CCAFS's Low-Emissions Development (LED) research and engagement impact on innovation and scaling-up mitigation options in agriculture

Working Paper No. 371

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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CGIAR
RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security
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About CCAFS working papers
Titles in this series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

About CCAFS
The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is led by the International Center for Tropical Agriculture (CIAT), part of the Alliance of Bioveristy International and CIAT, and carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. For more information, please visit https://ccafs.cgiar.org/donors.

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Abstract

The objective of CCAFS's Flagship 3 on Low-emission Development (LED) is to reduce agricultural greenhouse gas (GHG) emissions while ensuring food security at large scales. Research focused on estimating GHG emissions, developing LED technical options, and identifying mechanisms for scaling up options. Results informed the feasibility of an LED framework in agriculture and built a community of practice for implementation of LED at scale. This report provides a synthesis of the Flagship's outputs, outcomes, and impacts.

LED research outputs The Flagship reported 1,001 outputs from 2011 to 2020. CCAFS's other flagships and regional programs contributed an additional 866 outputs related to the LED program. Most outputs (42%) were reports and journal articles (Figure 1).

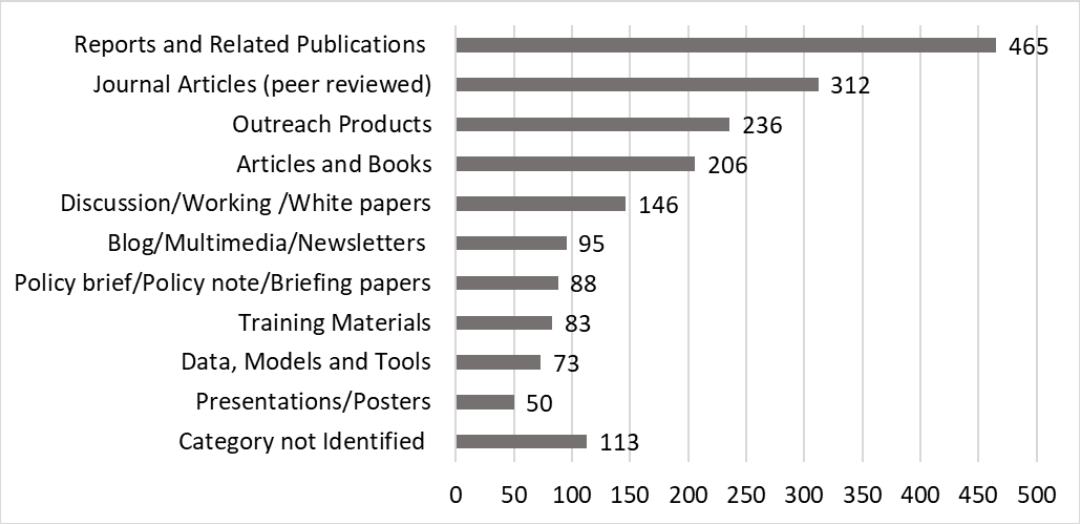

Figure 1: Category of research outputs

LED research outcomes The CCAFS LED Flagship generated 60 outcomes from 2011-2020 (Table 1). The Flagship informed 16 LED policies and plans, 8 improved MRV systems, and contributed to developing 8 LED finance and investment plans.

Table 1: CCAFS LED Flagship outcome categories

Category	Total	Major Contribution
Inform LED policy or plan	16	Realign policies to mitigation need and potential, and update NDC ambitions
Measurement, reporting and verification	8	Improve MRV system for national GHG inventories
LED finance/investment	8	Catalyze government and private sectors' finance and investment in LED
Use of LED methods/tools	6	Use of carbon accounting tools, models, and calculators
Nutrient management	6	Improve input use efficiency
Paddy-Rice/AWD	4	Improve water use efficiency
Livestock/pastureland management	4	Improve input use efficiency
Agroforestry	4	Enhance carbon sequestration and improved livestock feed
Food loss and waste	3	Improve efficiency in agriculture value chains
Agro-advisories	1	Knowledge transfer for informed decision making

This review of the CCAFS LED Flagship found that the Flagship**:**

- Produced significant new knowledge about greenhouse gas emissions for smallholder farmers, low-cost emissions estimation methods and tools, a database of emission factors representing agricultural systems in low and middle-income countries, a web-based knowledge platform for Measurement, Reporting, and Verification (MRV), and a web-based guidance to low-emission development resources; Emission factors were generated for paddy-rice (99), rice-wheat system (56), livestock (34), and maize-wheat systems (25).
- Provided evidence for climate action by providing decision-makers with ex-ante analysis and tools to identify targets, LED options, and the suitability of options for different production systems;
- Developed and tested approaches for integrating mitigation into national and sub-national agricultural development programs, sustainability initiatives, and private sector investment to support large-scale adoption of LED options;
- Contributed to 60 significant outcomes, i.e., use of research outputs at scale, from 2011-2020. The majority of outcomes informed LED policies and plans, improved MRV systems, or enhanced LED finance and investment at global, regional, and national levels; and

- Generated impacts over 10 years with the potential to reduce emissions by 196 M tons of CO_2e, including the adoption of mitigation options by 36 M farmers in 69 M hectares of land with more than US$4 billion investment committed from national and sub-national governments, global climate finance, the private sector, and bilateral/multilateral funding organizations.

Lessons from the CCAFS LED experience

- Partnerships with research users across the public and private sectors can lead to innovation in mitigation research and scaling. Partnering with entities who conveyed their research needs to us and wanted to use results to design their programs generated the most impact. This happened with USAID, DfID/FCDO, IFAD, ADB, World Bank, Climate Bonds Initiative, responsAbility, Impossible Foods, the GRA and others. It required an entrepreneurial approach to approaching partners to offer services rather than pre-determined research projects. Partnership with the GRA was especially productive, gave us government legitimacy and helped us develop access to a wider base of contacts. Regular UNFCCC COP presence helped us to build visibility and expand our partnerships.
- Research focused on countries with existing leadership in LED in agriculture where demonstrable progress was possible: Vietnam, Indonesia, Colombia, Brazil, Mexico, China, Kenya, and Ethiopia.
- Investing in communities of practice through initial workshops and science-policy forums helped rapidly develop the LED framework for agriculture and built CCAFS' networks for collaboration and impact.
- Rapid analysis of NDC data, e.g., after the 2015 Paris COP, providing infographics that can be used in a wide range of presentation contexts (e.g., maps of NDCs), and making databases widely available, such as the NDC analysis in 2015 generated a lot of interest and ongoing use.
- A focus on high-impact mitigation actions that contribute meaningfully to global targets is a priority, rather than on practices promising insignificant (i.e., low) mitigation co-benefits.
- Prioritize geographic emissions hotspots, countries, and value chains to generate large impacts.

- A huge appetite exists in the finance community for technical information and developing pipeline of mitigation projects in the supply chain and landscape.
- Support the transition to a policy, finance and market environment, for example, conditional finance, regulations, and company accountability; to mainstream GHG mitigation in the agriculture sector.

Keywords

Agriculture; climate change; food systems; food security; low-emissions development; climate change mitigation.

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Contents

Acronyms

AWD	Alternate wetting and drying
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CSA	Climate-smart agriculture
FP	Flagship
GHG	Greenhouse gas
INDC	Intended Nationally Determined Contributions
LED	Low-emissions development
LMIC	Low- and medium-income countries
MRV	Measurement, Reporting, and Verification
NAMA	Nationally Appropriate Mitigation Action
NDCs	Nationally Determined Contributions
SDGs	Sustainable Development Goals

Introduction

Purpose and objectives

The CGIAR launched a research program on Climate Change, Agriculture and Food Security (CCAFS) in 2011 to generate evidence and support the adoption of climate-smart agricultural policies, practices, and services to enhance food security, build resilient agriculture systems, and mitigate GHG emissions wherever possible. CCAFS promoted the integration of global science and expertise with local knowledge for climate action in agriculture and allied sectors. It followed a results-based management approach to link research and outputs to outcomes and impacts on people's wellbeing and the environment (Schuetz et al. 2017).

In CCAFS, the Low-Emissions Development (LED) Flagship aimed to test and evaluate the feasibility of reducing agricultural GHG emissions at a large scale while ensuring food and nutrition security of agriculture-dependent communities in low- and middle-income countries. This research flagship focused on quantifying GHG emissions from agriculture production systems, identifying priorities and options for low-emissions development, and evaluating policies, incentives, and finance for scaling up low emissions practices in agriculture and allied sectors. An LED approach was taken to jointly achieve food security and mitigation impacts. The Flagship's theory of change was that agricultural development would be the major driver of reduced emissions until mitigation-specific institutions emerged, such as the nationally determined contributions (NDCs) of the UNFCCC, at which point these would become the major drivers.

CCAFS completes its 11-year research program in 2021 just before the launch of the One CGIAR initiatives in 2022. CCAFS's science and experience can provide lessons to the One CGIAR and others concerned with research and development for low-emissions development. The purpose of this study is to provide a synthesis of the Flagship's outputs, outcomes, and impacts to inform innovation in agricultural GHG mitigation research and scaling up mitigation options in agriculture and food students. This assessment evaluated the LED impact pathway and theory of change (Appendix 1) and identifies the lessons for future research and development in climate actions. Key research questions include:

- **Outputs:** How have data, methods, analysis, tools, guidelines, workshops, and events been developed by Low-Emissions Development Flagship (including CGIAR and non-CGIAR partners) relevant to the mitigation planning and interventions in the agriculture and food systems contributed to knowledge and supported innovation for low-emission development?
- **Outcomes:** How have research outputs developed by Low-Emissions Development Flagship (including CGIAR and non-CGIAR partners) led to changes in behavior by next users (national/subnational governments, development organizations, private sector, and other stakeholders)?
- **Impacts:** What were the effects on GHG mitigation, input efficiency, policy change, and women's participation in decisions, including change in knowledge and skills, institutional reform, emission measurement and targets, and investments?
- **Lessons:** What lessons were learned from CCAFS initiatives on low emission development agriculture in relation to outputs, innovations, partnerships, and outcomes development? What worked and what did not work?

The objectives of this assessment are to synthesize the evidence and lessons for:

- the impact of CCAFS initiatives on outputs and outcome generation in relation to low emission development agriculture;
- the innovative approaches and necessary conditions to support large-scale adoption of mitigation options; and
- the partnership at global, national, and sub-national levels necessary for research and scaling up outputs.

Methods

Assessment of research outputs

This assessment extracted all outputs from the CCAFS' Planning and Reporting (P&R) and Managing Agricultural Research for Learning and Outcomes (MARLO) systems reported by the LED Flagship projects to CCAFS through 2020. The P&R system was utilized in CCAFS Phase I (2011-2015) and during CCAFS Phase II MARLO system was adopted for all planning and reporting. All outputs were evaluated based on their contribution to closing the existing knowledge gap in mitigation research in agriculture and allied sectors, focus on agriculture sub-sectors, and relevance for a particular location. To assess the outputs according to these criteria, a database of all CCAFS FP3 deliverables was compiled and analyzed using NVivo, a text mining software that assisted in mining text from the abstracts of all F3-related outputs and deliverables. Each output was assessed for its contribution to mitigation research based on the inclusion of keywords and phrases in the deliverable title, description, and abstract. A combination of automatic and manual coding was used to code deliverables to relevant keywords. This allowed us to assess the contribution of outputs and other activities to mitigation research across various themes (i.e., quantification of emissions, gender, mitigation practices, and contribution to policy), regardless of their assigned cluster or sub-sector.

Assessment of LED outcomes and impacts

For this assessment, outcomes and impacts were defined as changes in the behavior of next users that contributed to the LED Flagship's targets. Next users include international, national, and sub-national development organizations, private sector companies, and non-government organizations, but not include other researcher users (Jost et al. 2014). In the impact pathway, they are institutions with the mandate or capacity to deliver impact on the ground. CCAFS Low-Emissions Development flagship generated 60 outcomes between 2011 and 2020 in collaboration with partners. This study evaluated LED outcomes based on their linkages with LED outputs and changes in the next user's behavior.

Assessment of partnerships

Type of partners and their role in delivering Low-Emissions Development outcomes were evaluated for all 60 outcomes generated from 2011-2020. The assessment primarily focused on the role of partnership in knowledge transfer to next users in support of informed decision-making. Partnership for integration across disciplines and agriculture sub-sectors was evaluated by mapping flagship projects' focus areas, partnerships, and bilateral funding from 2011-2020. Assessment of partnership in three areas (e.g., science, outcome, and integration of disciplines and sub-sectors) provides evidence of demand and stakeholder commitment to Low-Emissions Development in agriculture. At the global and regional level, global mitigation targets and commitments create demand for outputs that support the implementation of low emission development strategies. At the national and sub-national levels, there is additional demand for the partnership to support national climate policy processes. This study also assesses the evidence of demand for CCAFS low emission development research and engagement based on the use of database, metrics and tools, policy positions (at global and regional levels), inputs to national policies (e.g., Nationally Appropriate Mitigation Actions - NAMA, Nationally Determined Contribution - NDC), and input to the private sector.

Results

LED research outputs

CCAFS LED Flagship reported 1,001 outputs in P&R and MARLO systems from 2011 to 2020. During this period, CCAFS's other flagships and regional programs reported additional 866 outputs related to the LED Flagship. The analysis below reports on the aggregate of all CCAFS outputs mapped to the LED Flagship. A majority of the outputs (42%) were reports and journal articles. Outreach products (e.g., brochures, briefs, Info Notes, infographics, etc.) and discussion/working papers also included a large number of outputs (20%). Figure 2 presents the number of outputs by publication category.

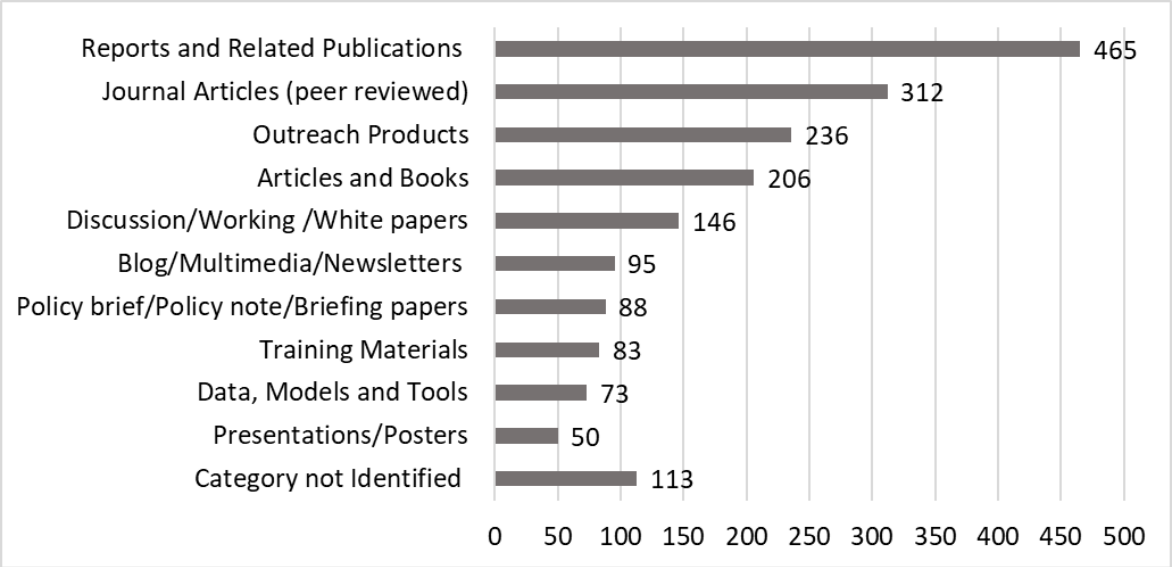


Figure 2: Category of research outputs

Outputs by cluster of activities

CCAFS's LED research produced emissions data, low-cost emissions estimation methods/tools, a shared database of emission factors representing developing countries, and a web-based knowledge platform for MRV. CCAFS supported studies in Asia, Africa, Latin America, and globally to estimate the potential net reduction of emissions and emissions intensities in different crop and cropping systems, evaluate the most cost-effective methods of quantifying GHG emissions, develop metrics for measuring progress on LED agriculture, and improve MRV procedures to Tier 2 levels. This cluster of activities generated 335 outputs (Figure 3), including 266 emissions factors (Table 1). The majority of the emission factors were generated for paddy-rice (99), rice-wheat system (56), livestock (34), and

maize-wheat systems (25). Emission factor assessments were mainly conducted in Vietnam, Indonesia, Philippines, China, India, Kenya, Mexico, and Brazil.

There is limited empirical evidence for the feasibility of LED practices for different agricultural production systems and their impact on emissions, food production, livelihood resilience, and equity. CCAFS has addressed this evidence gap by providing decision-makers with ex-ante analysis and tools to identify targets, low-emissions development (LED) options, and the suitability of options for different production systems. CCAFS closely worked with CGIAR and non-CGIAR partners to test the feasibility of different mitigation options and synthesized findings across diverse technological options and agroecological zones. This cluster of activity generated 391 different outputs that include field evaluation of LED options (e.g., Aryal et al. 2015; Tran et al. 2018, Thu et al. 2016; Sapkota et al. 2021; Kashangaki and Ericksen 2018), country mitigation targets, and potential (e.g., Tesfay et al. 2021; Mulia et al. 2020; Hijbeek et al. 2020; Frank et al. 2017), data/tool/methods for LED priority settings (e.g., SAMPLES; CCAFS-MOT; SECTOR; ACE Calculator for food loss and waste, Safavi et al. 2020), assessment of NDC and MRV systems (e.g., Richards et al. 2016; MRV Platform for Agriculture), and guidance and prioritization frameworks (e.g., Nash et al. 2015, CSA 101, AgLED).

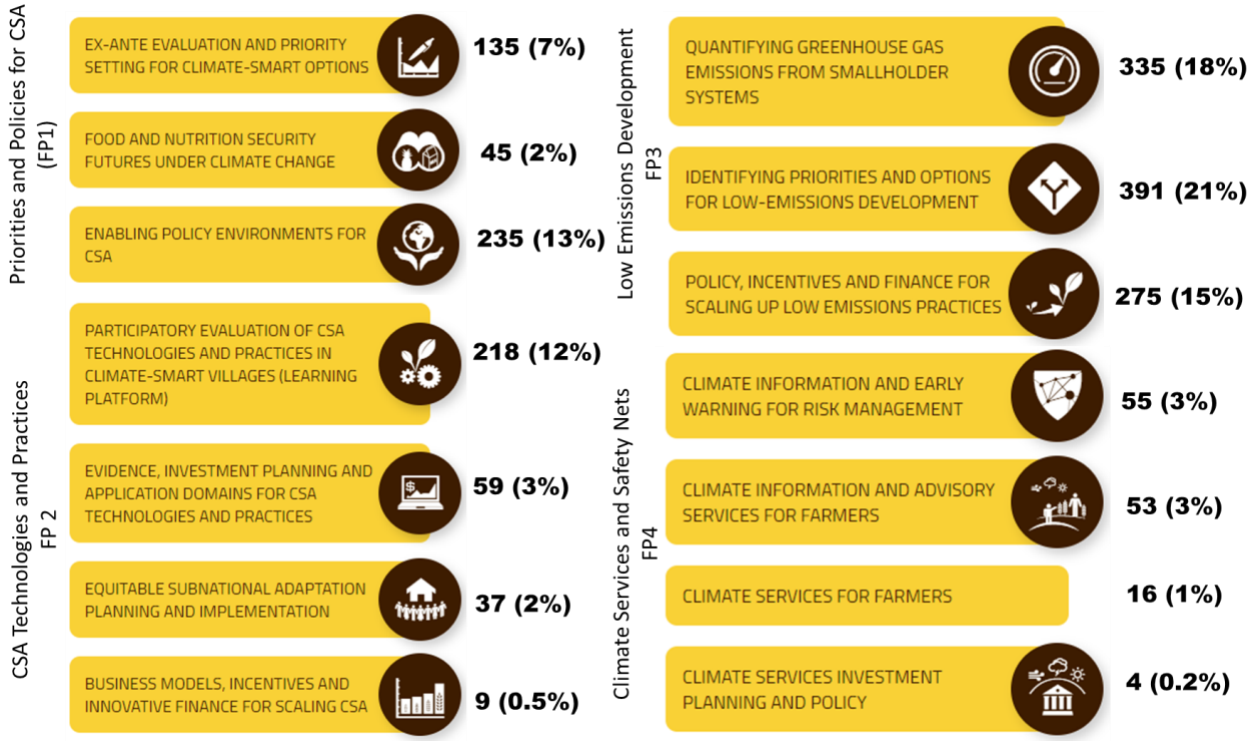


Figure 3. Low-Emissions Development outputs by flagship and cluster of activities.

The CCAFS LED Flagship developed and tested approaches for integrating mitigation into national and sub-national agricultural development programs, sustainability initiatives, and private sector investment to support the large-scale adoption of low emission agriculture technologies and practices. This cluster of activity generated 275 outputs, including suitability and feasibility assessments, policy briefs and business cases, technical and policy guidance, assessment of regulations, institutions and incentives for LED agriculture, and emissions footprints due to food loss and waste. Some examples of suitability analysis include alternate wetting and drying in paddy-rice in the Philippines, Thailand, and Vietnam (Prangbang et al. 2020, Sander et al. 2017) and MRV systems in Kenya's dairy sector (Wilkes et al. 2018). Assessment of finance and investment opportunities in low emission development includes low emissions dairy in Kenya (Khatri-Chhetri 2020, Wilkes et al. 2019), low emissions paddy-rice production in Vietnam (Tran et al. 2019), and food loss and waste reduction (Gromko et al. 2019). A range of economic and business cases are available on the CCAFS investment page (https://ccafs.cgiar.org/invest).

Table 1: Emission factors generated by sub-sectors

Sub-sector	Number of emission factors	Sub-sector	Number of emission factors
Rice	99	Maize-vetch	4
Rice-wheat	56	Maize-oat	3
Livestock	34	Rape (oilseed)	3
Maize-wheat	25	Livestock (dairy)	3
Land use change	8	Common bean crop	2
Rice-canola	6	Tea	2
Maize	5	Sugarcane	1
Maize+cowpea/ Oat+vetch	5	Wheat-soy	1
Pasture	4	Maize-pigeon pea	1
Forest	4	**Grand Total**	**266**

More than 50% of the LED Flagship's outputs were produced with or by other flagships and regional programs. Key outputs with FP1 includes decision support tools for helping to set priorities and target policy development for CSA (e.g., Dunnett et al. 2018; Thornton et al. 2018; WBCSD 2020), training materials (e.g., Chesterman et al. 2020; Acosta et al. 2020), food and nutrition security scenarios analysis (e.g., Cramer et al. 2017; Peou et al. 2020; Palazoo et al. 2014), and assessment of enabling policy environment for adaptation and mitigation options (e.g., Dinesh et al. 2018; Cramer et al. 2018). These outputs support a

better understanding of the broader enabling environment in which mitigation options in agriculture can be taken to scale by targeted investment and hotspot locations. Key outputs with FP2 include evidence of mitigation options evaluated in the Climate Smart Villages (CSV) across the regions and application domains for mitigation technologies and practices under CSA portfolios (e.g., Aggarwal et al 2018; CCAFS 2016; Nageli et al. 2019). These outputs are helping to set mitigation priorities based on the local relevance and context, including food security, livelihoods, gender, and environmental dimensions of promising CSA options.

Outputs by agriculture sub-sector

Research and scaling up mitigation options in the livestock sector was a primary focus of many projects in the CCAFS LED Flagship, as livestock are the largest source of emissions (Table 2). These outputs are related to emission reduction options for enteric fermentation, feed, breed and manure management, and pasture and grasslands management (e.g., Gaviria-Uribe et al. 2020; Ruden et al. 2018; Teenstra et al. 2016; Hongmin 2018; Bogaerts et al. 2016). Outputs for the paddy-rice sub-sector include estimating GHG mitigation potentials (e.g., Walton et al. 2020; Islam et al. 2018; Tariq et al. 2017), evaluation of alternate wetting and drying (AWD) (e.g., Tran et al. 2018; Thu et al. 2016; Chidthaisong et al. 2018), and straw and nutrient management (Tariq et al. 2017; Vu et al. 2015; Kantachote et al. 2016; Trinh et al. 2017) in different paddy-rice production systems. These studies were mainly conducted in Asia (Vietnam, Thailand, Philippines, Bangladesh, and India).

Table 2. Low-Emissions Development outputs by agriculture sub-sectors and cross-subsectoral themes.

Agriculture Sub-Sector	LED FP	With other FPs	Cross Subsectoral themes	LED FP	With other FPs
Livestock	184	34	Policy Analysis	45	74
Paddy-rice	90	20	Finance	24	24
Crop (without paddy rice)	74	99	MRV	19	0
Forestry-Agroforestry	69	12	NDC & NAMA	18	4
Soil	49	5	Climate-Smart Villages	11	78
			Gender	40	183

Outputs by locations

CCAFS LED Flagship produced outputs mapped to Kenya (186 outputs), Ethiopia (117), Vietnam (112), India (76), and Colombia (68) (Figure 4). These research areas represent hotspot locations of agriculture GHG mitigation. Outputs were also produced at the global level such as new databases, use of tools/methods, and policy and finance analyses to provide inputs to the UNFCCC process and NDC update and implementation.

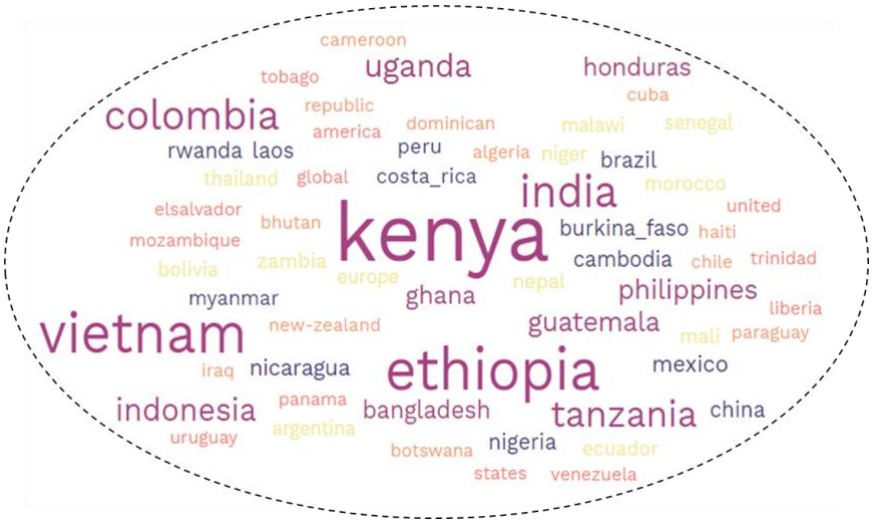


Figure 4: CCAFS LED Flagship s' outputs by country (large size, more outputs)

Delivering LED outcomes

CCAFS LED Flagship generated 60 outcomes from 2011-2020. Table 3 presents outcome categories based on the type and mitigation contribution. The Flagship informed 16 LED policies and plans, 8 improved MRV systems, and contributed to developing 8 LED finance and investment plans implemented at global, regional, and national levels. These outcomes mainly contribute to realign policies and plans to countries' mitigation needs and potential, improve MRV systems for national GHG inventories, and catalyze government and private sectors' finance and investment in LED agriculture. For example, CCAFS and its partners supported the government of Vietnam to build a climate-smart rice sector and achieve its NDC target. Improved understanding of animal nutrition allowed policymakers and producer organizations to develop low-emissions forage options in Colombia. CCAFS's research supported the government of Colombia to develop mitigation options for a NAMA for livestock and Colombia's livestock federation (FEDEGAN) to implement a sustainable livestock strategy.

Eight outcomes included the use of carbon accounting tools, models, and calculators for GHG emission estimation in crop and livestock production systems. Nutrient management, including the adoption of improved fertilizer practices, use of a yield gap atlas by a fertilizer industry for nutrient management planning, and use of a site-specific nutrient management decision support tool led to six outcomes. Scaling up AWD in rice and climate-smart rice production in Bangladesh, Thailand, Vietnam, and Colombia led to four outcomes, which focused on water, tillage and residue management in rice fields, and the use of improved varieties. Mainstreaming precision nutrient management in India, use of minimum nutrient requirements estimates by fertilizer industries (Yara and IFA), scaling up AWD in Thailand, Vietnam, and Bangladesh; and promotion of Solar Pump Irrigator's Cooperative Enterprise (SPICE) model in India were promising outcomes that support improving nutrient, water, and energy efficiency in agriculture. These outcomes contributed to GHG reduction by increasing input use efficiency in crop production.

Table 3: CCAFS LED Flagship outcome categories

Category	Total	Major Contribution
Inform LED policy and plan	16	Realign policies to mitigation need and potential, and update NDC ambitions
Monitoring, Reporting and Verification	8	Improve MRV system for national GHG inventories
LED Finance/Investment	8	Catalyze government and private sectors' finance and investment in LED
Use of LED Methods/Tools	6	Use of carbon accounting tools, models, and calculators
Nutrient Management	6	Improve input use efficiency
Paddy-Rice/AWD	4	Improve water use effiency
Livestock/Pastureland management	4	Improve input use efficiency
Agroforestry	4	Enhance carbon sequestration and improved livestock feed
Food loss and waste	3	Improve efficiency in agriculture value chains
Agro-advisories	1	Knowledge transfer for informed decision making

CCAFS LED initiative and its partners significantly contributed to developing a new national agroforestry policy in India, enhanced Vietnam's NDC with mitigation targets for agroforestry, adoption of sustainable land management practices in agricultural carbon credit projects in Kenya, improved silvopastoral systems in Colombia (Livestock NAMA).

These outcomes supported the reduction in further conversion of high-carbon forests and grasslands to intensive agricultural production systems and improve degraded lands.

CCAFS LED Flagship and its partners conducted hotspot analysis to identify the most critical crops and stages of the supply chains where major losses and emissions occur using the Agro-Chain Greenhouse Gas Emissions (ACE) calculator. This tool combines a calculation framework with datasets containing crops GHG factors and food loss factors along the chain. Bayer and Olam adopted this tool to estimate FLW and associated emissions from the value chains and prioritize mitigation actions along the value chain. Ethiopia's digital agro-climate advisory platform, a collaborative partnership between government institutions and CGIAR centers, represents a breakthrough in providing climate information and timely decision-support tools to smallholder farmers to enhance the adoption of CSA technologies and practices. The agro-advisory services include information about adaptation and mitigation options tailored to local needs. Research outputs that generated outcomes were primarily related to the evaluation of mitigation practices (Figure 5). More than 85% of outcomes (52 out of 60) referred to at least one output that evaluated mitigation practices.

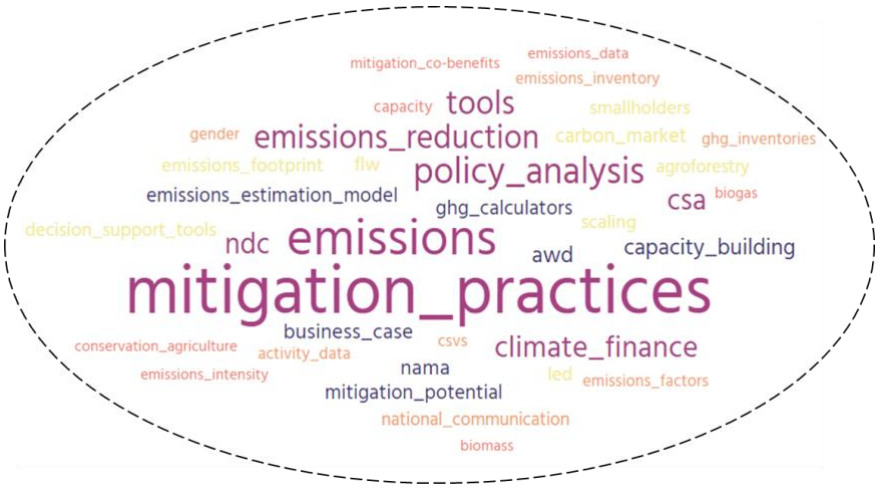


Figure 5: Use of outputs to generate outcomes (the larger the size, the more use of the output)

About one-third of Flagship's outcomes were generated in Sub-Saharan Africa (22), particularly in Kenya and Ethiopia (Figure 6). Vietnam, India, Bangladesh were the main focus countries in Asia (18) for outcomes related to scaling up nutrient, water, and energy management options. Eight outcomes were produced in Latin America, mainly for Colombia (7 out of 8). Global outcomes (8) included global policy and plans, use of method/tools, and LED finance/investment for scaling up mitigation technologies and practices.

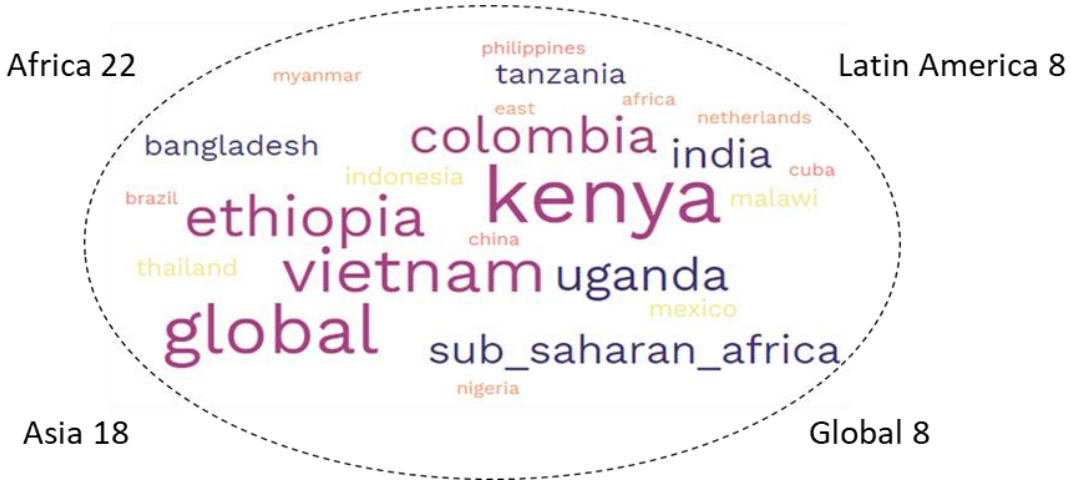


Figure 6: Number of outcomes by country and global focus (the larger the size, the more the outcomes)

Figure 7 presents a timeline of outcomes generated by the CCAFS LED Flagship and its partners. A majority of the outcomes occurred in the second half of the CCAFS program, likely reflecting the time required to generate outcomes as well as the mandate for mitigation action based on countries' NDCs for the 2015 Paris Agreement.

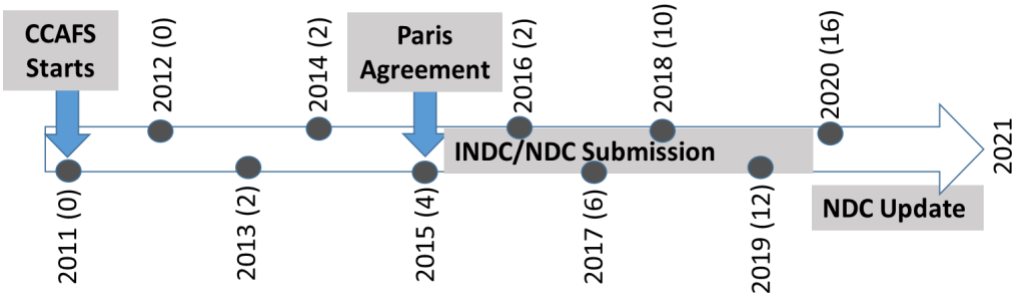


Figure 7: Outcome generation by years (Value in parenthesis indicates the number of outcomes)

Impact of LED outcomes

Overall Impacts: This assessment aggregated all estimated impacts reported in the outcomes. We found:

- The potential mitigation from F3 outcomes is estimated about 196 million tons of CO_2e over 10 years, including avoided emissions (92%) and carbon sequestration (above and below ground) (8%). Carbon sequestration (above-ground biomass) was only estimated for agroforestry-related outcomes. The levels of carbon sequestration in the soil that could be achieved in practice are highly uncertain. Avoided emissions included water

and nutrient management in paddy-rice and other crops, and improved livestock systems.

- 36 million farmers, who will adopt mitigation technologies and practices, or receive agro-advisory services, promote low emissions agriculture on 69 million hectares of land under mitigation technologies and practices.
- More than US$ 4 billion invested in mitigation programs and activities. This investment includes commitments from national and sub-national governments, global climate finance, the private sector, and bilateral/multilateral funding organizations.

Figure 11: Estimated impact of CCAFS LED Flagship and its partners on scaling mitigation practices, emissions reduction, and investment in mitigation actions

Impacts by agriculture sub-sectors and regions: The largest impacts on emissions reductions are estimated to occur due to fertilizer management and improving nutrient use efficiency, followed by improved paddy-rice management and agroforestry (Table 3). Agroforestry and improved nutrient management impacts covered large land areas. Despite their large mitigation potential, outcomes related to agroforestry, food loss and waste, and livestock and pasture land management included less than one million farmers.

Table 3: FP3 impacts by outcome theme and type

Outcome Type	Farmers (Million)	Land (Million Ha)	Estimated total emissions reduction (10 years period) M t CO_2eq	Investment (Million US$)
Agribusiness	0.23	-	-	40
Agro-advisories	15.00	-	-	-
Agroforestry	0.38	53.25	16.10	159.60

Climate-smart agriculture	1.89	-	-	2,695.40
Food loss and waste (FLW)	0.01	-	1.17	8.20
Improved nutrient management	4.52	14.00	104.3	170.00
Improved paddy-rice management	13.08	1.73	19.40	282.80
Livestock and pastureland management	0.99	0.16	8.80	243.00
Monitoring, reporting and verification (MRV)	0.50	-	2.00	250.00
Total in sub-sectors	**36.60**	**69.40**	**151.77**	**3,849**
Informed LED policy and plan	-	-	44.00	504.50
Total Impact	**36.60**	**69.40**	**195.80**	**4,357.00**

The largest investment impacts were for the promotion of climate-smart agriculture in Africa and Asia. There were significant investments in improved paddy-rice management (Philippines, Thailand, Vietnam, and Bangladesh) agroforestry, and livestock/pastureland management. Countries in South Asia (India, Nepal, Bangladesh) and Sub-Saharan Africa invested to promote improved nutrient management practices in croplands.

Table 4 presents impacts by regions, CCAFS's low emissions development flagship program and its collaboration with CCAFS's other flagships and regional programs. Total estimated GHG reduction and area under mitigation option are largely represented by South Asia. Southeast Asia region is receiving large investment (71.26%) in CSA, including low emissions agriculture development. CCAFS's LED flagship projects largely contributed to total estimated GHG emission reduction and number of farmers who are adopting CSA and mitigation practices in agriculture and allied sector. CCAFS's other flagships and regional programs also significantly contributed to scaling mitigation options and investment.

Table 4: Impacts by region and FPs

Region/FPs	Estimated total emissions in 10 years period (million ton)	Million farmers	Area in Million ha	Investment in Millions (USD)
Africa	43.25 (22.09%)	16.74 (46.14%)	2.88 (4.1%)	536.50 (12.31%)
Europe				8.20 (0.18%)
Global	44.00 (22.47%)		0.02 (0.02%)	504.50 (11.57%)

LAM	0.02 (0.01%)	0.02 (0.05%)	0.50 (0.72%)	
South Asia	74.00 (37.80%)	4.55 (12.54%)	64.30 (92.67%)	203.00 (4.65%)
SEA	34.50 (17.62%)	14.96 (41.24%)	1.68 (2.42%)	3104.82 (71.26%)
Flagship 3 (FP3)	109.773 (56%)	18.646 (51%)	13.456 (20%)	2111.60 (48%)
With other FPs and regional programs	86 (44%)	17.629 (49%)	55.925 (80%)	2245.42 (52%)

Comparison to FP3 Targets: Table 5 presents targets set by the CCAFS LED Flagship to achieve by 2022 and progress. The estimated areas under low-emission development actions and emission reduction potential surpass the targets set by the LED Flagship. The initiative also achieved the targets set for LED plans and policy decisions. The progress for the number of organizations/institutions and agriculture development initiatives adapting their plans that direct investment in LED actions almost meets the targets. Reporting likely underestimates outcomes for input efficiency because most projects reported only two or three outcomes and prioritized LED plans and GHG emissions reductions.

Table 5: Target set by CCAFS LED Flagship and achievement

Target Outcome	Target Value (2022)	Progress/ Achievement
Reduction of agriculturally-related greenhouse gas emissions compared with business as usual scenario in 2022 (8)	160 M t CO_2eq	195.7 M t CO_2eq**
# of million hectares targeted by research-informed initiatives for restoring degraded land or preventing deforestation	0.8 M ha	53.25 M ha*
# of low emissions plans developed that have significant mitigation potential for 2030, i.e., will contribute to at least 5% GHG emissions reduction or reach at least 10,000 farmers, with all plans examined for their gender implications	10 LED Plans	16
# of organizations adapting their plans or directing investment to increase women's participation in decision-making about LED in agriculture	15 Organizations or institutions	13
# of policy decisions taken (in part) based on engagement and information dissemination by CCAFS	15 Policy decisions taken	17
# of agricultural development initiatives where CCAFS science is used to target and implement interventions to increase input efficiency	20 Agricultural development initiatives	15

* and ** represent the targeted number of farmers and estimated GHG emissions reduction, respectively.

Research and impact partnerships

The partnership strategy of the CCAFS LED Flagship focused on national ministries of agriculture and environment and in the last five years the private sector as the key route of generating mitigation outcomes and impacts. The partnership also included global, regional and national research organizations, financial institutions, bilateral/multilateral funding sources/organizations, private sectors, national/sub-national governments, and NGO/INGOs (Appendix 4).

Partnership for research: Major non-CGIAR research partners included the Global Research Alliance for Agricultural Greenhouse Gases (GRA), IIASA, UN FAO, Wageningen University, which led three major projects, UNIQUE Forestry and Land Use, Imaflora, Applied GeoSolutions, and 4p1000 Initiative, among others.

CGIAR centers (primarily CIMMYT, IFPRI, CIFOR, ICRAF, ILRI, IRRI, and Bioversity-CIAT Alliance) and their partners focused on the participatory evaluation of mitigation options, identifying priorities and options for LED development, and research on gender and social inclusion under climate change. Outputs included the global N_2O database (SAMPLES, Tesfaye et al. 2021), CSA Data Atlas (ICRAF 2021), mitigation suitability maps (Prangbang et al. 2020, Sander et al. 2017), mitigation options, and finance (Khatri-Chhetri et al. 2020), and compendium of CSA technologies, practices and services (Sharma et al. 2020).

Partnership for delivering outcomes: In terms of delivering outcomes, the CCAFS LED Flagship partnered with financial organizations such as the Climate Bonds Initiative and responsAbility, bilateral/multilateral funding sources such as the World Bank and Asian Development Bank, private sectors such as Impossible Foods, international initiatives such as the Climate and Clean Air Coalition, and NGOs such as CARE or Vi Agroforestry at the global, regional and national levels. The partnership with national and sub-national government research and extension systems was also crucial to inform countries' LED policy and plans and improved MRV systems.

Evidence of demand: CCAFS's contribution to developing agriculture criteria for the Climate Bonds Initiative (CBI), EU Taxonomy for Sustainable Finance, and Multilateral Development Banks (MDBs) and analysis of the IFAD, DfID, and USAID portfolios were noticeable examples

of demand-driven actions (Wollenberg et al. 2021; EU 2020). Building on CCAFS contributions, the World Business Council for Sustainable Development (WBCSD) launched new metrics for CSA guiding the corporate value chains to operationalize and track the progress of their climate action commitments (WBCSD 2020).

Demand for improving MRV under UNFCCC and IPCC process has been continuously increasing since the 2015 Paris Agreement. CCAFS LED Flagship responded to this demand by developing an MRV platform for agriculture (AgMRV) focused on MRV resources to livestock, paddy rice, and agroforestry systems in partnership with the Global Research Alliance. The platform provides useful information to guide the technical and institutional design of MRV systems for agricultural mitigation actions, including those outlined in NDCs and NAMAs. Through South-South learning and national/international capacity building, CCAFS and its partners helped many countries to develop evidence-based, feasible to implement, and relevant for climate change mitigation policy goals in the agriculture sub-sectors.

Evaluation of the LED framework

Linking science to policy

Decision-makers in developing countries need evidence of mitigation actions, including knowledge on how to design better mitigation policies and plan to deal with mitigation needs in agriculture and allied sectors. To test the LED framework, CCAFS focused on generating empirical evidence for the suitability and feasibility of low-emissions development practices for different agricultural production systems and value chains (e.g., Hongmin et al. 2020; Sander et al. 2020; Wilkes et al. 2018; Hijbeek et al. 2020). The LED framework was also developed by generating global and country mitigation targets and potentials, and mitigation targets in NDCs to improve countries' capacities to meet UNFCCC, sustainable development goals (SDGs), and other commitments. The analysis includes policy impacts on mitigation potentials and ex-ante assessment of LED pathways to meet targets (e.g., Tesfay et al. 2021, Sapkota et al. 2018; Wollenberg et al. 2016; Richards et al. 2018; Wiese et al. 2019).

CCAFS LED Flagship developed and tested several approaches for integrating mitigation into domestic agriculture development programs, sustainability initiatives, and private sector investment to support the large-scale implementation of low emission agriculture. Key approaches, for instance, climate-smart paddy-rice cultivation (Bui et al. 2020); improved agroforestry and pastureland management (Mulia et al. 2018; Reppin et al. 2019; De Giusti et al. 2019), low-emissions dairy (Hongmin et al. 2020; Khatri-Chhetri et al. 2020), precision nutrient and crop residue management (Anderson et al. 2020; Sapkota et al. 2021; CCAFS 2021; Shyamsundar et al. 2019), and reducing food loss and waste (Guo et al. 2020; Gromko and Abdurasulova 2019) were evaluated and scaled up in different regions.

The LED framework was developed through sustained engagement between researchers and LED decision-makers. All projects involved with decision-makers from the beginning of the research to co-create knowledge and identify research demands. This strategic engagement with key stakeholders ensured that research findings reached the intended audience on time and in the appropriate format (Cochrane et al. 2017; Cramer et al. 2018). In addition, the CCAFS LED Flagship created communities of practice through workshops and science-policy forums that convened stakeholders of LED agriculture. Some noticeable examples include

collaboration and engagement with 4p1000 international initiative, expansion of climate bonds standard into sustainable agriculture, linking finance and carbon accounting to enhance investment in soil health, and organizing side events in Subsidiary Body for Scientific and Technological Advice (SBSTA) and UNFCC's Conference of the Parties (COP). The CCAFS LED Flagship organized several workshops and webinars on various topics under LED agriculture to inform policy and programs at global, regional, and national levels.

Building capacity and learning

CCAFS LED Flagship established, with Aarhus University (Denmark) the Climate, Food, and Farming scholarship (CLIFF) program which joined with the Global Research Alliance Development Scholarship and subsequently expanded to form the CLIFF-GRADS program to build the capacity of early-career scientists and Ph.D. students from developing countries to conduct applied research on climate change mitigation in agriculture. Scientists and graduate students have focused on the quantification of agricultural GHGs across different agricultural production systems and value chains (Schuetz 2019; GRA and CCAFS 2019). In 2011-2020, the program trained 177 fellows from Africa, Asia, and Latin American regions. Both CGIAR and non-CGIAR (Universities and NARS) research organizations hosted the research project and fellows. CLIFF-GRADS also facilitated South-South knowledge exchange. See Schuetz 2019 for an impact assessment.

Key areas of building capacity include measurement of GHG emissions, use of emissions estimation tools/methods, improvement in MRV systems, implementation of agricultural carbon credit projects, implementing NDCs, and development of investment plans for mitigation actions. Training manuals and guidebooks included crop nutrient management (Andersson and Kilakila 2020), quantification of GHG emissions from managed and natural soils (Milne et al 2012; Sapkota et al. 2014), designing smallholder carbon credit projects (Mesiga et al. 2014; Recha et al. 2014), low emissions rice cultivation (NAETC 2019), developing GHG inventories and MRV systems (Wilkes et al. 2020), manure management and feeding in dairy farming (Teenstra et al. 2016), and developing agroforestry systems (Xu et al. 2013; Simelton et al. 2013).

CCAFS LED Flagship and its partner developed three major web-based resource platforms: (1) Standard, Assessment of Agricultural Mitigation Potential and Livelihood (SAMPLES), (2)

AgMRV, an MRV Platform for Agriculture (https://www.agmrv.org/), and (3) AgLED (https://agledx.ccafs.cgiar.org/). These include data, tools, other resources, and case studies to guide MRV and mitigation action.

Gender and social inclusion

LED research and scaling projects included analysis of gender and social inclusion in the evaluation of mitigation technologies and practices. Low-emissions agricultural technologies and practices, such as crop nutrient, residue and water management, use of solar energy, minimum/zero tillage, agroforestry and pastureland management, and reduction of post-harvest losses, provide benefits to women and youth with mitigation co-benefits (Gartaula et al. 2020; Tavenner et al. 2021; Wilkes et al. 2020; Farnworth et al. 2017; Hottle 2015; Farnworth et al. 2017b; Raut et al. 2013). Gender analysis included the impact of commercialization and diversification of agricultural and livestock systems (Odhong' et al. 2019), best practice guide to gender-inclusive development in the dairy sector (Tavenneer and Crane 2016), youth opportunity spaces in low-emissions dairy development (Bullock and Crane 2020), and high-yield low-emission pathways for the cereal production system (Sapkota et al. 2017). CCAFS Climate-Smart Village (CSV) approach of scaling climate-smart agriculture technologies and practices integrates gender and social inclusion in technology prioritization, program design, and implementation of portfolios of CSA options (including mitigation co-benefits) in Asia, Africa, and Latin America (Aggarwal et al. 2018, Chanana et al. 2018; Hariharan et al. 2020; Bayala et al. 2021).

Key lessons and conclusions

This assessment draws the following key lessons for low emissions research and development under AR4D strategy:

Demand-driven research partnerships with research users across the public and private sectors can lead to innovation in mitigation research and scaling*:* CCAFS has moved from the business-as-usual approaches of CGIAR R4D in the agriculture sector to integrate a wide range of partners for implementation. The innovation and scaling up of low-emissions development in the agriculture and allied sectors were accompanied by not only think-tank research organizations, universities, national agricultural research systems (NARS), but also the private sector, development organizations, and donors. This partnership strengthened low emission research and scaling mitigation options in agriculture and allied sectors across the agro-ecologies and food systems. Partnering with entities who conveyed their research needs to CCAFS and wanted to use results to design their programs generated the most impact. This happened with USAID, DfID/FCDO, IFAD, World Bank, Climate Bonds Initiative, responsAbility, GRA, etc. It required an entrepreneurial approach to approaching partners to offer services rather than research projects. Partnership with the GRA was super productive gave the CCAFS government legitimacy and access to a wider base of contacts. Regular UNFCCC COP presence helps build visibility and expand partnerships.

Demand-driven outputs can generate high-impact LED outcomes: CCAFS LED Flagship used demand-driven research to inform governments, the private sector, and development organizations at global, regional, and national levels. The initiative responded to the demand for improving national GHG inventory and MRV systems, LED feasibility and suitability analysis, business case development, and evaluation of alternative LED policies and incentive systems. At the national level, there was additional demand associated with developing mitigation targets, and prioritization of mitigation options and finance. Rapid analysis of data and providing infographic maps as well as the raw data widely available, such as the NDC analysis in 2015 generated a lot of demand. All outcomes of LED Flagship s were linked to stakeholders' demand for low emissions research and development.

There is a need for moving from mitigation co-benefits, which may have insignificant impacts, to high-impact mitigation actions that can help make meaningful progress toward global targets: Many outcomes generated by CCAFS LED Flagship and its partners were the expansion of current agricultural development efforts with improved agricultural practices that can deliver mitigation co-benefits. Despite these co-benefits, more GHG mitigation in agriculture is needed to meet the Paris Agreement goals. Numerous opportunities for reducing GHG emissions from agriculture exist, such as a shift to healthy and sustainable climate-friendly diets, reducing food loss and waste, and promotion of alternative sources of protein to replace animal products. Very limited research has been done in these areas, and future research can prioritize these high-impact mitigation actions.

Target geographic emissions hotspots, countries and value chains to generate large impacts: Globally, 70% of agricultural emissions are produced by only 20 countries, and 47% by four countries (China, India, USA, and Brazil) and the European Union. Thirteen of the top 20 countries are low and medium-income countries (LMICs) including four in Sub-Saharan Africa (Nigeria, South Africa, Egypt, and Tanzania) and five in South and Southeast Asia (China, India, Pakistan, Vietnam, and Thailand). Regionally, agricultural GHG emissions hotspots are concentrated in Asia where paddy-rice and livestock farming are dominant. Emissions from land-use change are high in Africa and Latin America. CCAFS LED Flagship focused its research and scaling activities in these regions. More innovation and scaling of LED actions should focus on these regions to meet global emissions reduction targets.

Support the transition to a policy and market environment that supports mitigation to mainstream GHG mitigation in the agriculture sector: In many LMICs, agriculture is highly subsidized and markets are distorted from food price regulations. Private sector investment in mitigation and adaptation actions in agriculture is very limited. There is a large opportunity for redirecting subsidies and supporting blended and conditional sustainability finance for the private sector to promote climate action in agriculture and allied sectors. For example, the government of India is redirecting subsidies in solar energy-based irrigation systems and crop residue management, climate-smart agriculture programs are funded by agriculture extension systems in Myanmar, Vietnam, Philippines, Kenya, and other LMICs, and rice NAMA in Thailand is funded by blended finance. A huge appetite exists in the finance community for technical information and developing pipeline of projects.

Appendix 1: LED impact pathway and theory of change

The impact pathway and theory of change of the LED Flagship reinforces CCAFS's commitment to working with partners for climate action to achieve global climate change mitigation targets. CCAFS designed an impact pathway-based monitoring, evaluation and learning (MEL) system that combines indicators of process, outputs, and outcomes in research (Schuetz et al. 2017). The theory of change for Low-Emissions Development was based on the assumption that agricultural development would drive initial mitigation actions and that new incentives, institutions, and policies for mitigation were necessary to drive large-scale change. The Flagship set a target of achieving 160 M t CO2eq mitigation by 2022 and five outcome targets, listed in Figure 1 as Sub-Intermediate Development Outcomes.

The Flagship developed three clusters of activities to contribute to these outcomes: i) quantifying GHG emissions from agriculture production systems, ii) identifying priorities and options for low emissions development, and iii) evaluating policies, incentives, and finance for scaling up low emissions practices in agriculture and allied sectors. To identify priorities and options for LED in agriculture, the program used ex-ante assessment, published information from the IPCC's Fifth Assessment Report (2014), a strategic analysis commissioned by the Packard Foundation (Dickie et al. 2014), and a CCAFS-commissioned report (Scholes et al. 2014). In addition, an internally commissioned external mid-term evaluation was conducted in 2014. Outcomes and milestones of LED flagship program are presented in Appendix 1.

The first cluster of activities (Appendix 2) aimed to enhance the availability of robust data on GHG emissions and emissions reductions, and practical, low-cost methods for monitoring, reporting, and verification (MRV). To meet these needs, low-emissions development flagship worked across the CGIAR and with the Global Research Alliance on Agricultural Greenhouse Gases (GRA), Climate and Clean Air Alliance, and FAO to support better data, innovative emissions estimation methods, quantification of uncertainty, and a shared database of emission factors representing various agroecosystems.

The second cluster sought to improve technical options and identifies priorities for implementation. In this set of activities, researchers developed methods and tools to identify

targets, mitigation options, and the feasibility and suitability of options for different production systems. Gender analysis was conducted to assess opportunities to benefit women in mitigation, the research involved participatory evaluation and comparison of different mitigation options using trials with smallholders in regions with expected high potential for mitigation in agriculture and allied sectors.

The third cluster of activities focused on research to inform scaling up LED policies, incentives, and finance in agriculture and allied sectors. Evidence for the impacts of policy, incentives, finance, and economic and social feasibility enables scaling up LED options and strategies among different farmers, production systems, value chains, and countries. This cluster of activities also focused on developing good practice guidelines, methods for assessing stakeholder priorities and commitments, evaluation of business cases for green investment, and engagement with private and public sectors.

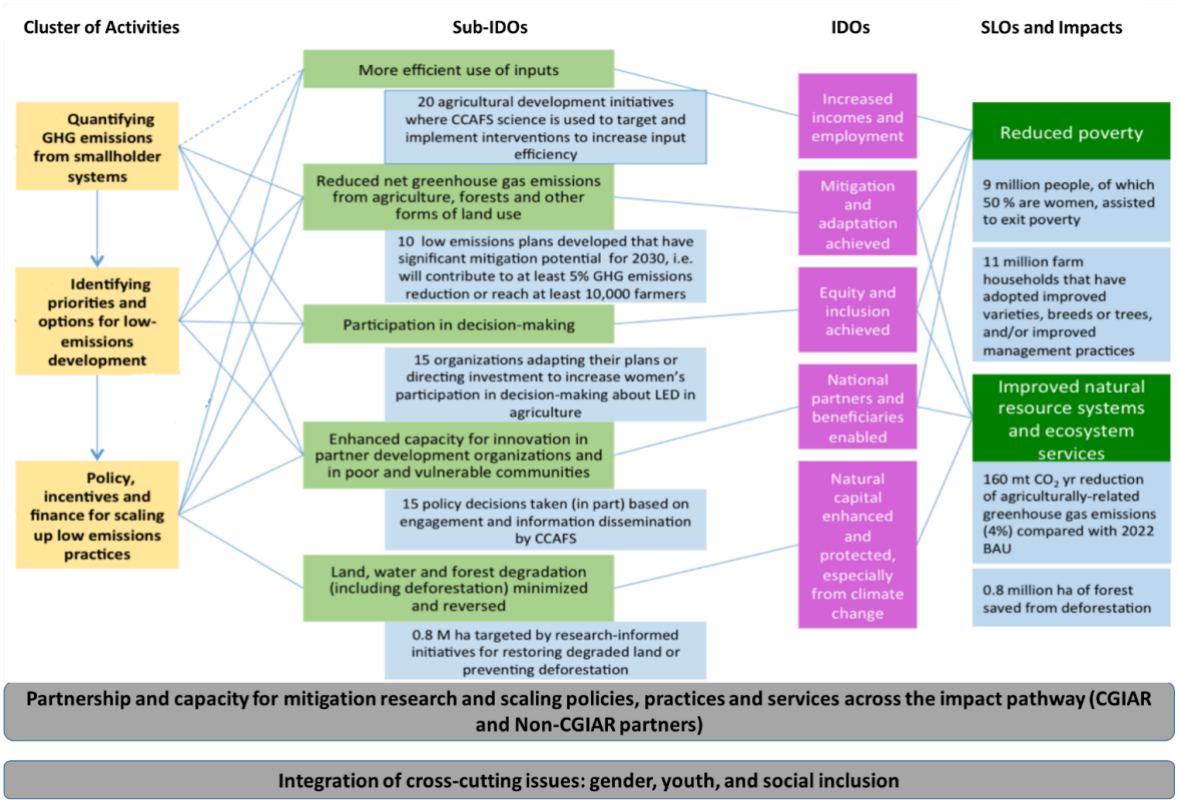


Figure 1: Low emission development flagship impact pathway and theory of change. IDOs = Intermediate Development Outcomes, SLOs = System Level Outcomes (CGIAR Level)

The LED Flagship impact pathway links research activities and outputs to desired outcomes at two levels: sub-intermediate development outcomes (Sub-IDOs) and intermediate

development outcomes (IDOs). The sub-IDOs represent practice-level outcomes e.g., more efficient use of inputs, informed decision making, enhanced capacity for mitigation research and actions, and implementation of mitigation options. The intermediate IDOs include results generated from the sub-IDOs, such as increased income and employment, achieved mitigation, enhanced natural capital, and enabled national and sub-national partners (public, private, and others). All Sub-IDOs and IDOs are logically linked to the System-Level Outcomes (SLOs) and the overall impact of the Low-Emissions Development Research Flagship under CCAFS.

Appendix 2: Outcomes and milestones of CCAFS's Low-Emissions Development flagship program

Outcome	Milestone
# of million hectares targeted by research-informed initiatives for restoring degraded land or preventing deforestation	Framework for institutional innovation and monitoring to enhance the performance of cattle farming
	CCAFS research has informed initiatives to prevent deforestation or restore degraded land
# of low emissions plans developed that have significant mitigation potential for 2030, i.e., will contribute to at least 5% GHG emissions reduction or reach at least 10,000 farmers, with all plans examined for their gender implications	The analysis supporting more ambitious INDC targets and resource guide to LED available to investors, donors, and country partners with analysis including gender implications
	Improved emission factors and estimation methods for smallholder emissions, for incorporation into LED planning and prioritization tools
	Mitigation hotspots and priorities by sector and country in 5-8 countries
	Piloting of economic and social incentives to adopt mitigation practices (livestock, rice, fertilizer, soil management)
	Proof of concept of mitigation practices for N management, rice, and livestock provided to focal countries based on field trials and scenarios
	Improved options for global donors to support LED and agricultural climate readiness, with options examined for gender implications
	Technical and policy guidance to focus countries, supply chains and donors for LED priorities, with emphasis on livestock systems
	At least five agricultural NAMA or other climate finance proposals in preparation with the NAMAs including consideration of gender impacts
	Lessons learned on NAMA and LED implementation and finance shared with country and global partners, including lessens related to the gender impacts
	Methods for MRV of agricultural emission reductions developed with focal countries and donors
	Revised targets and INDCs for agricultural mitigation
	Gender-sensitive business models and analysis of options for structuring finance for replication and scaling of priority LED options
	# of countries have used prioritization tools, analysis of incentives, business models and MRV methodologies to develop LED plans with significant mitigation potential and have included consideration of gender implications
# of organizations adapting their plans or directing investment to increase women's	Gender-disaggregated data on social factors influencing uptake of LED practices for rice and livestock
	Comparison of LED-related livelihood options for women and their mitigation co-benefits (e.g., in dairy sector)

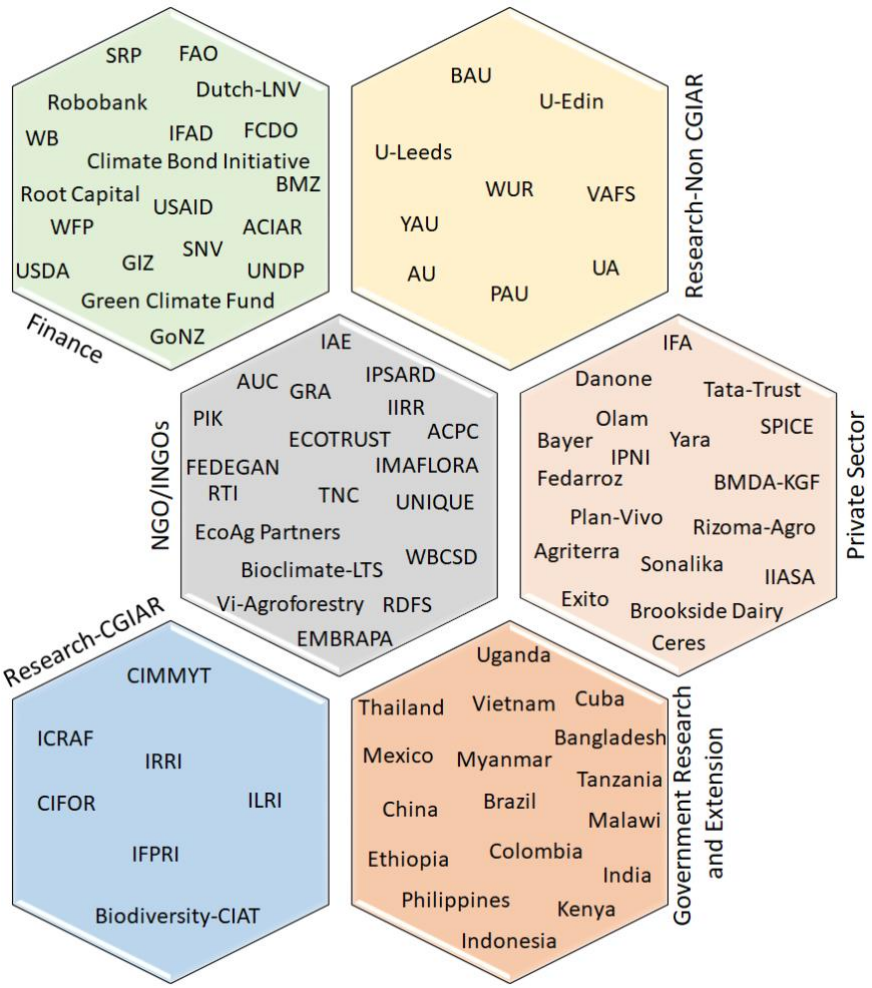
participation in decision-making about LED in agriculture	LED monitoring systems incorporate indicators of women's and men's participation and benefits
	Lessons learned and best practices on increasing women's and men's participation in NAMAs and LEDs disseminated
	NAMA or LED investment proposals for 6-8 countries include gender considerations
	15 organizations involved in NAMA and LED implementation are adapting their plans or directing investment to increase women's participation in decision-making about LED in agriculture
# of policy decisions taken (in part) based on engagement and information dissemination by CCAFS	Flagship knowledge products made available for partners including Mitigation Option Tool, online mitigation compendium, primer on LED in agriculture, smallholder emissions estimation platform with training materials and emission factors (SAMPLES)
	Agricultural LED readiness indicators available
	MRV methodology for livestock available to partner countries
	Improved emission models and factors (e.g., for N2O emissions) and LED suitability maps disseminated in partner countries
	6–8 countries trained in scenarios analysis for LED planning and MRV methodologies
	Global donors and agricultural development organizations informed of options to support LED and agricultural climate readiness
	Improved capacity at municipal, state and national levels levels for commodity sustainability standards and implementation of mitigation technologies
	Improved capacity of UNFCCC focal points and NAMA or LED policy implementers to measure and monitor mitigation
	Decision-makers in national governments and donor organizations are funding and implementing LED
	15 LED policy decisions have been made based (in part) on engagement and information dissemination by CCAFS
# of agricultural development initiatives where CCAFS science is used to target and implement interventions to increase input efficiency	Network of trial sites for more efficient management options for fertilizer, feed, water, and land use in 5-8 countries
	Identification of food loss and waste (FLW) opportunities for LED and commercially viable interventions in priority product value chains
	Analysis of LED (livestock systems, rice, fertilizer) synergies with food security development and suitability by geographic region, production system and farmer characteristics in 5-8 countries
	Analysis of the causes of FLW in priority value chains and related drivers of emissions reductions
	National governments, agri-food companies and agricultural development actors use improved emissions data and tools to support farmers' use of LED practices (e.g., for efficient fertilizer use)
	Analysis of farmers' incentives and barriers to adoption to increase input efficiency and reduce FLW while also reducing emissions
	Technical and policy guidance on more efficient management options with mitigation co-benefits, including impacts on women,

	synthesized and disseminated to focus countries, supply chains and donors
	Review of existing policies and programs and synergies with other policy domains (e.g., animal health, food security, feed hygiene and safety, trade) to support scaling up of LED
	Business models and analysis of options for structuring finance for replication and scaling of FLW reduction measures in priority value chains
	Global comparative analysis of countries' energy, water and fertilizer subsidy impacts on GHG emissions
	Analysis of lessons learned from trials for best practices using public-private dialogue to support scaling up of LED options in agri-food sectors
	National and international organizations use evidence for LED impacts and enabling conditions to plan 20 agricultural development initiatives to increase input efficiency

Appendix 3: FP3's cluster of activity, output category, and key outputs

Cluster of activities	Output category	Key outputs
Quantifying GHG emissions from smallholder systems	Data and methods for quantifying emissions and mitigation in smallholder systems to support LED plans and agricultural development initiatives.	Data: emission factors, global nitrogen database, INDCs data, CSA prioritization framework, and activity data, Tool: emission calculator and simulation tools Methods: field measurement of GHG emissions and improved MRV systems
	Strengthened capacity of national research organizations, young scientists, and decision-makers to quantify LED emissions and identify and prioritize technical LED options.	Partnership with NARS, global research organizations, universities, development organizations, private sector, networks Training and capacity building workshops, science-policy dialogue, engagement in global network and meeting, 50% of women
Identifying priorities and options for LED	Global and country mitigation targets/potentials and NDC analyses to improve countries' capacities to meet UNFCCC, SDG and other commitments.	Data, tool and methods used for LED priority settings by national and sub-national governments, development organizations, private sector, and financial institutions Assessment to meet global mitigation targets, NDC assessment, and contribution to improved MRV systems CSA guide and prioritization framework
	Identification of viable LED technical practices, and evaluation and comparison of their impacts/trade-offs for livelihoods, gender equity, food security and mitigation.	Field evaluations of LED technologies and practices (on-farm and participatory trials) including CSA indicators (productivity, resilience, income, GHG mitigation, synergy and trade-offs, gender and social inclusions) Economic assessments of LED options
Policy, incentives, and finance for scaling up low emissions practices	Evidence for policy, economic, financial, social and other feasibility measures that enable scaling up LED among different farmers, production systems/value chains and countries.	Suitability and feasibility assessments Policy briefs and business cases for scaling the use of LED research outputs including economic, financial, and social assessments (enabling environment)
	Technical and policy guidance and standards for supply chain and landscape-scale performance that support scaling up the LED.	Technical and policy guidance for scaling the use of LED interventions and improved MRV systems Assessments of public regulations, institutions, and incentives for LED agriculture Mitigation options in supply chains and demand-side (Food loss and waste)

Appendix 4: Research and scaling partners



Partner organizations for LED agriculture at global, regional, and national levels

Finance: SRP=Sustainable Rice Platform, FAO = Food and Agriculture Organization, Dutch-LNV = Dutch Ministry of Agriculture, Nature and Food Quality, WB = World Bank, FCDO = Foreign, Commonwealth & Development Office, IFAD = International Fund for Agricultural Development, BMZ = Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, WFP = World Food Program, USAID = United States Aid for International Development, ACIAR = Australian Center for International Agricultural Research, USDA = United States Department of Agriculture, GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit, SNV = Stichting Nederlandse Vrijwilligers, UNDP = United Nations Development Program, VAFS = Vietnamese Academy of Forest Science, GoNZ = Government of New Zealand.

Research Non-CGIAR: BAU = Banaras Agriculture University, U-Edin = University of Edinburgh, U-Leeds = University of Leeds, AU = Aarhus University, UA = University of Aberdeen, WUR = Wageningen University and Research, YAU = Yezin Agriculture University, PAU = Punjab Agriculture University. NGO/INGOs: IAE= Institute for Agricultural Environment, IPSARD = Institute of Policy and Strategy for Agriculture and Rural Development, GRA = Global Research Alliance, IIRR= International Institute of Rural Reconstruction, PIK = Potsdam-Institut Fur Klimafolgenforschung, ACPC = African Climate Policy Centre, IMAFLORA = Instituto de Manejo e Certificação Florestal e Agrícola, TNC = The Nature Conservancy, UNIQUE = Unique Forestry and Land Use GmbH, WBCSD = World Business Council for Sustainable Development, RTI = Research Triangle Institute, EMBRAPA = Brazilian Agricultural Research Corporation's

Private Sector: IFA = International Fertilizer Association, SPICE = Solar Pump Irrigators, Cooperate Enterprise, IPNI = International Pant Nutrient Institute, BMDA = Barind Multipurpose Development Authority, KGF = Krishi Gobeshona Foundation, IIASA = International Institute for Applied Systems Analysis.

Research – CGIAR: CIMMYT = International Maize and Wheat Improvement Center, ICRAF = World Agroforestry, IRRI = International Rice Research Institute, ILRI = International Livestock Research Institute, CIAT = International Center for Tropical Agriculture, IFPRI = International Food Policy Research Institute, CIFOR = Center for International Forestry Research.

Government Research and Extension: National Agriculture Research System (NARS), National Agriculture Extension System (NAES), and government-affiliated other research and development organizations.

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