ARM	UMIC	1	1	4		1	1	1	9
Antigua and Barbuda	ATG	HIC		3	5	1		2	3	14
Australia	AUS	HIC							1	1
Azerbaijan	AZE	UMIC	1		4		1	2	1	9
Burundi	BDI	LIC	1		12		2		1	16
Belgium	BEL	HIC		2	2	1			3	8
Burkina Faso	BFA	LIC		1	18		2	2	1	24
Bangladesh	BGD	LMIC	2	3	18	1	4	4	1	33
Bahrain	BHR	HIC		1	1			1	2	5
Bahamas	BHS	HIC	6	4	12		3	5	6	36
Belize	BLZ	UMIC	1	1	13	1		6	2	24
Bolivia	BOL	LMIC	4	1	12		1	2	4	24
Brazil	BRA	UMIC			8					8
Barbados	BRB	HIC	2	1	2		2	2	1	10

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
Bhutan	BTN	LMIC			13		1		1	15
Botswana	BWA	UMIC			8					8
Central African Republic	CAF	LIC	1	3	12		1	2	2	21
Canada	CAN	HIC	1		5			1	1	8
Switzerland	CHE	HIC			3				1	4
Chile	CHL	HIC			11					11
China	CHN	UMIC	3		11					14
Cote d'Ivoire	CIV	LMIC	2		10				1	13
Cameroon	CMR	LMIC	1	3	21	2	1		3	31
DR Congo	COD	LIC	5	6	20	1	5	2	2	41
Republic of Congo	COG	LMIC		3	12		4	2	3	24
Cook Island	COK	LMIC							1	1
Colombia	COL	UMIC	3	4	8		1		1	17
Comoros	COM	LMIC	3	3	17		5	1	2	31
Cabo Verde	CPV	LMIC	3	5	19	1	8	2	3	41
Costa Rica	CRI	UMIC	1	1	9	1	1	2	1	16
Cuba	CUB	UMIC		1	1				1	3
Djibouti	DJI	LMIC		1	4					5
Dominica	DMA	UMIC	2	3	22	2	1	1	2	33
Dominican Republic	DOM	UMIC	1		14				1	16
Algeria	DZA	LMIC	1	2	3		1	1	1	9
Ecuador	ECU	UMIC	4	3	2				1	10
Egypt	EGY	LMIC	2	4	11	1	2	1	1	22
Eritrea	ERI	LIC	2	1	5				2	10
Ethiopia	ETH	LIC	3	2	23	1	2	1	2	34
Fiji	FJI	UMIC		1			1	1	2	5
Micronesia	FSM	LMIC	1	1			3			5
Gabon	GAB	UMIC	1	1	13		4	1	2	22
United Kingdom	GBR	HIC	2		6	2	1	1	2	14
Georgia	GEO	UMIC		1	1					2
Ghana	GHA	LMIC		1	2					3
Guinea	GIN	LMIC	2	1	13	2	1			19

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
Gambia	GMB	LIC	1		12	2			1	16
Guinea-Bissau	GNB	LIC	3	2	12	2	1			20
Equatorial Guinea	GNQ	UMIC	1	1	8		1		3	14
Guatemala	GTM	UMIC	1		10			2		13
Guyana	GUY	HIC	1		3					4
Honduras	HND	LMIC	3	2	2				1	8
Haiti	HTI	LMIC	1	4	17		1	1	1	25
Indonesia	IDN	UMIC	4	2	10		1		3	20
India	IND	LMIC	1	1						2
Iraq	IRQ	UMIC	1		14					15
Iceland	ISL	HIC			5			1	1	7
Israel	ISR	HIC	1		1			1	1	4
Jamaica	JAM	UMIC			2	1		1	1	5
Jordan	JOR	LMIC	4	4	13		2	3	1	27
Japan	JPN	HIC			2		1	2	1	6
Kazakhstan	KAZ	UMIC	2		13		1	1	1	18
Kenya	KEN	LMIC		1	7			2		10
Kyrgyzstan	KGZ	LMIC	1	2	5				1	9
Cambodia	KHM	LMIC	2	3	18	2	1	3	4	33
Kiribati	KIR	LMIC			6			1		7
Saint Kitts and Nevis	K	HIC	2	1	3					6
Korea (Republic of)	KOR	HIC			5		2			7
Kuwait	KWT	HIC	5		10	1	1	1	1	19
Laos PDR	LAO	LMIC	2	2	9		4	1		18
Lebanon	LBN	LMIC	1	5	17		1	2	4	30
Liberia	LBR	LIC	4	4	16	3	4	2	1	34
Saint Lucia	LCA	UMIC			1					1
Sri Lanka	LKA	LMIC	6	7	36	4	7	3	5	68
Lesotho	LSO	LMIC	4	5	12	1	1			23
Morocco	MAR	LMIC	1	1	10		4	3		19
Moldova	MDA	UMIC	5	4	13		2	4	2	30
Madagascar	MDG	LIC	3	2	16		2	2	2	27

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
Maldives	MDV	UMIC	4	2	6		1	2	3	18
Mexico	MEX	UMIC	1		7		1	2	1	12
North Macedonia	MKD	UMIC		1	6				1	8
Mali	MLI	LIC	1	2	16		1		2	22
Myanmar	MMR	LMIC	7	8	38	3	10	5	8	79
Montenegro	MNE	UMIC		1	2	1	1			5
Mongolia	MNG	LMIC			7					7
Mozambique	MOZ	LIC	3		12	2		1		18
Mauritania	MRT	LMIC	1	2	20		1	4	3	31
Mauritius	MUS	UMIC	2		7					9
Malawi	MWI	LIC	3	4	22	2	4	2		37
Malaysia	MYS	UMIC	2	2	4					8
Namibia	M	UMIC	5	2	17	2	3			29
Niger	NER	LIC	2	4	17		2	1		26
Nigeria	NGA	LMIC	1	1	12	3	1		1	19
Nicaragua	NIC	LMIC	2	2	9		1			14
Nepal	NPL	LMIC	2	2	9	1	1			15
Nauru	NRU	HIC		1	2					3
New Zealand	NZL	HIC	2		3					5
Oman	OMN	HIC	2	1	6	1	2	2	3	17
Pakistan	PAK	LMIC	2	7	20	2	4	4	3	42
Panama	PAN	HIC		1	3				1	5
Papua New Guinea	PNG	LMIC	4	6	12	2	7	3	3	37
Paraguay	PRY	UMIC	2	3	8		2			15
Palestine	PSE	UMIC	1		13	2	1		1	18
Qatar	QAT	HIC	1	1	1			1		4
Russia	RUS	UMIC			2				2	4
Rwanda	RWA	LIC	1	2	21	1		1	1	27
Saudi Arabia	SAU	HIC	1	1	5				1	8
Sudan	SDN	LIC	5	4	15	1		3		28
Senegal	SEN	LMIC	3	1	19	2		1		26
Solomon Islands	SLB	LMIC		2	2			2		6

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
Sierra Leone	SLE	LIC	3	2	15		2	2	2	26
El Salvador	SLV	UMIC	7	3	14		3			27
San Marino	SMR	HIC	1						3	4
Somalia	SOM	LIC		2	9		3		2	16
Serbia	SRB	UMIC		2	6	1			1	10
South Sudan	SSD	LIC	6	4	28	3	6	1	2	50
Sao Tome and Principe	STP	LMIC	1	1	5		1	2	1	11
Suriname	SUR	UMIC	2	2	7				1	12
Eswatini	SWZ	LMIC	2	2	12	2	3		1	22
Seychelles	SYC	HIC	3	4	8	1	2	1	1	20
Syria	SYR	LIC	2	4	12	1	2		1	22
Chad	TCD	LIC	1		18		1	1	1	22
Togo	TGO	LIC	3	3	18		4	3	3	34
Thailand	THA	UMIC	1	2	9		1		4	17
Tajikistan	TJK	LMIC	5	1	20	1	3			30
Turkmenistan	TKM	UMIC	3	3	10	2	1	2	4	25
Timor-Leste	TLS	LMIC	2	3	11		1	2	3	22
Tonga	TON	UMIC		4	8				1	13
Tunisia	TUN	LMIC	4	5	16	1			1	27
Turkey	TUR	UMIC	3	3	26	2		3	3	40
Tuvalu	TUV	UMIC			7					7
Tanzania	TZA	LMIC	4	2	7		1	1	1	16
Uganda	UGA	LIC			12	2	1			15
Uruguay	URY	HIC	3	1	7			2	1	14
United States	USA	HIC	2		15			1	1	19
Uzbekistan	UZB	LMIC	2	1	10	1	1	1		16
Vatican City	VAC	HIC							1	1
Saint Vincent and the Grenadines	VCT	UMIC	1		2		1	1	1	6
Venezuela, RB	VEN	UMIC	5	2	12			1	4	24
Viet m	VNM	LMIC	3	1	20	1		3	1	29
Vanuatu	VUT	LMIC	5	5	15	1	5	4	1	36
Samoa	WSM	LMIC	1		6				1	8

COUNTRY	ISO	INCOME GROUP	INNOVATION CATEGORY							TOTAL MENTIONS
			R&D systems	Information systems	On-farm production	Post-harvest handling	Markets	Finance	Policy	
South Africa	ZAF	UMIC		2	1					3
Zambia	ZMB	LMIC	1		4			1		6
Zimbabwe	ZWE	LMIC	3	2	16	1	1	2	1	26

† International Organization for Standardization (ISO) created and maintains standard codes for the representation of names of countries and their subdivisions.

ANNEX 3 – EXAMPLES OF AGRICULTURE AND FOOD SYSTEMS INNOVATION IN NDCS

Examples in the table below illustrate how countries have already included agriculture and food systems innovation in the NDC documents reviewed (as described in Section 3).

Table 8. Examples from selected NDC documents.

COUNTRY	EXAMPLE OF RELEVANT NDC TEXT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
		Innovation category						
LOW-INCOME COUNTRIES								
Democratic Republic of Congo	Organization of commercialization channels; policy of remunerative prices for farmers; subsidies for smallholders for adoption of agroecological practices.					x	x	
The Gambia	Improved harvesting techniques; adequate storage using hermetic bags or metal silos; application of mobile processing units, solar dryers, graters, and pressers; contractual and aggregation points; warehouse receipt systems; improved transport conditions and cold storage capacity.				x			
Malawi	Conservation agriculture; conservation tillage; promotion of efficient fertilizer use and manure management, improve rice management; planting 25 trees per ha on 155,000 ha of crop fields and 31,784 ha of village forest areas for agroforestry; expansion of fruit tree production on 27,000 ha.			x		x		
Niger	Improved commercialization systems for local agricultural products.					x		

COUNTRY	EXAMPLE OF RELEVANT NDC TEXT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Rwanda	Crop rotation on up to 600,000 ha; land protection terracing structure in sloped arable areas on 165,000 ha; multi-cropping of coffee and bananas on up to 40,000 ha; minimized tillage; increased crop residue on soil surface; agroforestry.			x				
Sierra Leone	Establishment of weather stations. Support to research into climate-resilient crop varieties and production practices at national Agriculture Research Institute and Njala University.	x						
South Sudan	Crop rotation; reduced tillage; modern grazing practices (e.g., common grazing, rotational grazing, zero grazing); agroforestry; construction and rehabilitation of rainwater harvesting and storage infrastructures; increased uptake of leguminous fodder shrubs; development and adoption of digital solutions for improved market access of farmers; index-based livestock insurance system.			x		x	x	
LOW MIDDLE-INCOME COUNTRIES								
Bolivia	Full titling of all agrarian land by 2030; technology transfer to increase production of strategic crops by 70% by 2030.							x
Cabo Verde	Quality and environmental label for fishery products by 2027.					x		
Cambodia	Increased research capacity for animal genetics, breeding, and feed; improvement of agricultural support services; capacity-building for crop producers; research, testing, and scaling of climate-smart agriculture.	x	x					

COUNTRY	EXAMPLE OF RELEVANT NDC TEXT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Cameroon	Intermittent irrigation of rice fields; use of nitrification inhibitors by 5% of farmers by 2030; supplement fat in ruminant feed by 12%; 12,500 new food plantations; anti-erosion farming practices; organic farming; new composting units with a daily production capacity of 50-100 tons in all regions of the country for biofertilizer production; pyrolysis of agricultural residues for on-farm energy use (biochar, biogas, biofuel). Methanization of manure.			x				
The Comoros	Subsidies for smallholders for adoption of agroecological practices.						x	
Pakistan	Legal reforms to enable female farmers to buy and sell land; sell their goods at farmers markets; access loans and finance; and ensure governmental incentives target women farmers.							x
Papua New Guinea	Scaled and replicated infrastructure, technology, training, and knowledge management on climate-smart agriculture for market access of smallholders.					x		
Senegal	Use of storage and drying techniques in post-harvest management of foods; processing and value addition to agricultural products.				x			
Sri Lanka	Research & Development and knowledge transfer for precision agriculture, genetic improvement of livestock, new crop cultivars, enhanced productivity and agrotechnology, and climate-resilient urban and coastal development.	x						
Timor-Leste	Land tenure reform through 2030 to facilitate nature-based solutions in the land-use sector and benefit from Article 6 of Paris Agreement and global carbon markets.							x

COUNTRY	EXAMPLE OF RELEVANT NDC TEXT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Vanuatu	Subsidies, small grants, and soft loans for smallholders in agriculture, livestock, forestry, and fisheries; increased access of farmers and enterprises to agricultural and climate financing including risk sharing and insurance; micro-insurance and climate insurance; public-private partnerships for finance.						x	
Zimbabwe	Value addition to agricultural products.				x			
HIGH MIDDLE-INCOME COUNTRIES								
Albania	New subsidy scheme for farmers for adoption of new technologies in crop production.						x	
Belize	Public-private partnerships for crop development, livestock production, and improved soil quality; new financing facility for investments in climate-smart agriculture through local financial institutions.						x	
Brazil	Recovery of degraded lands; nitrogen fixation; increased accumulation of soil organic matter; no-till farming; integration of forestry, crop production, and cattle breeding; agroforestry; forest planting.			x				
Ecuador	Development of information systems.		x					
El Salvador	Development and establishment of agroclimatic information system for farmers.		x					
Thailand	Capacity-building for relevant agencies; development of climate information services; enhancement of early warning systems.		x					
Turkmenistan	Development and adoption of new laws and regulations for agricultural innovation.							x

COUNTRY	EXAMPLE OF RELEVANT NDC TEXT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
HIGH-INCOME COUNTRIES								
United Arab Emirates	The National Farms Sustainability programme seeks to support local farms with sustainable market access by increasing governmental purchases of local products to 100% by 2030.					x		
The United States of America	Plans to support scaling of climate smart agricultural practices (including, for example, cover crops), reforestation, rotational grazing, and nutrient management practices.	x		x				
New Zealand	Maori-focused research aligned with integrated farm systems, which seeks to assist the Maori pastoral sector to increase resource efficiency and farm productivity while lowering greenhouse gas emissions.		x	x				

ANNEX 4 – COMPLEMENTARY FINDINGS: COUNTRY REQUESTS FOR SUPPORT THROUGH THE NDC PARTNERSHIP

The NDC Partnership is a global coalition, bringing together more than 120 developed and developing countries and nearly 100 institutions to deliver ambitious climate action that helps achieve the Paris Agreement and drive sustainable development. Through the Partnership, countries draw upon members' expertise and funding, turning their NDCs into actionable policies, programs, and projects. This includes requests for technical and financial support to integrate agriculture and food systems innovation into their NDC.

The NDC Partnership's knowledge management system, the Knowledge Nook (kNook), draws together data from official requests for support on NDC implementation or enhancement circulated through to the NDC Partnership by country members. The analysis presented in Section 5.3 in this report and the examples below of country requests submitted via the NDC Partnership was drawn from kNook in June 2024 by filtering for requests tagged with the "Agriculture" sector. This data search was further narrowed by searching for the same set of 130 keywords used for the agriculture and food systems innovation NDC review.[2]

Table 9. Examples from country support request database.

COUNTRY	REQUESTS FOR SUPPORT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
		Innovation category						
LOW-INCOME COUNTRIES								
Gambia	Strengthening and upscaling the participation of private sector actors in management of urban agriculture and green spaces.							x

[2] To gain access to kNook or to request an account: https://ndcpartnership.knack.com/knook#home/

COUNTRY	REQUESTS FOR SUPPORT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Liberia	Roll out incentives and programs to promote low-carbon agriculture practices, e.g., conservation agriculture, no/low tillage, agropastoral systems, improved lowland rice cultivation, multi-cropping, organic fertilizers, fustigation, composting, crop rotation, and sustainable agricultural waste management.		x		x		x	x
Mozambique	Dissemination of improved technologies for conservation agriculture and livestock.	x		x				
Sierra Leone	Provide national emissions profile of food waste and livestock waste. Introduce climate resilient agriculture tools and approaches to 500 farmers in the country.		x	x	x			
Togo	Support to estimate costs of priority mitigation and adaptation actions; and analyze macro- and socio-economic impacts and implications for sustainable development and poverty eradication of achieving revised NDC targets and net-zero emissions by 2050 in key sectors, including: agriculture, forestry and other land uses (AFOLU), water, human health, transportation, energy, waste and coastal and marine resources.							x
LOW MIDDLE-INCOME COUNTRIES								
Cambodia	Improvement of animal breeding technology in Cambodia through AI which can adapt to climate change.	x						
Nigeria	Technical support to develop “bankable projects”: improved soils and nutrient management, agroforestry, improved systems for both crops (drought resilient seeds and species) and livestock.					x	x	
Lebanon	At least 30 dairy or poultry farms benefiting from awareness raising and capacity building on animal wastes valorization.				x			
Pakistan	Support to build a Robust Water, Food, and Energy (WEF) Nexus Platform to Mobilize Sustainable Finance for Project Identification and Funding Requirements		x					

COUNTRY	REQUESTS FOR SUPPORT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Tunisia	Conservation agriculture based on fossil energy-saving cultivation techniques and promoting carbon sequestration are applied by farmers.							
HIGH MIDDLE-INCOME COUNTRIES								
Georgia	Support climate-friendly agricultural practices through extension and awareness-raising campaigns.			x				
South Africa	Develop bankable business plans for pilot cases: As far as agriculture is concerned, there is a need for measures to accelerate diffusion of early warning systems and tools to emerging farmers to ensure food security.						x	
Thailand	Capacity-building of responsible agencies to enhance early warning systems for disaster management in human settlement and security, agriculture, tourism, and health sectors.		x					
Jordan	Improving productivity of farmers through mechanized farming.	x		x				
Albania	Adopting a new law on Agriculture, mainstreaming climate change consideration in a comprehensive manner and aligned with the NDC and the NAP.							x
HIGH-INCOME COUNTRIES								
Panama	Capacity development to improve the measurement of field data and generate specific emission factors for enteric fermentation and manure management.	x	x					
Chile	Support for the development of a baseline study of the soil component, to determine the uses in Rapa Nui.		x					
Antigua and Barbuda	Develop a recommended architecture and recommended path forward for further development and implementation of a National Insurance Scheme schemes aimed at reducing the vulnerability of farmers and fishers.						x	x

COUNTRY	REQUESTS FOR SUPPORT	R&D SYSTEMS	INFORMATION SYSTEMS	ON-FARM PRODUCTION	POST-HARVEST HANDLING	MARKETS	FINANCE	POLICY
Saint Kitts and Nevis	Establish Early Warning System for agricultural hazards. Establish and integrate additional Agrometeorological stations representatively across both Islands. Identify and assess viable agricultural insurance options to address loss and damage from natural hazards (e.g., micro insurance for farmers and fishermen). Build technical and organizational capacities of Agricultural extension services (incl. officers) to support Agricultural risk and disaster management.	x	x					

ANNEX 5 – LITERATURE SOURCES

1. Agnew J, Hendery S. 2023. Global agricultural productivity report: Every farmer, every tool. Thompson T (Ed.) Blacksburg, Virginia, USA: Virginia Tech College of Agriculture and Life Sciences.
2. Albuquerque A, Assunção J, Castro P, Hoover El Rashidy N, Miranda G. 2023. Smallholders in the Caatinga and the Cerrado: A Baseline Analysis for a Rural Just Transition in Brazil. Rio de Janeiro: Climate Policy Initiative (CPI).
3. Amarante V, Burger F, Chelwa G, Cockburn J, Kassouf A, McKay A, Zurbrigg J. 2022. Underrepresentation of developing country researchers in development research. Applied Economics Letters, 29(17): 1659-1664.
4. Alston JM, Pardey PG, Rao X. 2020. The payoff to investing in CGIAR research. Arlington, Virginia, USA: SOAR Foundation.
5. AU. 2024. Africa sustainable development report. The African Union, African Development Bank, United Nations Development Programme and the United Nations Economic Commission for Africa.
6. AUDA-NEPAD. 2023. Scaling climate-smart agriculture for accelerated agri-food systems transformation in Africa.
7. Baldos ULC. 2023. Impacts of US public R&D Investments on agricultural productivity and GHG emissions. Journal of Agricultural and Applied Economics, 55(3): 536-550.
8. Birachi E, Rubyogo JC, Abang M et al. 2023. Bean commodity corridors scaling up production and market expansion for smallholders in Sub-Saharan Africa. Nairobi, Kenya: Pan-Africa Bean Research Alliance (PABRA); International Center for Tropical Agriculture (CIAT). 72 p.
9. Burwood-Taylor L, Devermann S, Zook D. 2024. Climate capital: Financing adaptation pathways for smallholder farmers. AgFunder / ISF Advisors.
10. Caldwell M, Alayza N, Larsen G. 2022. Paying for the Paris Agreement. Washington, DC: World Resources Institute.
11. Cassman KG, Grassini P. 2020. A global perspective on sustainable intensification research. Nature Sustainability, 3: 262–268.
12. CBI. 2024. Transition in action: Agri-food. London, UK: Climate Bonds Initiative. 18 p.
13. CGIAR. 2023. Investing in a food, nutrition and climate secure future: The case for investment.
14. Chikowo R, Chirwa R, Snapp S. 2022. Cereal–legume cropping systems for enhanced productivity, food security, and resilience. Chapter 3 in Sustainable agricultural intensification: A handbook for practitioners in East and Southern Africa. Oxfordshire, UK: CAB International. pp 33-47.
15. Clark MA, Domingo NGG, Colgan K, et al. 2020. Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science, 370: 705–708.
16. CPI [Daniela Chiriac, Harsha Vishnumolakala, Paul Rosane]. 2023a. Landscape of climate finance for agrifood systems. Climate Policy Initiative. 63 p.
17. CPI [Daniela Chiriac, Harsha Vishnumolakala, Paul Rosane]. 2023b. The climate finance gap for small-scale agrifood systems: A growing challenge. Climate Policy Initiative. 44 p.
18. Conti C, Hall A, Percy H, Stone-Jovicich S, Turner J, McMillan L. 2024. What does the agri-food systems transformation agenda mean for agricultural research organisations? Exploring organisational prototypes for uncertain futures. Global Food Security, 40: 100733.
19. Convergence. 2023. Blended finance and leveraging concessionality.
20. Crippa M, Solazzo E, Guizzardi D, et al. 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2: 198–209.
21. CSAF. 2023. State of the sector 2023. Council on Smallholder Agricultural Finance. 26 p.
22. Dalberg Asia. 2021. Funding agricultural innovation for the Global South: Does it promote sustainable agricultural intensification? Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification.
23. Dehmer SP et al. 2019. Reshuffling the global R&D deck, 1980-2050. PLoS ONE, 496;14(3): e0213801.
24. Delandmeter M, de Faccio Carvalho PC, Bremm C, dos Santos Cargnelutti C, Bindelle J, Dumont B. 2024. Integrated crop and livestock systems increase both climate change adaptation and mitigation capacities. Science of the Total Environment, 912.
25. Díaz-Bonilla E. 2023. Financing the transformation of food systems: A flow of funds approach. Food Systems Economics Commission.

26. Fan S, Chen K, Zhu J, Si W. 2022. China and Global Food Policy Report 2022: Reforming agricultural support policy for transforming agrifood systems. Beijing: China Agricultural University. 128 p.
27. FAO. 2024. The state of food security and nutrition in the world 2024 – Financing to end hunger, food insecurity and malnutrition in all its forms. Rome: UN Food & Agriculture Organization. 286 p.
28. FAO. 2023. The state of food and agriculture: Revealing the true cost of food to transform agrifood systems. Rome: UN Food & Agriculture Organization. 150 p.
29. FAO. 2022. Report of the Council of FAO – Appendix D: FAO Science and Innovation Strategy. Rome: UN Food and Agriculture Organization.
30. FAO. 2019a. Proceedings of the International Symposium on Agricultural Innovation for Family Farmers - Unlocking the potential of agricultural innovation to achieve the Sustainable Development Goals. Ruane, J. (ed.). Rome: UN Food and Agriculture Organization).
31. FAO. 2019b. The State of Food and Agriculture 2019: Moving forward on food loss and waste. Rome: UN Food & Agriculture Organization.
32. FOLU. 2024. Country platforms. Food and Land Use Coalition. Accessed 25 June 2024.
33. Fourat E, Blanchart E, Cué Rio M et al. 2024. Holistic approaches to assess the sustainability of food systems in low- and middle-income countries: A scoping review. PLOS Sustain Transform 3(7): e0000117.
34. Friedman-Heiman A, Miller SA. 2024. The impact of refrigeration on food losses and associated greenhouse gas emissions throughout the supply chain. Environmental Research Letters, 19(6): 064038.
35. Fuglie KO, Echeverria RG. 2024. The economic impact of CGIAR-related crop technologies on agricultural productivity in developing countries, 1961–2020. World Development, 176: 106523.
36. Freyer B, Ellssel P, Nyakanda F, Saussure S. 2024. Exploring the off-farm production, marketing and use of organic and biofertilisers in Africa: A scoping study. Report to the European Commission. DeSIRA-LIFT. 254 p.
37. Fuglie KR. 2018. Capital, R&D spillovers, and productivity growth in world agriculture. Appl. Econ. Perspect. Policy, 40: 421-444.
38. GAFF. 2022a. Untapped opportunities for climate action: An assessment of food systems in Nationally Determined Contributions. Global Alliance for the Future of Food. 46 p.
39. GAFF. 2022b. Untapped opportunities: Climate financing for food systems transformation.
40. Gautam M, Laborde D, Mamun A, Martin W, Piñeiro V, Vos R. 2022. Repurposing agricultural policies and support: Options to transform agriculture and food systems to better serve the health of people, economies, and the planet. Washington, DC: World Bank. 112 p.
41. Gildemacher PR, Wongtschowski M. 2015. Catalysing innovation: from theory to action. KIT Working Papers. Amsterdam: Royal Tropical Institute.
42. Giller KE, Delaune T, Silva JV, et al. 2021a. The future of farming: Who will produce our food?. Food Security, 13: 1073–1099.
43. Giller KE, Delaune T, Silva JV, van Wijk M, Hammond J, Descheemaeker K, van de Ven G, Schut AGT, Taulya G, Chikowo R, Andersson JA. 2021b. Small farms and development in sub-Saharan Africa: Farming for food, for income or for lack of better options? Food Security, 13:1431–1454
44. GNAFC. 2024. 2023 Financing Flows and Food Crises Report – Analysis of humanitarian and development financing flows to food sectors in food crisis countries. Rome. Global Network Against Food Crises.
45. Gollin D, Hansen CW, Wingender AM. 2021. Two blades of grass: The impact of the Green Revolution. Journal of Political Economy, 129: 2344–2384.
46. Haddad L. 2020. Viewpoint: A view on the key research issues that the CGIAR should lead on 2020–2030. Food Policy, 91:101824.
47. Hellin J, Fisher E, Bonatti M. 2024. Transforming agricultural research and development systems to meet 21st century needs for climate action. Frontiers in Sustainable Food Systems, 8:1398079.
48. Hou Jones X, Sorsby N. 2023. The unsung giants of climate and nature investment: Insights from an international survey of local climate and nature action by smallholder forest and farm producers. London: IIED.
49. I&P. 2023. Using catalytic capital to foster African entrepreneurs in underserved markets.
50. Iese V, Halavatau S, N'Yeurt AD, et al. 2020. Agriculture under a changing climate. In: Kumar L. (eds) Climate Change and Impacts in the Pacific. Springer Climate. pp 323–357.
51. IPCC. 2023. Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva, Switzerland: IPCC. 34 p.
52. 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 – Summary for Policymakers. Intergovernmental Panel on Climate Change. 43 p.
53. Ishtiaque A et al. 2024. Overcoming barriers to climate-smart agriculture in South Asia. Nature Climate Change.

54. Jayne TS, Zingore S, Niang AI, Palm C, Shah S, Kovak E, Sanchez P. 2024. Building 21st century agricultural research and extension capacity in Africa. Oakland, California: Breakthrough Institute.
55. Kabede EA, Abou Ali H, Clavelle T, et al. 2024. Assessing and addressing the global state of food production data scarcity. Nature Reviews Earth & Environment.
56. Kadirgamar A, Rehbein K, Stutz M. 2024. Global Sovereign Debt Monitor 2024. Entwicklung braucht Entschuldung eV and Bischöfliches Hilfswerk MISEREOR eV. 58 p.
57. Kibaara B. 2023. Q&A with Betty Kibaara: Innovations that can deliver "good food" for Africa. One Earth, 6: 467-469.
58. Kinkpe AT, Grethe H. 2023. Enhancing Domestic Food Processing for a More Sustainable Food System in Benin. 52 p.
59. Koh H. 2024. 5 myths preventing catalytic capital from going where it's needed. Stanford Social Innovation Review.
60. Ruggeri Laderchi C, Lotze-Campen H, DeClerck F, et al. 2024. The economics of the food system transformation. Food System Economics Commission (FSEC), Global Policy Report.
61. Lowder SK, Ruggeri Laderchi, C, Cerutti N, Parsons K. 2022. Food system policies: A global snapshot from the Food System Policy Database (FSPD).
62. Lowder SK, Sánchez MV, Bertini R. 2021. Which farms feed the world and has farmland become more concentrated? World Development, 142: 105455.
63. Malabo Montpellier Panel. 2022. Adapt: Policy Innovations to Unlock Climate Finance for Resilient Food Systems in Africa. Kigali, Rwanda: Malabo Montpellier Panel / AKADEMIYA2063.
64. Marshall Q, Fanzo J, Barrett CB, Jones AD, Herforth A, McLaren R. 2021. Building a global food systems typology: A new tool for reducing complexity in food systems analysis. Frontiers in Sustainable Food Systems 5: 746512
65. Nandi R, Nedumaran S, Ravula P. 2021. The interplay between food market access and farm household dietary diversity in low and middle income countries: A systematic review of literature. Global Food Security, 28: 100484.
66. Nature Plants. 2020. Feast and famine in agricultural research. [Editorial] Nature Plants 6: 1195.
67. Nature. 2020. To end hunger, science must change its focus. [Editorial] Nature, 586: 336.
68. Nicolini G, Bladon A, Ducros A, Swiderska K, Torres Ledezma C, Bortoletti M. 2023. Food systems governance and the environmental agenda. London: IIED. 48 p.
69. Nin-Pratt. 2021. Agricultural R&D investment intensity: A misleading conventional measure and a new intensity index. Agricultural Economics, 52:317-328.
70. NISR. 2019. The Third National Strategy for the Development of Statistics (NSDS3). National Institute of Statistics of Rwanda. https://www.statistics.gov.rw/publication/nsds3
71. Nowak AC. 2023. Compendium of impact pathways for adaptation of African agriculture, version 1.0. Alliance Bioversity / CIAT. 24 p.
72. Okem AE, Ali E, Chevallier R, Attoh EMNAN, Kapesa T, Efitre J, Lukorito CB, Nying'uro PA, Ogola C, Osei-Amponsah C, Wamukoya G. 2023. How can Africa attain climate resilient development? Nairobi, Kenya: African Group of Negotiators Expert Support (AGNES). Policy brief no. 20. 11 p.
73. OXFAM. 2022. Climate finance in West Africa: Assessing the state of climate finance in one of the world's regions worst hit by the climate crisis. Oxford, UK: Oxfam International. 34 p.
74. Oyinbo O, Chamberlin J, Abdoulaye T, Maertens M. 2022. Digital extension, price risk, and farm performance: experimental evidence from Nigeria. American Journal of Agricultural Economics, 104(2): 831–852.
75. Pardey PG, Beddow JM. 2019 Revitalizing agricultural research and development to sustain US competitiveness. Philadelphia, PA, USA: Farm Journal Foundation.
76. Pardey PG, Alston JM, RR Piggot. 2017. Introduction and Overview: Chapter 1 in Agricultural R&D in the developing world: too little, too late? Washington, DC: International Food Policy Research Institute (IFPRI). Pp. 1-10.
77. Perera O, Smaller C, El Harty K, Lefebvre L. 2024. Unleashing the catalytic power of donor financing to achieve Sustainable Development Goal 2. Global Donor Platform for Rural Development and Shamba Centre for Food & Climate. 48 p.
78. Rao X, Hurley TM, Pardey PG. 2019. Are agricultural R&D returns declining and development dependent? World Development, 122: 27–37.
79. Reardon T, Echeverria R, Berdegué J, Minten B, Liverpool-Tasie LSO, Tschirley D, Zilberman D. 2019. Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. Agricultural Systems, 172:47-59.
80. Resnick D, Swinnen J. 2023. The political economy of food system transformation: Pathways to progess in a polarized world. Washington, DC: International Food Policy Research Institute (IFPRI). 401 p.
81. Reynolds M, Atkin OK, Bennett M. 2021. Addressing research bottlenecks to crop productivity. Trends in Plant Science, 26(6):607-630.
82. Ricciardi V, Ramankutty N, Mehrabi Z, et al., 2018 How much of the world's food do smallholders produce? Global Food Security, 17: 64-72.

83. Roe S, Streck C, Beach R, Busch J, Chapman M, Daioglou V, et al. 2021. Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 1– 34.
84. Romero-Silva R, Akkerman R, de Leeuw S. 2024. Understanding and improving global agri-food supply chains in an interconnected world: a systems approach. Burleigh Dodds Science Publishing. 426 p.
85. Rosegrant MW, Sulser TB, Wiebe K. 2022. Global investment gap in agricultural research and innovation to meet Sustainable Development Goals for hunger and Paris Agreement climate change mitigation. Frontiers in Sustainable Food Systems, 6: 965767.
86. Russell A. 2023. Strengthening market systems for small-scale farmers in developing dountries. UC Davus Feed the Future Innovation Lab for Markets, Risk and Resilience. 24 January 2023.
87. Savvidou G, Atteridge A, Omari-Motsumi K, Trisos CH. 2021 Quantifying international public finance for climate change adaptation in Africa, Climate Policy, 21:8, 1020-1036.
88. Liverpool-Tasie LSO, Wineman A, Young S, Tambo J, Vargas C, Reardon T, Adjognon GS, Porciello J, Gathoni N, Bizikova L, Galiè A, Celestin A. 2020. A scoping review of market links between value chain actors and small-scale producers in developing regions. Nature Sustainability, 3: 799–808.
89. Schoneveld GC. 2022. Transforming food systems through inclusive agribusiness. World Development, 158: 105970.
90. Stads G-J, Nin-Pratt A, Beintema N. 2022. Boosting investment in agriculture research in Africa: Building a case for increased investment in agricultural research in Africa. AU-SAFGRAD. 84 p.
91. Stevenson JR, Vlek P. 2018. Assessing the adoption and diffusion of natural resource management practices: Synthesis of a new set of empirical studies. Rome: Independent Science and Partnership Council (ISPC).
92. TEC-UNFCCC. 2022. Support for climate technologies provided by the operating entities of the Financial Mechanism: Experience and lessons learned. Bonn, Germany: United Nations Framework Convention on Climate Change (Technology Executive Committee).
93. Tenkouano A, Isah A, Panchbhai A, Bilaro A, Karanja D, Nampanzira D, Phekani G, Keti H, Shimelis H, Rubyogo JC, Bekunda M, Diop M, Sibomana M, Odeke M, Samaké OB, Negra C. 2023. Empower climate-resilient smallholder agriculture by investing in African research and innovation. Washington, DC: United Nations Foundation.
94. Tubiello FN, Rosenzweig C, Conchedda G, et al. 2021. Greenhouse gas emissions from food systems: building the evidence base. Environmental Research Letters, 16: 065007.
95. UN Climate Change News. 2022. UN: Early warning systems must protect everyone within five years. 23 March 2022.
96. UNDP. 2024. Human Development Report 2023-24. United Nations Development Programme.
97. UNEP. 2024. Food Waste Index report 2024. Think eat save: Tracking progress to galve global food waste. Nairobi: United Nations Environment Programme. 191 p.
98. van Gaal C, Kesseler N, Puri J, Chowdhury J, McKee A, Brean D, Brean P. 2023. An integrated investment framework for climate-adaptive and water-resilient food systems. NDC Partnership.
99. Waldman KB, Todd PM, Omar S, et al. 2020. Agricultural decision making and climate uncertainty in developing countries. Environmental Research Letters, 15: 113004.
100. Westendorg E. 2019. The benefits of US investment in global wheat research collaboration. U.S. Wheat Associates, February 28, 2019.
101. WFO. 2023. Report on the first global producers' consultation on climate-smart agriculture. Rome: World Farmers' Organisation. 61 p.
102. WMO. 2023. Early warnings for all: The UN global early warning initiative for the implementation of climate adaptation: Executive action plan 2023-2027. Geneva: World Meteorological Organization. 56 p.
103. World Bank. 2021. Food finance architecture: Financing a healthy, equitable and sustainable food system.
104. WRI. 2019. Creating a sustainable food future. Washington D.C: World Resources Institute. 564 p.
105. WWF / Climate Focus. 2024. Food Forward NDCs.
106. WWF. 2023. Solving the great food puzzle: Right innovation, right impact, right place. Gland, Switzerland. 38 p.
107. WWF. 2022. Scaling and accelerating adaptation in food systems in Africa: An assessment of Nationally Determined Contributions and National Adaptation Plans. WWF. 41 p.
108. WWF. 2021. Driven to Waste: Global food loss on farms. 145 p.
109. Zucker-Marqes M, Gallagher KP, Volz U. 2024. Defaulting on development and climate: Debt sustainability and the race for the 2030 Agenda and Paris Agreement. Debt Relief for Green and Inclusive Recovery Project (DRGR).

UNITED NATIONS FOUNDATION

CLIMATE FOCUS