

Climate-Smart Agriculture Investment Plan for Ghana



Alliance



Public Disclosure Authorized

Public Disclosure Authorized

Public Disclosure Authorized

Public Disclosure Authorized

FOREWORD

Ghana's agriculture sector is one of the keys to its national development agenda and is therefore expected to lead the growth and structural transformation of the economy. However, agriculture in Ghana is still primarily rainfed, making it susceptible to impacts of climate variability and change. The manifestations of climate change in the agriculture sector are erratic, including increasing, unpredictable rainfall patterns; frequent, long dry spells; flash floods; and shortening of the rainy season. Intensifying climate impacts pose one of the largest risks to the agricultural sector's ability to contribute to improved livelihoods of farmers and to lead in the transformation of the economy. Therefore, it is vital to identify and implement interventions that will reduce the negative impacts of climate change on agriculture in Ghana.

This Climate Smart Agriculture Investment Plan (CSAIP) responds to this need to identify interventions that will help the agriculture sector to better adapt to climate change. The CSAIP aims to produce evidence of the climate-smart agriculture (CSA) technologies that offer the greatest potential to increase productivity and enhance household incomes in Ghana's agriculture sector under a changing climate. It also provides opportunities for building the agricultural system's resilience and in so doing ensures that future agriculture practices do not follow a path that could threaten environmental integrity through greenhouse gas emissions, pollution of water systems, or destruction of ecological systems.

The CSAIP is an outcome of a stakeholder engagement process that identified and prioritized the CSA technologies that have proved to be most suitable for and impactful in Ghana's agriculture. The CSAIP is a result of a close collaboration between the World Bank and the Ministry of Food and Agriculture (MoFA), with technical assistance from the CGIAR Research Program (CIAT, World Agroforestry Centre, and CCAFS) and financial support from the Adaptation of African Agriculture (AAA) initiative.

This document builds on several national policies and plans that demonstrate Ghana's commitment to dealing with climate change in agriculture and beyond, such as the National Climate Change Policy and

the National Climate Smart Agriculture Food and Security Action Plan. It aligns with the country's priorities to create jobs, improve agriculture value chains, reduce food imports, and increase exports through identifying key crops and value chains for development, such as cocoa or fisheries and aquaculture. The implementation of this investment plan will help Ghana take significant strides toward meeting national and international commitments such as the Agenda for Jobs, Comprehensive Africa Agriculture Development Program (CAADP), Sustainable Development Goals (SDGs) and the implementation of Nationally Determined Contributions (NDCs) to the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC).

The Government of Ghana anticipates and looks forward to soliciting support from our partners in the international development community, the private sector, and among other key stakeholders for the much-needed funding toward the realization of this investment portfolio and for the agriculture sector to lead the structural transformation of the country's economy.

Owusu Afriyie Akoto (MP)

Minister of Food and Agriculture

ACKNOWLEDGEMENTS

The team wishes to thank the Ministry of Food and Agriculture for their guidance, contributions, and support throughout the study. The team also wishes to thank and acknowledge the continuous guidance and support of Henry Kerali(former Country Director Directors for Ghana, Liberia and Sierra Lon) and Pierre Laporte (new Country Directors for Ghana, Liberia and Sierra Lone), Juergen Voegele (Senior Director, Food and Agriculture Global Practice), Martien van Nieuwkoop (Director, Food and Agriculture Global Practice), Marianne Grosclaude (Practice Manager, Food and Agriculture Global Practice), Tobias Baedeker(former Task Team Leader of Climate-Smart Investment Plans - Programmatic Approach and Nkulumo Zinyengere (outgoing and new Task Team Leader of Climate-Smart Investment Plans - Programmatic Approach), and all of the World Bank Group. We also want to specially thank and recognize the leadership and guidance provided by Mr. Robert Ankobia, the Chief Director of MoFA; Mr. Seth Osei-Akoto, Director of Crops Services Directorate; and Ms. Angela Dannson, Director of Policy Planning, Monitoring, and Evaluation of MoFA for the preparation of the report.

The report ‘Climate Smart Agriculture Investment Plan for Ghana’ was prepared under the joint leadership of the World Bank and Ministry of Food and Agriculture with technical support from the Alliance-Bioversity-CIAT. The Ministry of Food and Agriculture group was led by Mr. Amoaka Kwako Kingsley of the Directorate of Crop Services, and included Ahmed Gibrila, Kingsley Agyemang, Enyonam Edwina Quist, and Nathaniel Laryea and Richmond Konadu-Amoah. The World Bank Group core team consisted of Sheu Salau (Task Team Leader), Amos Gyau (co-Task Team Leader), Nabil Chaherli (co-Task Team Leader), and Samuel Taffese (co-Task Team Leader), all of whom are from the World Bank’s Food and Agriculture Global Practice. The CIAT team was led by Evan Girvetz, and consisted of Jonathan Mockshell, Stephanie Jaquet, Todd Rosenstock, Steven Pager, and Sekou Traore. All the teams were greatly supported by Rose Ampadu, Senior Operations Assistant, and Elizabeth Naa Amoah Akushey, Team Assistant, throughout the period of the study.

The entire team, on behalf of the Ministry of Food and Agriculture, is especially grateful for the unqualified support and cooperation of all Regional Directors of Agriculture, the Ministry of Fisheries and Aquaculture Development, the Environmental Protection Agency (EPA), the HATOF Foundation, and the Ghana Science-Policy Platform on Climate Change, Agriculture, and Food Security. Special mention is due for the invaluable contributions from Messrs. Delali Nutsukpo, Vincent Botwe, Kingsley Odum Sam, Dr. George Essegbey, Dr. Dilys S. McCarthy, and Dr. Naaminon Karbo from the Ghana Science Policy Platform; Mr. Wahab Suleman from COCOBOD; and Prof. Adiku, independent consultant, and Terry Ansah, Associate Professor (Ruminant Nutrition) University for Development Studies who made time available for data collection, presentations, reviews, and discussion. We acknowledge the invaluable contribution and leadership of the CIAT team in stakeholder consultations; the conceptualization of the CSAIP; and the analysis, drafting, and validation of the report.

The report benefitted greatly, at different stages of development, from peer reviewers' comments, especially from Ademola Braimoh, Vikas Choudhary, Joanne Gaskell, and Grant Milne from the World Bank Group. It also benefitted from the invaluable guidance and suggestions of the many stakeholders who participated in inception and validation workshops and other technical consultation meetings throughout the process.

CONTENTS

EXECUTIVE SUMMARY	I
CHAPTER 1: WHY CLIMATE-SMART AGRICULTURE	1
1.1 The Climate-Smart Agricultural Investment Planning Framework.....	5
CHAPTER 2: SITUATIONAL ANALYSIS OF AGRICULTURE, CLIMATE CHANGE, AND LIVELIHOODS	10
2.1. Ghana’s Rural and Agricultural Sector in Brief	10
2.2 Climate Change in Ghana’s Agriculture.....	17
2.3. Climate Change Impacts on Ghana’s Food Security and Agricultural Economy	23
2.4. The Potential for Digital Agricultural Solutions in Ghana.....	27
2.5. Climate Change Impacts and Ghana’s Overall Risk and Resilience	28
CHAPTER 3: ASSESSING PRIORITIZED INVESTMENTS FOR CLIMATE-SMART AGRICULTURE PORTFOLIO IN GHANA.....	32
3.1. Assessing Geographic Distribution of Ghana’s Priority Investments	35
3.2 Assessing Beneficiaries and Benefits of Ghana’s Priority Investments	36
3.3. Assessing Climate-Smart Agriculture Pillars (Productivity, Resilience, Mitigation) of Ghana’s Priority Investments	37
3.4. Economic and Financial Assessment of Ghana’s Priority Investments	39
3.5. Climate Modeling Assessment of CSAIP Priority Investments	41
3.6. Assessing CSAIP Investment Alignment with Ghana’s Nationally Determined Contribution	44
3.7. Policy Coherence: Alignment, Gaps, and Distortions with Other Policies, Strategies, and Commitments	47
3.8. Assessing Design and Implementation Opportunities in CSAIP Priority Investments.....	52
3.9. Assessing the Potential for Supporting Collaboration and Partnerships and Institutionalizing CSAIP Investments	55
3.10. Assessing Financing in CSAIP Priority Investments	57
3.11. Key Objectives of CSAIP Priority Investments	59
CHAPTER 4: SUMMARIES OF THE NINE PRIORITIZED CSAIP INVESTMENTS FOR GHANA.....	61
4.1 KNOWLEDGE SYSTEMS AND ADVISORY SERVICES SUPPORTING CSA	62
4.2 INTEGRATED WATER RESOURCE MANAGEMENT FOR RICE.....	64
4.3 CEREAL-LEGUME INTEGRATION.....	66
4.4 CLIMATE-SMART COCOA PRODUCTION.....	68
4.5 CLIMATE-RESILIENT POULTRY PRODUCTION	70
4.6 CLIMATE-RESILIENT RUMINANTS.....	72
4.7 SUSTAINABLE FISHERIES AND AQUACULTURE.....	74
4.8 DIVERSIFIED TREE CROPS	76
4.9 ROOTS AND TUBERS-LIVESTOCK INTEGRATION.....	78
CHAPTER 5: MONITORING AND EVALUATION: ASSESSING OUTCOMES AND IMPACTS	80

5.1.	Context.....	80
5.2	Theory of Change	81
5.3	Results Framework and Core Indicators	83
5.4	Key considerations for next steps	87
ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES		92
A-1.	Cereal-legume integration	92
A-2.	Diversified tree crops	102
A-3.	Climate-smart cocoa production.....	113
A-4.	Roots and tubers-livestock integration	127
A-5.	Climate-smart poultry	138
A-6.	Climate-resilient ruminants and genetic resource conservation	145
A-7.	Sustainable fisheries and aquaculture	153
A-8.	Knowledge systems and advisory services supporting climate-smart agriculture.....	163
A-9.	Integrated water resource management for rice	172
ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA		181
B-1.	Ghana’s International and Regional Commitments, Frameworks, and Plans	181
B-2.	National Policies and Plans	182
B-3.	Select CSA Related Projects in Ghana	185
B-4.	Potential Financing Sources and Mechanisms for CSAIP in Ghana	186
ANNEX C: PRIORITIZING INTERVENTIONS: THE PROCESS FROM LONG-LISTS TO FINALISTS		193
C-1.	Producing a Long List of Investments.....	193
C-2.	Producing a Short List of Priority Investments.....	195
C-3.	Investment CSA Practices, Location, Risks, and Institutions	197
C-4.	Participants at Prioritizing Workshop	197
ANNEX D: METHODOLOGY FOR INTEGRATING CLIMATE CHANGE, CROP RESPONSE, AND ECONOMIC IMPACT		199
D-1.	Climate Change Vulnerability and Economic Impacts in the Agricultural Sector	199
D-2.	Present Climate Data and Future Climate Modeling.....	200
ANNEX E: METHODS FOR EX-ANTE FINANCIAL AND ECONOMIC PERFORMANCE		204
E-1.	The Model.....	204
E-2.	Data Sources	204
E-3.	Data Analysis.....	211
BIBLIOGRAPHY.....		212

List of figures

Figure 1: CSA - The Triple Win of Sustainability, Resilience, and Lower Emissions	3
Figure 2: Developing Ghana's CSAIP - Process Summary	6
Figure 3: Concentration of Poverty across Districts.....	11
Figure 4: Agroecological Zones of Ghana.....	13
Figure 5: Calorie Consumption Per Capita Per Day in Ghana, 1973–2013, Most Recent Data	16
Figure 6: Harvested Area in Ghana, 1973–2017	16
Figure 7: Geographic Distribution of Floods and Droughts in Ghana.....	18
Figure 8: Annual Rainfall Excesses and Deficits Across Ghana, 1901–2014	18
Figure 9: Significant Changes in Rainfall as of 2014.....	19
Figure 10: Significant Temperature Changes in Ghana Between 1900 and 2014	20
Figure 11: Mean Annual Average Rainfall and Temperature for Ghana (1901–2014)	20
Figure 12: Significant Changes in Rainfall and Temperature as of 2014.....	20
Figure 13: GHG Emission Sources in Ghana.....	23
Figure 14: IMPACT Analysis: Net Trade Projections to 2050. SSP2 RCP 8.5	26
Figure 15: Potential Impact of Cereal-Legume Integration CSA Interventions on Maize, Sorghum, and Groundnut Yields and Balance of Trade	42
Figure 16: Potential Impact of the Roots and Tubers-Livestock Integration CSA Intervention for Yields and Balance of Trade	43
Figure 17: Potential Impact of the Cocoa Production CSAIP on Rainfed Cocoa Yields and Balance of Trade	43
Figure 18: Potential Impact of the Water Harvesting Technologies and Irrigation CSAIP on Irrigated Rice Yields and Balance of Trade	44

List of tables

Table 1: Land Area and Land Use by Agro-Climatic-Ecological Zones in Ghana	13
Table 2: Land Cover Changes in Ghana.....	14
Table 3: Key Food and Commodity Crops in Ghana.....	15
Table 4: Import, Export, Production, and Total Demand for Key Commodities in Ghana.....	17
Table 5: IMPACT Analysis: Percentage Difference in Ghana Rainfed Yield	25
Table 6: IMPACT analysis: percentage difference in Ghana rainfed crop area.	26
Table 7: Complete and Shortened Names of Proposed Project Investments	33
Table 8: Final List of Prioritized CSAIP Investments.....	33
Table 9: Investments, Their Importance, Scenarios, and Objectives.....	34
Table 10: CSAIP Investments by Agroecological Zones in Ghana	36
Table 11: Beneficiaries in Each Project	36
Table 12: Percentage change in yield.	37
Table 13: Chance of a Positive NPV With and Without Climate and Pest Risks	38
Table 14: Emissions from Priority Investments (MtCO ₂), Based on Analysis Using FAO's EXACT GHG Calculator	39
Table 15: Climate Pillars: Ranking the Top Five Investments in Each CSA Smartness Category.	39
Table 16: Assessing Economic and Financial Performance of the Nine Priority Investments (With and Without Climate and Pest Risks).....	40
Table 17 : Comparison of Mean Investment NPV (US\$, millions) Under Carbon Price and Risk Scenarios.....	41
Table 18: Alignment of CSAIP with NDC	46

Table 19: Alignment of CSAIPs with Policy Gaps and Distortions.....	49
Table 20: Select Current CSA Projects in Ghana	53
Table 21: Opportunities Supporting CSAIP Investment, Design and Implementation	55
Table 22: Most Frequent Key Public Institutional Collaborators Identified by Investment	56
Table 23: Financing Needed and Key Identified Potential Sources	58
Table 24: Objectives of Investments - Main Benefits from Each Investment.....	60
Table 25: Sample Output-Level Indicators Relevant for the CSAIP, by Project	84
Table 26: Sample Outcome-Level Indicators Relevant to the CSAIP, With Contribution to CSA.....	85
Table 27: Sample Impact Indicators Relevant to the CSAIP	86
Table 28: Key Policies and Plans Relevant to CSA in Ghana and Main Relevant Outcomes.....	89

ACRONYMS

AAA	Adaptation of African Agriculture
AEZ	Agroecological zones
AFOLU	Agriculture, Forest, and Land-Use sector
AfDB	African Development Bank
AFR100	African Forest Landscape Restoration Initiative
AgDevCo	Africa Agriculture Development Company
ASAP	Adaptation for Smallholder Agriculture Program
AUDA-NEPAD	African Union Development Agency - New Partnership for Africa's Development Agency
BAU	Business As Usual
BCR	Benefit Cost Ratio
CAADP	Comprehensive Africa Agriculture Development Program
CBA	Cost-benefit analysis
CCAFS	Climate Change, Agriculture, and Food Security (part of CGIAR)
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CLIMCOCOA	Climate-Smart Cocoa Systems for Ghana
CSA	climate-smart agriculture
CSAIP	climate-smart agricultural investment plan
EID	Emerging infectious disease
ERA	Evidence for Resilient Agriculture
ESP	Environmental Sustainability and Policy for Cocoa Production in Ghana
EU	European Union
FAO	Food and Agriculture Organisation
FASDEP	Food and Agriculture Sector Development Policy
FIP	Ghana Forest Investment Program
GASIP	Ghana Agricultural Sector Investment Programme
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	German Development Agency
GNI	Gross national income
Food IAP	Sustainable land and water management – Second additional financing
IFAD	International Fund for Agricultural Development
IFJ	Investing for Food and Jobs
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IoT	Internet of things
IPM	Integrated Pest Management
KPI	Key Performance Indicators
LEDs	Low Emissions Development Strategies
METASIP	Medium-Term Agricultural Sector Investment Plan
MoFA	Ministry of Food and Agriculture
M&E	Monitoring and Evaluation
MTNDPF	Medium-Term National Development Policy Framework

NCCP	National Climate Change Policy
NGO	Nongovernmental organization
NDC	Nationally Determined Contributions
NPV	Net Present Value
PFJ	Planting for Food and Jobs
PMIS	Project Management Information System
PO	Policy Objectives
PPMED	Policy Planning, Monitoring and Evaluation
PPP	Public-Private Partnership
RCP	representative concentration pathway
REDD	Reducing Emissions from Deforestation and Forest Degradation Program
ROI	return on investment
RIMA	Resilience Index Measurement and Analysis
R&D	Research and Development
SDG	Sustainable Development Goal
SSP	Shared Socioeconomic Pathway
TOC	Theory of Change
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WAATP	West Africa Agricultural Transformation Program
WHO	World Health Organization

EXECUTIVE SUMMARY

- 1. Ghana's economy is growing at a rapid pace, with the gross domestic product (GDP) increasing 8.8 percent in 2019, nearly double the pace of most emerging economies.** This growth comes partly from a diversification of the economy away from agricultural production over the past several decades. Yet, agriculture is still vital to Ghana's economy, outpacing the overall economy with a growth of 8.4 percent in 2017 alone, employing 34 percent of the nation's workforce, supplying over 70 percent of national food demand, and contributing nearly 20 percent of national GDP. Diversifying the sector and increasing postharvest and value-added industries are government priorities. Ghana is a net importer of agricultural goods primarily composed of consumer-ready commodities, including poultry, rice, wheat, and sugar.
- 2. Improving agriculture is vital to reduce Ghana's growing poverty and geographic inequality.** Cassava, yam, plantain, maize, and rice are Ghana's primary staple crops, and are crucial to food security in its smallholder-dominated agricultural system. Smallholder farming accounts for about 80 percent of Ghana's total agricultural production. Agriculture is Ghana's main land use (70 percent of area) and its primary employer, especially in the Volta, Northern and Upper West regions. In the Northern and Upper West regions, farmers lack access to modern inputs, extension services, irrigation, electricity, markets, and roads to support the development of a vibrant agriculture sector. Although smallholder productivity has increased recently, reducing national poverty levels, overall growth in agricultural yields has been modest, and smallholder agriculture has low productivity with large yield gaps.¹ Agriculture spans diverse agro-climatic zones, offering significant potential for diversifying agricultural production.
- 3. Climate change is apparent and widespread in Ghana.** Temperatures have been increasing since the 1960s,² and Ghana's current climate is the driest on record (since 1901). Climate change impacts will

¹ Breisinger, ed. Diao, Xinshen, P. Hazell, S. Kolavalli, and D. Resnick., 2019.

² Tawia Abbam et al., "Spatiotemporal Variations in Rainfall and Temperature in Ghana Over the Twentieth Century, 1900–2014," 2018, <https://doi.org/10.1002/2017ea000327>.

worsen, particularly from March to June, as precipitation is projected to decrease by 4 percent annually by 2040. Temperature increases will continue, particularly in the north, with 1.4–4.2°C increases and up to 90 percent of days exceeding 35°C by 2100.

4. **Ghana’s agriculture sector is already affected by climate change.** Ghanaian farmers are already experiencing effects of climate change such as erratic rainfall that differ from historical patterns; high and increasing temperatures; longer periods of Harmattan (dry winds); shorter dry seasons; frequent droughts; ecosystem deterioration, and concomitant losses of arable land through desertification; outbreaks of crop and livestock pests and diseases; increase in postharvest losses; and, in coastal areas, salinization of agricultural soils from sea level rise and tidal flooding that will make land unproductive.

5. **The structure of Ghanaian agriculture makes it more vulnerable to climate change.** Ghana’s current low agricultural diversification intensifies climate risk for crops. Although they have been developing their own coping strategies, the sector is dominated by poor farmers that are vulnerable to climate change. Climate change will intensify vulnerability in the north, since the region is particularly hot and dry, has lower quality agricultural lands, and is most susceptible to drought, soil erosion, and land degradation. Additionally, Ghana’s agriculture sector is almost entirely rainfed; Ghana has only realized about 4 percent of its irrigation potential. Limited cropping diversity, low value addition, and high postharvest losses necessitate a resolute and substantial commitment to address climate change impacts.

6. **The agriculture sector’s vulnerability to climate change will require Ghana to reorient its approach toward climate-smart agriculture (CSA).** CSA addresses agricultural vulnerabilities to climate change by bolstering productivity, enhancing resilience (adaptation) and implementing mitigation measures. Productivity increases help fill gaps in nutritional and economic security for households and build economic prosperity at the national level. Resilience adjusts or transforms current practices and introduces improved coping methods in the face of climatic vagaries without major disturbance to the agricultural production system. Mitigation helps reduce the risk of further climate change by reducing greenhouse gas (GHG) emissions or increasing carbon storage. Together, these three CSA pillars (Figure ES.1) will enable farmers to increase their productivity—and thus income—and will improve the agricultural sector’s ability to cope with climate change and its associated extreme weather events, reduce emissions, and increase sequestration through less GHG per unit of agricultural produce.

Figure ES.1: CSA - The Triple Win of Sustainability, Resilience, and Lower Emissions³



³ Food and Agriculture Organization of the United Nations, *Climate-Smart Agriculture Sourcebook*, 2014.

7. **Climate-smart agricultural investment plans (CSAIP) allow countries to plan for the future, and Ghana is developing this national CSAIP as part of the Adaptation of African Agriculture (AAA) Initiative.**

The AAA Initiative is a coordinated multi-country initiative, launched at the 22nd Session of the Conference of Parties (COP22) to the United Nations Framework Convention on Climate Change (UNFCCC) in Marrakech, Morocco (2016). This CSAIP was developed within the institutional arena of the Ghanaian Science-Policy National Dialogue Platform for Climate and Agriculture, which is coordinated by the Consultative Group on International Agricultural Research (CGIAR) Program on Climate Change, Agriculture, and Food Security (CCAFS). Funding and technical support were provided by the World Bank. Strong government partnership and stakeholder engagement are the foundation of this CSAIP.

8. **This Ghanaian CSAIP prioritizes a set of nine investments and actions needed to boost crop resilience and enhance yields for nearly 1.7 million beneficiaries and their families, helping them adapt to climate change.**

Ghanaian stakeholders identified and prioritized a final set of proposed investments. An expert stakeholder workshop in Accra used an iterative, qualitative, and quantitative prioritization process to rate and review the 22 initially proposed CSA priorities. They also grouped this long list of investments by agroecological zones to represent all regions of Ghana. The long list of potential investments was reduced from 22 to a shortlist of 9 priority CSA investments. Stakeholder experts represented a variety of organizations, including government ministries, institutions, research organizations, farmer groups, and international development organizations.

9. **The CSAIP team reviewed the proposed Ghanaian investments, using economic and financial analysis, integrated modeling of climate and socioeconomic factors on crops and commodities, assessments of barriers and opportunities of individual priority investments, financing avenues, and policy analysis.** The process used to develop this plan supports engagement and capacity strengthening. It also provides key elements of program design and implementation.

10. **Climate modeling shows that the shifting economic landscape from climate change could exacerbate damages for key food security and commercial crops.** Climate impacts do not affect all commodity groups uniformly, but they affect most commodity groups. Most cereals, especially maize, exhibit high vulnerability to climate change with losses between 8 percent and 11 percent in the next 10 years (2030) and between 16 percent and 21 percent in 2050. Other cereals, such as millet and sorghum, show relatively smaller declines in the short term, but both have losses of around 4–6 percent by 2050. Cacao is Ghana's most important agricultural export and, without investments to transform the sector, its yield is expected to decline. Some of the investments in this CSAIP were proposed because of their importance to food security, nutrition, or the national economy. CSA practices supporting resilience are essential to anticipate climate impacts and stop yields from declining.

11. **Climate modeling scenarios for other crops show that some are climate resilient; CSA emphasis should be on promoting practices that reinforce and maintain this resilience.** In general, livestock, rice, roots, and tubers show fewer impacts from climate change. For these crops and livestock, a higher investment commitment supporting resilience and yield-enhancing technologies could increase yields and production. Ghana's rice, groundnut oil, and groundnut imports may decline as national production increases. Maize imports will likely increase; but Ghana may also have a fledgling comparative advantage in plantain.

12. **This CSAIP includes two national-scale investments and seven regional climate-smart crop and animal investments.** The national investments are designed to provide information, capacity building, infrastructure, and national-level services to enable CSA to be practiced across Ghana. The seven regional

investments are focused on , productivity, adaptation, resilience and reducing the GHG emissions of specific crops and animals in certain regions of the county by introducing climate-smart practices into different investments. There are:

Two national-scale investments in Ghana's CSAIP:

- **Knowledge system and advisory services** supports evidence-based research, extension agents, and information and communication technology (ICT) advisory services for all crop commodities, fish, and livestock.
- **Water harvesting technologies and irrigation management** is focused on rice, with possible expansion to other commodities, and

Seven regional climate-smart crop and animal investments in Ghana's CSAIP:

- **Cereal-legume integration** improves crop varieties (heat- and drought-tolerant, disease-resistant), and supports soil fertility management for maize, sorghum, legumes in the coastal savannah and savannah areas.
- **CSA cocoa production** supports improving cocoa-growing area suitability, improving soil fertility and management, planting new resilient cocoa strains (heat- and drought-tolerant, disease-resistant), replacing old trees, and integrated pest management (IPM) in both forest and transitional areas.
- **Poultry feed improvement and genetic resource enhancement** is for both chickens and guinea fowl in transitional and savannah areas.
- **Climate-resilient ruminant production and genetic resource conservation** will introduce water harvesting technologies, promote irrigation for growing feed, establish grazing and watering pathways for livestock, create fodder banks, and improve breed varieties (heat-stress and disease-resistant) for cattle, sheep and goats in transitional, savannah, and forest areas.
- **Sustainable fisheries and aquaculture** will introduce heat- and disease-resistant fish varieties; improve feed for aquaculture; support culture-based fisheries for tilapia, catfish, shrimp, mussels and clams in the forest and coastal savannah areas.
- **Diversified tree crop production** supports improving tree crop varieties (heat- and drought-tolerant, disease-resistant) and soil fertility management for cashew and oil palm in the forest and transitional areas.
- **Roots, tubers, and livestock integration** will improve crop varieties and livestock species (heat- and drought-tolerant, disease-resistant) and soil fertility management for roots and tubers (cassava and yam) in the savannah, coastal savannah, and transitional zones.

13. **Table ES.1 shows the proposed investments, how vulnerable a sector or commodity is to climate impacts, why the proposed investment matters, and likely future scenarios with and without the investments.** Of the nine investments, cereal-legume integration addresses the commodity most vulnerable to climate change. Investments in cocoa, poultry, ruminants, fisheries and aquaculture, and tree crops all address commodities' vulnerability to climate change. Investments in roots and tubers-livestock are targeted to mixed vulnerability, as roots and tubers are generally resilient to climate change. The two national-scale investments for knowledge and advisory services and water management (for rice) support Ghana's efforts toward building a resilient production system.

Table ES.1: Proposed Investments

Climate Impact	Project Importance	Scenario WITHOUT Investment	Scenario WITH investment
Knowledge systems and advisory services supporting CSA			
Resilient	Foundational: leverage all CSA objectives to transform knowledge and extension by creating two-way information flow to identify emerging problems	Farmers make short-term decisions when facing uncertainty or high risk, perpetuating the poverty cycle, degrading resources, and increasing vulnerability. Local knowledge is less helpful with sudden shocks from climate or other factors.	Strong flow of good information on CSA suite of interventions supporting improved practices and productivity. Awareness and demand are driven by project. Project supports OneHealth, allows early action for pests, drought, and so on.
Water harvesting technologies and irrigation management focused on rice			
Resilient	Shows links for managing water and crop production (rice)	Rice imports increase while prices increase globally; environmental resources continue to be degraded while water scarcity increases; crop failure.	Efficient water capture and management allows Ghana to use rice resilience to meet its own demand and possibly to export rice.
Cereal-legume integration			
Highly vulnerable	Optimize existing cereal-legume farm practices to increase yields and improve soils	In 10 years, maize yields drop 8–11%; millet and sorghum drop 2–3%; soil degradation reaches critical levels, forcing people to move and clear land, increasing emissions.	Cereals are resilient; productivity increases; groundnut exports are supported; there is a 40% yield boost to 200,000 farm families; diversified on-farm crops increase resilience to shocks.
Climate-smart cocoa production			
Vulnerable	Transform a well-established sector with CSA practices to reverse declining yields	Old trees and climate impacts lead to yield declines; continued deforestation exacerbates climate impacts, causing additional yield declines.	Sector is transformed by climate-resilient practices that reduce encroachment on forest areas and boost yields.
Climate-smart poultry			
Vulnerable	Make sector climate resilient; create jobs; lower costs and sale prices; reduce imports; improve phytosanitary conditions and monitoring	Climate-related diseases and heat, along with feed costs, accelerate sector shutdown; Ghana becomes reliant on imports; native resilient stock ignored, potential for avian disease vectors.	Resilient domestic poultry sector provides jobs, income, protein and reduces import demand. High demand for local poultry products is met with supply. Mitigation benefits achieved. Value chains increased.
Climate-resilient ruminant and genetic resource conservation			
Vulnerable	Make sector climate resilient; create jobs; lower costs and sale prices; reduce imports; improve phytosanitary conditions and monitoring	Reduced productivity as feed sources decline while heat stress and mortality increase. Pastoralist-smallholder conflict increases as does reliance on bushmeat.	Crop-livestock integration and resilient breeds with improved health boosts productivity for income and consumption, enabling climate resilience; established water sources and corridors reduce conflict.
Sustainable fisheries and aquaculture			
Vulnerable	Make a highly profitable sector sustainable and climate-resilient, build value chains to create jobs and grow sector	Climate shocks affect the sector; overharvesting and poor resource management impact productivity; prices increase; protein intake suffers. Jobs and value chains decline.	A burgeoning sector is built on climate-resilient and sustainable feeds, breeds, and practices to ensure long-term profitability and well-developed value chains. Export market, jobs, and economic growth are enabled.

Climate Impact	Project Importance	Scenario WITHOUT Investment	Scenario WITH investment
Diversified tree crop			
Vulnerable	Leverage agroforestry practices in profitable export sectors to ensure continued food production and reduce forest encroachment	A 3–4% drop in oil palm yields; forest and soil health decline as does income; forest clearing; a significant decline in food production leads to increased prices, food insecurity, and reliance on imports	Resilient agroforestry practices ensure long-term productivity of export tree crops and reduce forest loss; enhanced ecosystem services mitigate climate change impacts; food production and security is maintained or improved
Roots and tubers-livestock integration			
Mixed	Integrate two key farming systems to foster resiliency, increase productivity, reduce costs in both, and monitor livestock health	Climate impacts further reduce feed availability and increase mortality; overgrazing exacerbates soil degradation; low crop and livestock productivity creates poverty trap; smallholder-pastoralist conflict is increased.	Resilient varieties, new feed resources, and relevant value chains bring climate resiliency and increase productivity, resulting in increased incomes, new jobs, productivity, and relevant sectoral growth.

14. **All the projects in the CSAIP improve CSA ‘smartness’, which is equal to improving productivity, resilience, and mitigation.** The nine priority CSA investments increase productivity (yield) by a minimum of 20 percent, and up to 59 percent for sustainable fisheries and aquaculture, compared to scenarios without the projects. Without a CSA project, the loss for maize is projected to be 8–11 percent in the next 10 years, and, for cereals generally, about 4–6 percent in the next 40 years; for cocoa losses of 3 percent by 2030 and up to 5–7 percent by 2050 are projected. The nine investments show a high degree of resilience, even when climate and pest risks are included. All investments have at least a 50 percent chance of a positive net present value (NPV) in the face of uncertain climate and pest risks. This suggests that the entire investment plan is robust for tomorrow’s environmental conditions. The roots, tubers, and livestock integration CSA investment are poised to build on the projected resilience of yams and cassava while offsetting potential damages to livestock production. The water harvesting and irrigation investment is poised to capitalize on rice’s resilience under climate change.

15. **The nine investments are predicted to provide significant benefits for Ghanaian farmers.** All investments are expected to improve farmers’ productivity and income. Without risks included in the model, NPV (20 years) ranges from US\$28.5 million with the aquaculture program to more than US\$231 million with the program focused on CSA cocoa production. Each investment will present positive returns relative to its costs, based on the analysis. Investment in improved agricultural practices increases farm outputs, whether by introducing new breeds of livestock or drought-tolerant seeds for crops or by providing information for better farming decisions (for example, knowledge, advisory and climate services). In some, the return on investment (ROI) is expected to reach as high 9 percent (for example, with the tree crop program). Even accounting for risks, ROIs and benefit-cost ratios (BCRs) remain positive. A sensitivity analysis was performed for NPV, using two levels of carbon pricing (low and high) with and without climate and pest risks, and it demonstrated that many of the economic analysis results are very sensitive to carbon pricing.

16. **Results from climate modelling show the positive impacts of CSAIP investments on trade.** Cocoa, one of Ghana’s major exports, is projected to decline under climate change. The cocoa production investment could offset potential damages to Ghana’s cocoa production and sustain its competitive edge in critically important cocoa exports by improving production and resilience compared to the business-as-usual (BAU) scenario. The CSAIP also supports improvement in maize, sorghum, and groundnut yields and is projected to improve the trade trajectories for these crops.

17. **Five investments appear especially strong when assessed using the CSA pillars of productivity, resilience, and mitigation.** Of the nine investments, cocoa production, water management, and cereal integration appear in the top five in each of the CSA pillars categories, while tree crops and poultry production each appear twice in the top five in each of the CSA pillars categories.

18. **While this CSAIP focuses directly on the three CSA pillars, there strong co-benefits offered by the proposed investments that help mitigate other risks and build resilience across multiple sectors.** CSA creates resilient systems that lend stability to food supplies, livelihoods, and other crucial networks in times of upheaval, whether the shock is an extreme weather event, health crisis, or other national emergency. Digital agricultural presents a new portfolio of potential solutions to challenges in the agricultural system that can improve agricultural efficiency and resiliency by reducing financial and labor costs, providing timely decision-support information, decreasing losses, improving quality, supporting sustainable use of resources, and increasing productivity.

19. **The CSAIP is clearly aligned with Ghana’s Nationally Determined Contributions (NDC), both for high-level objectives and for specific investment activities.** Knowledge and advisory, roots and tubers-livestock, and ruminants have the strongest links to the NDC, while poultry has the lowest. The ways in which each of the proposed investments are likely to be affected by policy gaps and distortions differs, with cereal-legume integration showing the fewest possible policy impacts. The Ghana CSAIP investments will be both sources and sinks for GHGs, but if all priorities were implemented, they would together sequester an estimated 7.31 MtCO₂. Five of the investments produce low levels of additional emissions; this is unsurprising since four of them are focused on meeting Ghana’s future protein needs, with livestock (cows and small ruminants), poultry, and fisheries and aquaculture. However, even these reduce GHG production intensity.

20. **Further design and implementation should build on existing institutional capacities and ongoing CSA-related projects.** The most important supportive element for eight of the nine projects was the strong research capacity, knowledge base, and expertise that exists in Ghana given its network of universities and research institutions and its leadership in agricultural sciences. Sustainable fisheries and aquaculture, cocoa production, and tree crop production, each found implementation support in four or five identified areas.

21. **Improved institutional arrangements and strong partnerships are important ingredients in successful CSAIP implementation.** Institutional arrangements should build on existing networks and arrangements established to support CSA-related projects. The execution of the proposed investments will require strengthening research capacity, knowledge bases, expertise, and networks. In Ghana, a dialogue fostered by a formal forum of universities and research institutions, thematic nongovernmental organizations (NGOs), the private sector, commodity boards, and value chain operators will be of critical importance. CSAIP implementation will also require strong and functional partnership between public sector institutions and among other national and international agencies. The Ministry of Food and Agriculture (MoFA) was the most frequently mentioned collaborator, suggesting that as the CSAIP moves forward, special channels should perhaps be opened to facilitate support with those entities. Links with Ghanaian universities was also prioritized by six of the investments. Many of the prioritized investments identified a strong set of international and national NGOs. The ruminant investment had the greatest number of potential collaborators identified (eight overall), with cocoa, cereal-legume, and root-tuber-livestock each identifying seven potential partners. This level of engagement has both benefits and costs; the higher the number of collaborators, the more important it is to have a clear plan for what the collaboration entails.

22. **Finance remains a major issue for implementing climate actions in Ghana, and a significant portion of Ghana’s NDC commitments are contingent on funding support.** The estimated finance requirement for the nine CSAIP project is US\$389.54 million. The CSAIP identified potential sources of financing for each investment—from multilateral and bilateral organizations, foundations, and donors, to national budgets, NGO support, and private sector financing. Six of the priority investments will mainly target multilateral and donor organizations for financing. Conversely, the investment in cocoa production could potentially come solely from the private sector. Financing for ruminants, fisheries, and tree crops will primarily be based on a mix of public and private sector funds. The Ghanaian government estimates that US\$22.6 billion will be needed to finance its NDC commitments—making this portfolio of projects a small component of overall financing.

23. **The investment build on Ghana’s own policy priorities, namely, to create jobs, improve value chains, reduce food imports, and increase exports.** Investments such as diversified tree crops, irrigated rice, aquaculture, and cocoa are critical to transforming the agriculture sector, enhancing food security, and improving resilience. Many of these investments are specifically targeted in national strategies and have strong national support. Aquaculture, irrigation and rice, cocoa and diversified tree crops, because of their potential to enhance value chains and jobs, are all directly identified crops or strategies in the Investing for Food and Jobs (IFJ) plan. These investments are intended to maintain and build resilience for commodities important to the country but vulnerable to climate impacts (for example, cocoa) or to introduce new technologies and practices for resilience and sustainability (for example, aquaculture) while supporting value chains or building new infrastructure (water management and irrigation for rice) that can reduce flooding and support production.

Table ES.2: Objectives of Investments

	Food security	Resilience	Value Chains	Trade	Mitigation	Transform Sector
Cereal-Legume Integration	✓	✓	✓	✓	✓	✓
Knowledge and Advisory	✓	✓	✓	✓	✓	✓
Poultry Production	✓	✓	✓	✓	✓	
Tree Crop Production		✓	✓	✓	✓	
Cocoa Production		✓	✓	✓		✓
Water Management	✓	✓		✓		✓
Root-Tuber-Livestock	✓	✓		✓		✓
Fisheries and Aquaculture	✓	✓	✓	✓		
Ruminant Production	✓	✓			✓	

24. **All the investments were identified as priorities for Ghana, but there are certain investments that are more likely to appeal to specific potential investors.** As shown in Table ES.1, the cereal-legume and knowledge and advisory investments address each of the six national objectives, including supporting the transformation of the sectors. Poultry production meets the next highest number of objectives. This provides a lens for identifying investments based on the specific objectives it plans to achieve. The assessments included in this CSAIP help to identify the potential trade-offs, advantages, and disadvantages of each of the priority investments.

25. **All investments support smallholder productivity and help small producers manage and reduce risks from climate change impacts and other shocks.** From extension agents providing timely and accurate information (for example, what to do if there is a drought), to resilient seeds and animal breeds, this portfolio focuses on increasing resilience and decreasing or managing risks. It also targets the vulnerable in different ways. These investments support the poor and most vulnerable through geographic targeting to Ghana's poorest regions, investments in farm systems used by Ghana's poorest farmers, and investments that support women and youth by creating new jobs and value chains. While policy interventions are not a focus of the CSAIP, having a strong portfolio of CSA investments helps bring policy coherence and furthers CSA across the policy arena by demonstrating what policies are supportive and by identifying barriers.

26. **Taken together, these investment opportunities represent a well-balanced portfolio.** The investments span different sectors of the country, have different levels of risk, target divergent groups of beneficiaries, and introduce a wide range of well-demonstrated CSA technologies and practices (see Annex A for details). All the investments support CSA pillars, and contribute to meeting objectives identified in Ghana's national plans that are fundamental to addressing its future. Through geographical focus on Ghana's poorest regions and by targeting poor farmers, women, and youth as direct beneficiaries of investments, this CSAIP will directly contribute to the generation of new jobs and reduction of poverty. Further, productivity gains translate to improved food security, enhanced well-being, maintenance of social cohesion, political stability, improved prospects for export trade, and to macroeconomic stability.

CHAPTER 1: WHY CLIMATE-SMART AGRICULTURE

1. **Ghana has made major economic gains and by some projections may now be the fastest-growing economy in the world.** Gross domestic product (GDP) rose 8.8 percent in 2019, which is nearly double the pace of most emerging economies. This growth comes partly from a diversification of the economy away from agricultural production over the last several decades. Yet agriculture is still vital to Ghana's economy, outpacing the overall economy,⁴ employing 34 percent of the nation's workforce, and contributing nearly 20 percent of national GDP.⁵ Emphasis is being given to diversifying the agricultural sector and increasing postharvest and value-added industries.

2. **Climate change is already adversely affecting Ghana, lowering agricultural production and decreasing opportunities for future prosperity.** At local levels, climate change provokes extreme and unpredictable events, including prolonged droughts, strong floods, deadly heat waves, and erratic beginnings and ends to the rainy seasons. At regional scales, distinct patterns are apparent in each agroecological region. At the national level, the clear trend over time is increasing temperatures and reduced precipitation. These changes are expected to catalyze desertification, ecosystem deterioration, and concomitant losses of arable land. Higher temperatures, drought, intense rainfall, and standing water could create the conditions for pest and disease outbreaks, affecting crops, livestock, and people. Postharvest losses may increase due to erratic and unpredictable weather conditions.⁶ Sea level rise and tidal flooding—and the salinization they bring—could displace significant number of people and will

⁴ Ghana Statistical Service, "Provisional 2017 Annual Gross Domestic Product," April 2018, http://www.statsghana.gov.gh/docfiles/GDP/GDP2018/2017%20Quarter%204%20and%20annual%202017%20GDP%20publications/Annual_2017_GDP_April%202018%20Edition.pdf.

⁵ CIA, "Ghana," The World Fact Book, 2015, <https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html>; The World Bank Group, "Ghana," Data, 2019, <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=GH&view=chart>; CIA, "Ghana."

⁶ M.A. Akudugu and A.R. Alhassan, "The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana," *International Journal of Sustainable Development & World Policy* 1, no. 3 (2012): 80–95.

reduce productivity in coastal regions.⁷ Ghana's agricultural economy, although more diverse now than in the past, remains heavily reliant on just a few key crops such as cocoa. This situation implies that the possible failure of even one crop could have major impacts on the national economy.

3. **A broad and robust suite of agricultural and rural development initiatives is needed to help ensure that Ghana's growth continues and adapts to climate impacts.** Nutritional security, decent livelihoods, and economic prosperity must be resilient to extreme climate events and variability. Responding to this need, a team of Ghanaian experts identified and prioritized a portfolio of investments to support Ghana's rural sector in addressing climate change through climate-smart agriculture (CSA). This document analyzes these investments and their context in detail.

4. **CSA agriculture addresses agricultural vulnerabilities to climate change by bolstering productivity, resilience, and mitigation.** Productivity increases help fill gaps in nutritional and economic security for households and build economic prosperity at the national level. Adaptation adjusts or transforms current practices into those that are resilient in the face of climatic vagaries. Mitigation helps reduce the risk of further climate change by reducing greenhouse gas (GHG) emissions or increasing carbon storage. Taken as a whole, these three pillars of CSA aim to identify and implement *methods for increasing productivity that are...resistant or resilient to extreme weather and...reduce GHG intensity (the amount of GHG per unit of food produced).*⁸

5. **CSA acknowledges the synergistic effects between these three pillars, aiming to maximize co-benefits and minimize tradeoffs between them.** When tradeoffs are necessary, the well-being of the rural poor is prioritized through a focus on boosting production and adaptation. CSA also brings tertiary mitigation co-benefits by increasing food production at a greater rate than GHG emissions, thus reducing GHG intensity.

6. **CSA is not a silver-bullet approach; rather, it is a process of identifying and implementing highly site-specific and time-specific solutions tailored to each community's unique needs.** Thus, the relative importance of each of the three pillars will vary from one situation and stakeholder group to the next. While CSA is inherently agriculture-oriented, it is multisectoral in its effects on household livelihoods, national food security, and the sustainable use of natural resources (Figure 1).

⁷ J.A. Yaro, "Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana." (Friedrich Ebert Stiftung, 2013), <http://library.fes.de/pdf-files/bueros/ghana/10517.pdf>.

⁸ Leslie Lipper et al., "Climate-Smart Agriculture for Food Security," *Nature Climate Change* 4, no. 12 (December 2014): 1068–72, <https://doi.org/10.1038/nclimate2437>.

Figure 1: CSA - The Triple Win of Sustainability, Resilience, and Lower Emissions⁹



7. **Climate-smart agricultural investment plans (CSAIP) are a way for countries to plan for the future, and Ghana is developing this national CSAIP as part of the Adaptation of African Agriculture (AAA).** AAA is a coordinated, multi-country initiative that was launched at the United National Climate Change Conference 22nd Conference of Parties in Marrakech, Morocco (2016). This CSAIP was developed within the institutional arena of the Ghanaian Science-Policy National Dialogue Platform for Climate and Agriculture, which is coordinated by the Consultative Group on International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture, and Food Security (CCAFS). Funding and technical support were provided by the World Bank. Strong government partnership and stakeholder engagement are the foundation of this CSAIP.

8. **Ghana is invested in the success of the CSAIP, and the Government of Ghana has been implementing foundational policies supporting CSA.** Climate change policies and plans, agricultural sector policies, and combined plans show strong support to CSA. The National Climate Change Policy, for example, has strong links to CSA. Notably, Ghana has policies that jointly look at both issues, such as the Action Plan on National Climate Smart Agriculture and Food Security (2016–2020), the National Climate Smart Agriculture Food and Security Action Plan, and the Medium Term National Development Policy Framework (MTNDPF), which is operationalized with the Investing for Food and Jobs (IFJ): An Agenda for Transforming Ghana’s Agriculture (2018–2021).¹⁰ IFJ contains innovative flagship programs such as Planting for Food and Jobs (PFJ), Planting for Export and Rural Development, and Rearing for Food and Jobs. These programs offer strong support for CSA. Ghana is also signatory to several prominent international commitments that inform this CSAIP, including the Sustainable Development Goals (SDGs), the Malabo Declaration, and the United Nations Conference on Climate Change Nationally Determined Contributions (NDCs). The CSAIP supports both domestic Ghanaian policies and initiatives and Ghana’s contributions to several international agreements.

9. **Transforming the agricultural sector is a major goal of the IFJ: An Agenda for Transforming Ghana’s Agriculture (2018–2021).** The IFJ agenda integrates key goals taken by Ghana at the international level such as its SDGs and its commitment to the Malabo Declaration, which entails the target of investing at least 10 percent of the national budget into agriculture. IFJ’s goal is to efficiently address cross-cutting issues such as biodiversity, climate change, agricultural development, gender equity, poverty and food

⁹ Food and Agriculture Organization of the United Nations, *Climate-Smart Agriculture Sourcebook*, 2014.

¹⁰ Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture” (Republic of Ghana, January 2018).

security.¹¹ To accomplish this, the IFJ agenda underlines the importance of addressing agricultural sector development issues intersectorally by working across other ministries and government agencies.

10. **Agriculture is a major component of Ghana's NDCs.** The country's NDCs integrate climate adaptation, increased productivity, and reduced emissions intensity to guide Ghana's efforts toward truly sustainable development. Four NDC target project areas are relevant to agriculture: forest resources, agricultural landscapes, water distribution and access, and inclusive development for women and vulnerable populations.

11. **Ghana has been a leader among low GHG-emitting signatories to the United Nations Nationally Determined Contributions Partnership.** The country hosted the Africa Low Emissions Development Strategies (Africa LEDS) convened in June 2019 which was supported by the European Union - United Nations Environment Programme (EU-UNEP). This meeting was the platform for establishing the Accra Action Agenda to drive climate action. At the September 2019 Climate Action Summit, Ghana joined other nations in committing to enhance their intended NDCs in 2020 with the goals of further and faster global GHG emission reductions and fostering climate resiliency.

12. **This CSAIP supports the three pillars of productivity, adaptation, and mitigation.** The global community, including Ghana, is already challenged to meet the food security requirements of a growing population. This challenge will be increasingly exacerbated by climate change.¹² Ghana already has a vulnerable population that will feel the impacts of climate change keenly: 5 percent of the population is undernourished,¹³ 13 percent lives on less than US\$1.90 per person per day, and 23 percent is below the national poverty line.¹⁴ Meanwhile, Ghana contributes only 0.08 percent of global GHG emissions. This CSAIP therefore improves the productivity and climate adaptiveness of Ghanaian farming systems, supports resilience and adaptation, and buttresses mitigation co-benefits.

13. **In alignment with Ghana's NDCs and the IFJ agenda, this CSAIP has identified specific investments that help reduce the GHG intensity.** Each investment concept proposes actions that reduce GHG intensity by decreasing emissions and/or sequestering carbon in biomass and soils. Improving livestock nutrition, utilizing crop residues as feed and manure as fertilizer, reducing forest encroachment, crop system intensification, and agroforestry techniques are just a few examples of the mitigation activities promoted in this CSAIP. Please see Chapter 4 and Annex A for complete details.

14. **The CSAIP provides a tangible, prioritized, and vetted set of investments for investors and donors to fund.** The proposed investments were identified and developed through an iterative, on-the-ground process supported by scientific literature, economic analyses, climate impact modeling, and policy analysis. The result is a suite of synergistic investments that can be developed and implemented as stand-alone projects or as a comprehensive program for innovation in Ghana's agricultural sector. This investment portfolio has been prepared with an eye toward engaging private sector actors, public institutions, international donors, and other key stakeholders in providing the much-needed funding for transforming Ghana's agricultural sector.

15. **The proposed investments in the CSAIP and the portfolio as a whole offer a nationally supported suite that could be rapidly deployed to support post-COVID-19 economic recovery efforts while also**

¹¹ Ministry of Food and Agriculture.

¹² Global Commission on Adaptation, "Adapt Now: A Global Call for Leadership on Climate Resilience," September 13, 2019, https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf.

¹³ AUDA-NEPAD, "Tracking Progress: Ghana," NEPAD Transforming Africa, 2019, <https://www.nepad.org/caadp/countries/ghana..>

¹⁴ The World Bank Group, "Ghana."

reducing future risks and impacts from abrupt shocks. The portfolio enhances resilience in multiple sectors, including supporting on-farm productivity, value chain creation and employment, reducing dependency on imported food and other commodities, and benefitting OneHealth objectives. The investments directly support 1.7 million beneficiaries in all regions of Ghana and provide both short- and long-term benefits to livelihoods and food security, while also reducing risks and building resilience across multiple sectors.

1.1 The Climate-Smart Agricultural Investment Planning Framework

16. The Ghana CSAIP team has developed the investment plans described herein based on the four components of CSA planning and implementation.

These are:

- (a) Situation analysis
- (b) Prioritizing interventions
- (c) Program design
- (d) Monitoring, evaluation, and learning¹⁵

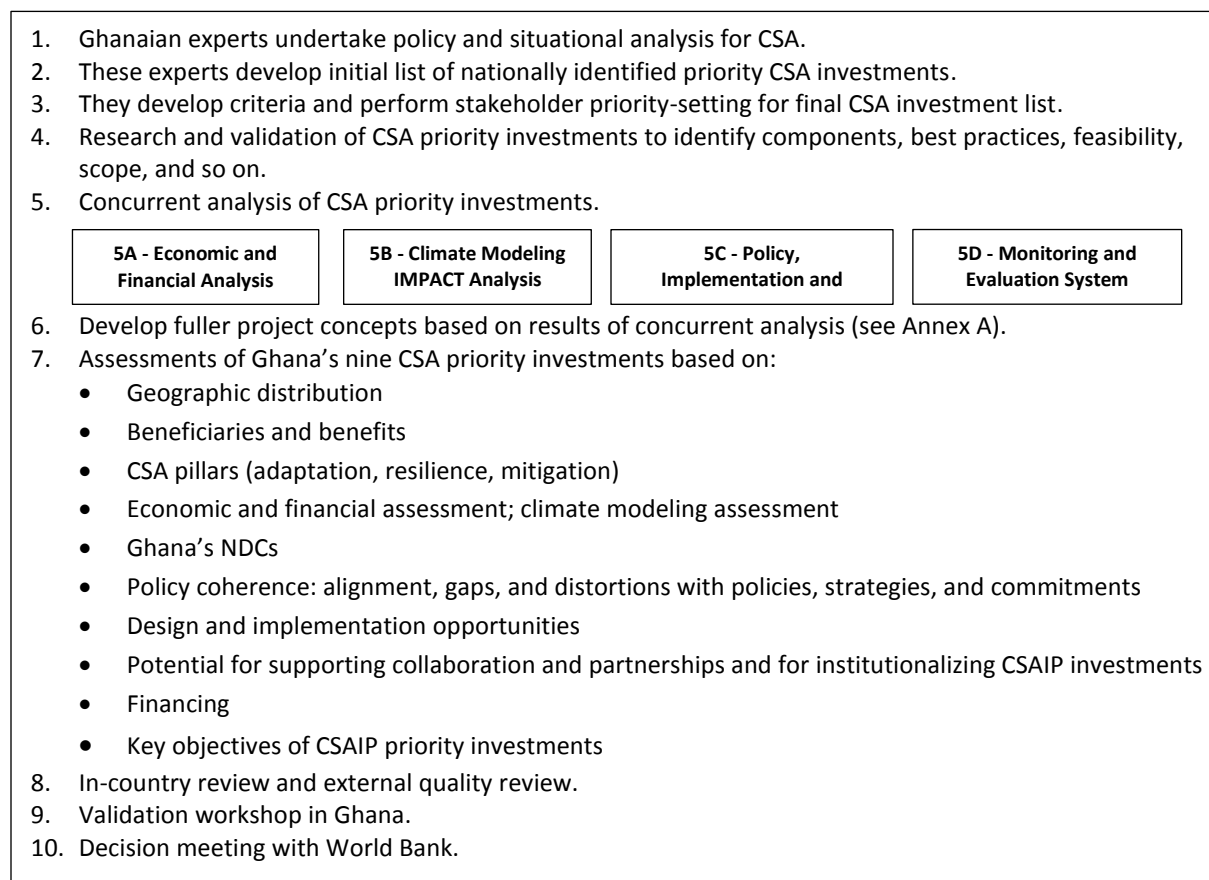
These four components of CSAIP planning (Figure 2) are based on strong stakeholder engagement, topical expert contributions, and capacity building at the institutional and individual levels. This CSAIP focuses on the first two components: situation analysis and prioritizing interventions. In addition, it discusses elements of program design and monitoring, evaluation, and learning. In-country expertise, priorities, policies, stakeholder engagement, and capacity building were at the crux of this CSAIP's development. The analysis used herein is built on both qualitative and quantitative assessments and methods. The process described below generally follows the CSA Prioritization Framework (see the CSAIP Development Guide and Figure 3.)

17. A stakeholder workshop used detailed criteria to evaluate the long list of 22 proposed investments. Stakeholder experts represented a variety of organizations, including government ministries, public institutions, research organizations, farmer groups, and international development organizations. The International Center for Tropical Agriculture (CIAT) and its counterparts organized a workshop in Accra where participants used an iterative, qualitative and quantitative, CIAT-developed, prioritizing process to rate and review each of the 22 proposed CSA priorities (see Chapter 3 and Annex B for specifics). They also grouped the long list of investments by agroecological zones to represent all regions of Ghana and to reflect regional differences emanating from climate change impacts. The long list of potential investments was reduced from 22 to 9 priority CSA investments.

18. The priority-setting workshop provided a strong rationale for and key information on each proposed CSA investment. The process of reducing the long list of priorities to a shorter list elicited detailed information on each investment, which needed to be further refined to fully reflect the scope of each proposed investment. To do this, CIAT uses a process that (a) refines the investment shortlist to insure relevant CSA best practices are followed; (b) conducts a thorough literature review on similar projects; (c) identifies current and potential yields of crops, technology packages, and other project components such as designing value chains; and (d) reviews related projects for best practices, implementation issues, lessons learned, barriers, and opportunities. Investment concept notes (see Annex A) are prepared for each priority investment.

¹⁵ Evan Girvetz et al., "‘CSA-Plan’: Strategies to Put Climate-Smart Agriculture (CSA) into Practice," *Agriculture for Development* 30 (2017): 5.

Figure 2: Developing Ghana’s CSAIP - Process Summary



19. **Prioritized Investments are analyzed along five dimensions when concept notes are completed: economic and financial; IMPACT climate modeling; policy and financing alignment; implementation issues; and monitoring and evaluation.** Each of these are described in detail in a technical appendix (see Annexes B, C, D, E), but the highlights of each are presented below.

20. **Economic and financial assessments are based on detailed analysis of how the investments will perform within a given agroecological context.** A key input for the analysis is Evidence for Resilient Agriculture (ERA), a new African-centered database. It contains information on 112 technologies used in crop, livestock, and tree production and uses 58 indicators of performance (for example, yield, net economic returns, soil carbon). ERA draws on more than 1,400 peer-reviewed studies to create a meta analyses of the results of research into productivity, resilience, and climate change mitigation when there is a shift from one technology to another. Each investment may include multiple technologies, so ERA provides field-based data on outcomes for each different technology in a proposed investment. To ensure comparability, ERA results from similar African agroecological regions are used. Standard financial and economic parameters for the project are calculated by using data on project costs from similar projects within Ghana, or for similar agroecological regions in nearby countries if data for Ghana does not exist. (See Annex E for the economics methodology.)

21. **The results from the economic modeling across all investments are presented in Chapter 3.** These include assessments of the net present value (with different scenarios of risk and carbon pricing); the impact of investments on the three pillars of CSA (productivity, resilience and mitigation); financial

and economic analyses looking at returns on investment (ROI) and cost-benefit analyses (CBA), with and without different risks. This CSAIP plan and its economic analysis use the best available information on certain risks. It allows a direct targeting of investments for the climate and pest risks threatening productivity and growth in the future. This can be contrasted to many examples of ex ante assessment where the analysis presents an overly optimistic picture of likely success by not integrating specific risks to the CBA.

22. Climate modeling is a key component to identify future suitability of different commodities. Climate modeling used in preparing this CSAIP utilized several potential climate scenarios to see their impact in Ghana, and the impact they will have on trade dynamics. Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas (for example, entire countries) but also creating pockets of increased suitability. At a global scale, these shifts will be significant in determining which countries can grow what crops, in turn affecting international trade. Demographic and economic growth trajectories and GHG mitigation policies will impact demand and consumption. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)¹⁶ models the complex interplay of all of these demographic, economic, mitigation, demand, and consumption factors.

23. Climate modelling for Ghana assesses future suitability of different crops and the potential for CSA practices to improve performance under different conditions. Specifically, climate modeling has three key components: (a) climate impact of all of Ghana's basic commodities for 10 years into the future; (b) Ghana's future comparative advantage in these commodities compared to other countries; (c) CSA impact of proposed investments on future yields. Assumptions regarding demographic and economic growth are reflected by modeling the shared socioeconomic pathway (SSP) for the middle-of-the-road/business-as-usual (BAU) pathway assuming indeterminate challenges (see Annex D). Assumptions regarding the severity of increased GHG concentration are reflected in the choice of three representative concentration pathways (RCPs) (4.5, 6.0, and 8.5), from least to most severe, for two points in time, 2030 and 2050. The climate modeling provides insights into what comparative advantage Ghana may have in the future for different commodities given demographic, economic, demand, and trade factors. It also provides insights on the difference that investments with new technologies introduced now can have at the 10- and 30-year mark for different potential climate impacts.

24. Prioritized investments were reassessed for their alignment to Ghana's NDC and other key policies and strategies. These included Investing for Food and Jobs (IFJ). A strong emphasis has been placed on reassessment, because the long list of potential investments and the nine prioritized investments were initially selected for their alignment to Ghanaian national plans and policies. Reassessment was performed to more fully indicate the nuances of policy links for the nine priority investments. For example, policy gaps and distortions were identified for each investment, and are summarized in Chapter 3.

25. The Ghanaian agriculture sector is extremely vulnerable to negative impacts from climate change. High temperatures and reduced rainfall are expected to catalyze desertification, ecosystem deterioration, and concomitant losses of arable land and forests due to fire. Higher temperatures, drought, intense rainfall, and standing water could instigate outbreaks of crop and livestock pests and diseases (see Box 1 for additional details). Postharvest losses may increase due to erratic and unpredictable weather conditions.¹⁷ Salinization of agricultural soils from sea level rise and tidal flooding

¹⁶ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

¹⁷ Akudugu and Alhassan, "The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana."

will have detrimental impacts on productivity in coastal regions and displacement of large section of the society.¹⁸ Ghana's current low agricultural diversification intensifies the risk of crop failure. Climate change will intensify production vulnerability in north, since the region is particularly hot and dry, has lower quality agricultural lands, and is most susceptible to drought, soil erosion, and land degradation.¹⁹ Climate change is also having major impacts on agricultural pests and diseases. Box 1 has some examples of these, and synergistic actions to deal with these issues are discussed in Chapter 2.

26. **Design and implementation considerations were also assessed.** Relevant projects for CSA and non-CSA projects for similar production systems within Ghana were examined and are discussed in Annex A. Many aspects of these projects were assessed. Some of the findings were noted by participants at the prioritizing workshop, while others were based on extensive literature review of scientific papers, project documents, white papers, and so on. Some of the factors briefly considered and discussed in Chapter 3 are (a) implementation experiences to understand potential lessons; (b) positive contributors or risks and barriers to project success; (c) potential collaborators, in government, nongovernmental organizations (NGOs), and the private sector. This information is included in the individual investment concepts in Annex A and summarized in Chapter 4.

27. **Financing opportunities and the potential for private sector involvement were assessed in several ways.** As part of the prioritizing workshop and investment concept development process, the potential for private sector collaboration and financing, public financing opportunities, and international financing were reviewed. The World Bank's Maximizing Finance for Development Framework was developed by private sector experts in Ghana for each of the prioritized investments. Results are presented in Chapter 3 and in the individual investment concepts in Annex A.

Box 1: Pests and Disease in Ghana²⁰

The evidence is clear that climate change is leading to a global surge of pests and diseases, both within and outside of agricultural settings. It is also increasing the spread of other emerging infectious diseases (EIDs), such as COVID-19, and the movement of invasive species that can lead to disruptions in the agricultural sector. Pest populations and diseases are already spreading and extending their ranges, driven by climate change, biodiversity loss, and increased trade and travel. A recent study of crop losses to pests globally found, for Ghana, that current maize losses are 168,212 out of 1.2 million tons, and future losses will increase by an additional 28–33 tons. Common pests in Ghana include rodents, locusts, borers, caterpillars, nematodes, aphids, and mealybugs. Habitat change and biodiversity loss has generally increased the prevalence of EIDs and zoonotic diseases, which come from animals. This is unsurprising as these changes lead to closer contact between wild animals, domesticated animals and livestock, and people. In Ghana, animals such as bats are consumed for bushmeat. Agriculturally, bats can be important for pest control and pollination, but they also can be reservoirs of many serious zoonotic diseases. Livestock and poultry can also transmit zoonotic diseases. Invasive species include fruit flies and cashew mealybugs which destroy crops, leading to major economic consequences.

28. **A monitoring and evaluation (M&E) plan was developed for the entire portfolio.** For more detail, see Chapter 5. Additionally, a theory of change (TOC) was developed for both the entire CSAIP and each individual priority investment (see Annex A). The M&E plan aims to provide CSAIP implementers—particularly the government—with a manageable system to generate, collect, and analyze standardized

¹⁸ Yaro, "Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana."

¹⁹ GFDRR, "Country Program Update: Ghana," 2013, http://www.gfdrr.org/sites/gfdrr.org/files/Ghana_Country_Program_Updates_2013.pdf.

²⁰ Akudugu and Alhassan 2012; Yaro 2013; GFDRR 2013; <https://royalsocietypublishing.org/doi/10.1098/rsos.181577>; Rohr et al 2019; Deutsch et al. 2018; https://www.wvi.org/sites/default/files/PMP-Final_1.pdf; Civitello et al. 2015; Ohemeng et al. 2017.

CHAPTER 1: WHY CLIMATE-SMART AGRICULTURE

data to assess the success of individual investments or the whole portfolio. The goal of the plan is to inform operational and strategic decision-making. The TOC includes four action areas for the entire CSAIP and for individual investments: (a) robust research and development (R&D); (b) uptake of climate-smart production technologies and value-added practices; (c) stakeholder engagement and partnerships; (d) system-wide capacity to implement CSA actions.

CHAPTER 2: SITUATIONAL ANALYSIS OF AGRICULTURE, CLIMATE CHANGE, AND LIVELIHOODS

2.1. Ghana's Rural and Agricultural Sector in Brief

29. **Ghana is at an important stage in national development.** Ghana's GDP is growing at approximately double the rate of that of most developing economies, and its high-speed growth has driven down poverty at unprecedented rates. The country has been at the forefront of poverty reduction and was the first African nation to achieve the first Millennium Development Goal of reducing the national poverty rate by more than half, from 52.7 percent in 1991 to 24.2 percent in 2012. The national poverty headcount declined by a stunning 12.2 percent from 1991 to 1998, an additional 11 percent from 1998 to 2005, and another 7.7 percent from 2005 to 2012. The poverty rates among cocoa farmers alone declined from 60 percent in 1991 to 24 percent in 2005. During this same time, food production doubled, the country went through significant structural transformation and rapid urbanization, and services replaced agriculture as the largest sector of the economy.²¹ The country is also undergoing a vast demographic change as the population becomes younger,²² representing a major opportunity to leverage a young workforce for continuing transformation of the national economy.

30. **These robust patterns of poverty reduction have significantly slowed.** The poverty reduction rate slowed dramatically to only 0.8 percent during 2012–2016, indicating a fundamental change in growth patterns and drivers.²³ Approximately 23 percent of the population lives below the national

²¹ Michael Geiger, Tomomi Tanaka, and Camille Nuamah, "Ghana's Growth History: New Growth Momentum since the 1990s Helped Put Ghana at the Front of Poverty Reduction in Africa," World Bank Blogs, December 10, 2018, <https://blogs.worldbank.org/african/ghanas-growth-history-new-growth-momentum-since-the-1990s-helped-put-ghana-at-the-front-of-poverty>.

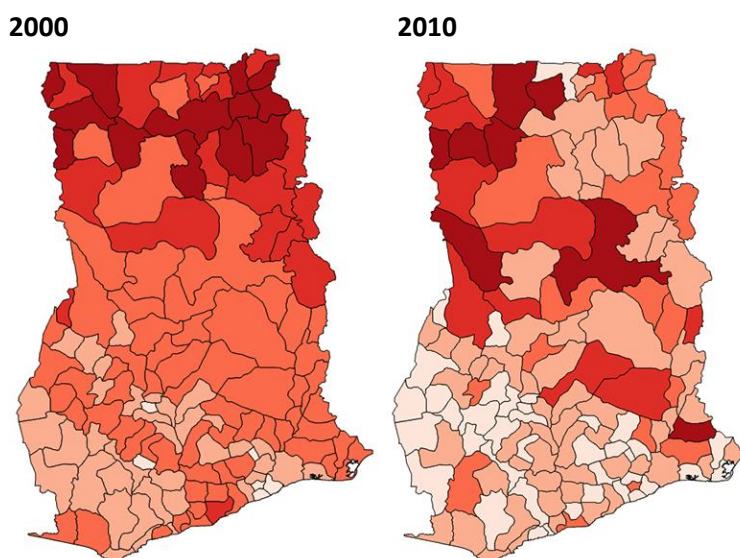
²² International Food Policy Research Institute (IFPRI), "Public Agricultural Spending and Growth in Ghana: Spending More, Smarter" (Washington, DC: International Food Policy Research Institute, 2019), <https://doi.org/10.2499/p15738coll2.133333>.

²³ Geiger, Tanaka, and Nuamah, "Ghana's Growth History."

poverty line, and 13 percent lives on less than US\$1.90 per day.²⁴ Ghana received an unfavorable African Agricultural Transformation Scorecard from the African Union in 2018,²⁵ mainly because of its low budgetary allocations for the agricultural sector.

31. **Ghana has also seen persistent and growing spatial inequality in poverty rates (Figure 3).** The poverty reduction rates have stagnated and the absolute number of poor has increased in the Volta, Northern, and Upper West regions. These inequalities reflect both the harsher environmental conditions in the north and lower rates of service provision. Although agriculture remains the dominant employer in these impoverished regions, farmers still face challenges. Planting for Food and Jobs (PFJ) has expanded farmer access to inputs such as seeds and fertilizer, but access to extension services, irrigation, and markets are still inadequate. There are also marked differences in access to infrastructure such as electricity and roads. These circumstances have led to unsustainable farming practices, which degrade natural resources and decrease agricultural outputs.²⁶

Figure 3: Concentration of Poverty across Districts²⁷



32. **Important work remains to improve Ghana’s upward development trajectory.** The 2018 national GDP was US\$65.56 billion or US\$2,202 per capita. While this is significantly higher than the Sub-Saharan African average of US\$1,574,²⁸ it is far below the world average of US\$11,300 per capita. Ghana’s population is approximately 30 million, with a relatively high population density of 131 per km² (versus the global average of 60 per km²).²⁹ The population is expected to balloon to more than 51 million by 2050.³⁰ Ghana ranked 140 out of 189 countries on the Human Development Index in 2017; with a score

²⁴ The World Bank Group, “Ghana.”

²⁵ Muchero Martin, “Africa Agriculture Transformation Scorecard: Performance and Lessons for the Southern Africa Development Community-SADC,” n.d., 10.

²⁶ Tomomi Tanaka, Camille Nuamah, and Michael Geiger, “Ghana’s Challenges: Widening Regional Inequality and Natural Resource Depreciation,” World Bank Blogs, December 14, 2018, <http://blogs.worldbank.org/africacan/ghanas-challenges-widening-regional-inequality-and-natural-resource-depreciation>.

²⁷ Tanaka, Nuamah, and Geiger.

²⁸ The World Bank Group, “Ghana.”

²⁹ The World Bank Group.

³⁰ UNDESA, “World Population Prospects: The 2017 Revision, Key Findings and Advance Tables,” Working Paper, 2017, https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.

of 0.592 versus a Sub-Saharan African average of 0.537.³¹ Greater investments in agriculture are needed to enhance Ghana's human development and address its socioeconomic challenges.

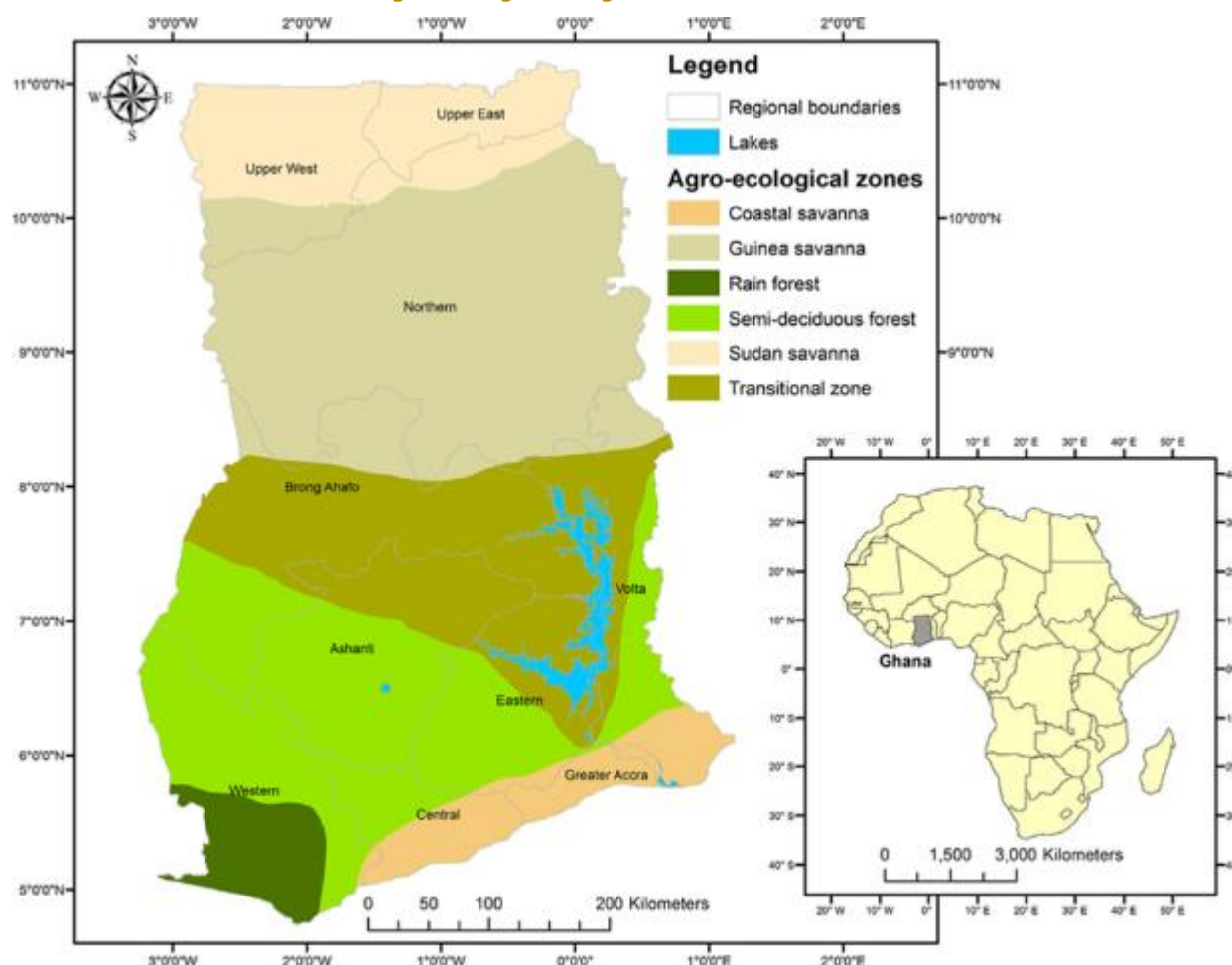
33. **Agriculture is Ghana's predominant land use, and its diverse agroecological zones offer significant potential for diversity in agricultural production.** Ghana has four major agroecological zones (Figure 4, Table 1) in just 227,540 km² of land area. By 2016, about 70 percent of this land area was used for agriculture, with half of the total land area in permanent crop or pasture systems, and over 20 percent in arable systems (Table 2). The forest and transition zones produce roots and tubers as the primary food crop, and cocoa dominates cash crop production.³² In the northern savannah, grains are the main food crop grown and groundnuts are the primary cash crop. The northern savannah covers over 40 percent of the country, and its main products are subsistence (Table 1). This region has immense potential for commercial production, which remains almost entirely untapped. Compared to the south, the northern regions suffer from inadequate services and infrastructure that, along with the harsh climate, constrain agricultural production and keep farmers in a cycle of poverty.³³

³¹ United Nations Development Programme, "Human Development Index," 2017, <http://hdr.undp.org/en/composite/HDI>.

³² United States Department of Agriculture, "Ghana Exporter Guide," Gain Report, 2012, <http://goo.gl/ImrBSz>.

³³ World Bank, "Transforming Agriculture for Economic Growth, Job Creation and Food Security," Agriculture Sector Policy Note, June 2017, <http://documents.worldbank.org/curated/en/336541505459269020/text/119753-PN-P133833-PUBLIC-Ghana-Policy-Note-Ag-Sector-Review.txt>.

Figure 4: Agroecological Zones of Ghana³⁴



Note: Due to their agroecological similarities, deciduous and evergreen forests are treated as a single zone in this document.

Table 1: Land Area and Land Use by Agro-Climatic-Ecological Zones in Ghana³⁵

Zones	% of Area	Dominant Land Use/Crops
Savannah	64	Annual food and cash crops, livestock, millet, sorghum, cowpea, maize, yam, rice
Transitional Zone	28	Annual food and cash crops, maize, cassava rice, yam, plantains, cashew
Forest	6	Forest, plantations, annual food and cash crops cassava, plantains, cocoa, oil palm
Coastal	2	Annual food crops cassava, rice, maize, coconut

34. **Ghana has a tropical climate with significant temporal and geographic variation.** Average temperatures are consistently high throughout the country; the national monthly mean temperature

³⁴ Tiemen Rhebergen et al., "Climate, Soil and Land-Use Based Land Suitability Evaluation for Oil Palm Production in Ghana," *European Journal of Agronomy* 81 (November 1, 2016): 1–14, <https://doi.org/10.1016/j.eja.2016.08.004>.

³⁵ Aquastat, "Ghana" (FAOSTAT, 2005), http://www.fao.org/fileadmin/user_upload/aquastat/pdf_files/GHA_tables.pdf.

remains between 25 and 30°C year-round.³⁶ The north has relatively higher temperatures, with up to 200 days each year exceeding 35°C (versus 0 days per year near the coast). The north also has greater day-night temperature changes; the number of nights above 25°C range from 0 per year in the north to up to 130 per year near the coast. Rainfall is also highly variable, both geographically and temporally. Annual mean rainfall ranges from 900 mm in the north to 1,800 mm in the southwest.³⁷ In the north, rainfall occurs in one long rainy season from May to October, with ‘Harmattan’ winds from the Sahara Desert blowing in from November to February. In the south, rainfall occurs in two seasons, from April to July and September to October, with approximately 20–25 percent of total rainfall occurring in the latter part. El Niño years bring relatively drier conditions across the country.³⁸

Table 2: Land Cover Changes in Ghana³⁹

Land use	Area (km ²)		% Change
	1990	2016	
Forest	86,270	93,654	8.2
Arable agriculture	1961	2017	
	17,000	47,000	176.5
Irrigated agriculture	2005	2014	
	107	356	235.4
Pasture	1961	2017	
	84,000	83,000	-1.2
Permanent agriculture	1975	2013	
	16,000	27,000	68.8
Settlements	1,550	4,135	166.8

Note: Columns do not represent a single point in time and therefore column sums may not be equivalent.

35. **Agriculture is the main source of livelihoods and employment in Ghana.** Agriculture employs 38.3 percent of the Ghanaian workforce, supplies over 70 percent of national food demand, and contributes nearly 20 percent of national GDP.⁴⁰ As the economy has diversified, agriculture’s percentage contribution to national GDP has fallen, especially since 1983 when agriculture represented approximately 60 percent of national GDP.⁴¹ Yet, overall agricultural production has increased rapidly since the 1990s,⁴²

³⁶ D.K. Nutsukpo et al., “Chapter 6 – Ghana,” in *West African Agriculture and Climate Change* (IFPRI & CGIAR, 2012), <http://www.ifpri.org/sites/default/files/publications/rr178ch06.pdf>; Lisa Murken et al., “Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana’s Agriculture Sector” (Potsdam Institute for Climate Impact Research & Deutsche Gesellschaft für Internationale Zusammenarbeit, May 2019); Potsdam Institute for Climate Impact Research, “Climate Risk Profile: Ghana” (Deutsche Gesellschaft für Internationale Zusammenarbeit & Federal Ministry for Economic Cooperation and Development, June 2019).

³⁷ Nutsukpo et al., “Chapter 6 – Ghana”; Murken et al., “Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana’s Agriculture Sector”; Potsdam Institute for Climate Impact Research, “Climate Risk Profile: Ghana.”

³⁸ Climate Service Center, “Benin-Ghana-Togo,” Climate Fact Sheet, 2015, http://www.climate-service-center.de/products_and_publications/fact_sheets/climate_fact_sheets/index.php.en.

³⁹ Index Mundi, “Ghana - Agricultural Irrigated Land,” 2014, <https://www.indexmundi.com/facts/ghana/agricultural-irrigated-land>; Index Mundi, “Ghana - Agricultural Land,” 2014, <https://www.indexmundi.com/facts/ghana/agricultural-land>; Index Mundi, “Ghana - Forest Area (Sq. Km),” 2015, <https://www.indexmundi.com/facts/ghana/indicator/AG.LND.FRST.K2>; FAOSTAT, “Ghana,” Food and Agriculture Organization of the United Nations, 2017, <http://www.fao.org/faostat/en/#country/81>; EROS, “Land Use and Land Cover Trends in Ghana,” United States Geological Service, 2013, <https://eros.usgs.gov/westafrika/land-cover/land-use-land-cover-and-trends-ghana> Settlement numbers based on estimates from graphic presentation.

⁴⁰ CIA, “Ghana”; The World Bank Group, “Ghana.”

⁴¹ The World Bank Group, “Ghana.”

⁴² Vikas Choudhary et al., “Ghana Agricultural Sector Risk Assessment,” Note, Agriculture Global Practice (Washington DC: World Bank Group, 2016), <http://documents.worldbank.org/curated/en/412431468198000868/Ghana-agricultural-sector-risk-assessment>.

and the agriculture sector has outpaced the general economy, growing by 8.4 percent in 2017 alone.⁴³ The export of cocoa and nontraditional commodities provides a significant source of foreign exchange earnings. It is still necessary to boost agricultural production, due to the fact that Ghana remains a net importer of agricultural goods; imports are primarily composed of consumer-ready commodities, including poultry, rice, wheat, and sugar.⁴⁴

36. **Smallholders account for about 80 percent of total agricultural production in Ghana,**⁴⁵ with crops, livestock, and fisheries all contributing to Ghana’s agriculture sector. Smallholder productivity has increased in recent years and has been a significant source of national poverty reduction,⁴⁶ yet smallholder agriculture has low productivity with substantial yield gaps.⁴⁷ The country’s primary staple crops, including cassava, yam, plantain, maize, and rice, are crucial to food security (Table 3).⁴⁸

Table 3: Key Food and Commodity Crops in Ghana⁴⁹

	% of Cultivated Land	Yield (tons/ha)	Production (tons, thousands)	Food Consumption (kg/capita/day)	Kcal/capita /day
Cassava	12.6	19.1	18471	0.58	654
Yam	4.70	17.1	7953	0.31	363
Plantain	4.80	11.0	4051	0.29	351
Maize	12.10	2.0	1965	0.12	111
Rice	5.09	2.8	721	0.07	132
Fish	n.a.	n.a.	380	0.05	58
Wheat	0.02	510.0	510	0.04	145
Coconut	1.52	53,860.0	384	—	—
Cowpea	3.50	1.2	201	—	63.8*
Millet	3.55	9,996.0	167	—	55.1*
Sorghum	4.70	10,422.0	316.3*	—	95.8*
Soybean	0.50	1.6	900*	—	46.5*
Cashew	3.1	6,097.0	9	n.a.	n.a.
Cocoa	10.6	5,228.0	879.4*	n.a.	n.a.
Cotton	—	—	5	n.a.	n.a.
Oil Palm	7.02	7.0	2529.5*	n.a.	n.a.
TOTAL	74	86,174.77	38,382.50	1.47	1815

Note: Darker colors show higher values for each indicator. Data resources vary from 2014 to 2018. A dash (—) indicates no data found; n.a. is not applicable.

⁴³ Ghana Statistical Service, “Provisional 2017 Annual Gross Domestic Product.”

⁴⁴ Johannes Jansen, “Transforming Agriculture for Economic Growth, Job Creation, and Food Security,” Policy Note, Ghana Agriculture Sector (World Bank, June 2017).

⁴⁵ Bernard Darfour and Kurt Rosentrater, “Agriculture and Food Security in Ghana” (2016 ASABE International Meeting, Orlando FL: Iowa State University, 2016), <https://doi.org/10.13031/aim.20162460507>.

⁴⁶ Darfour and Rosentrater.

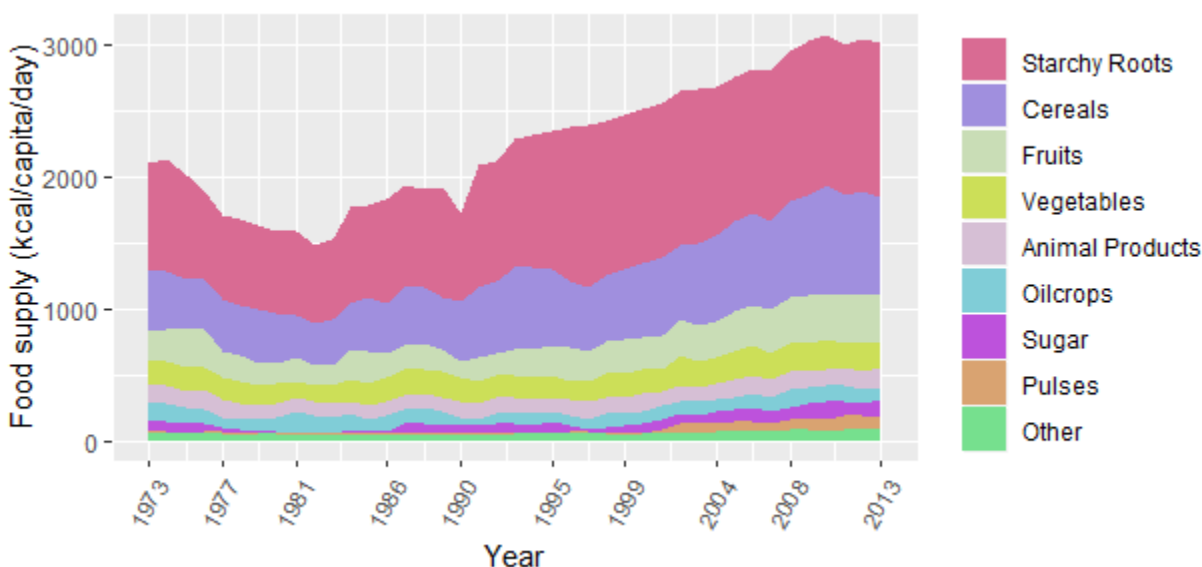
⁴⁷ United States Department of Agriculture, “Ghana Exporter Guide,” 2012..

⁴⁸ Potsdam Institute for Climate Impact Research, “Climate Risk Profile: Ghana.”

⁴⁹ Nutsukpo et al., “Chapter 6 – Ghana”; The World Bank Group, “Ghana”; Healthline, “Nutrition Facts,” 2019, <https://www.healthline.com/nutrition/cassava>; FAOSTAT, “Ghana.”

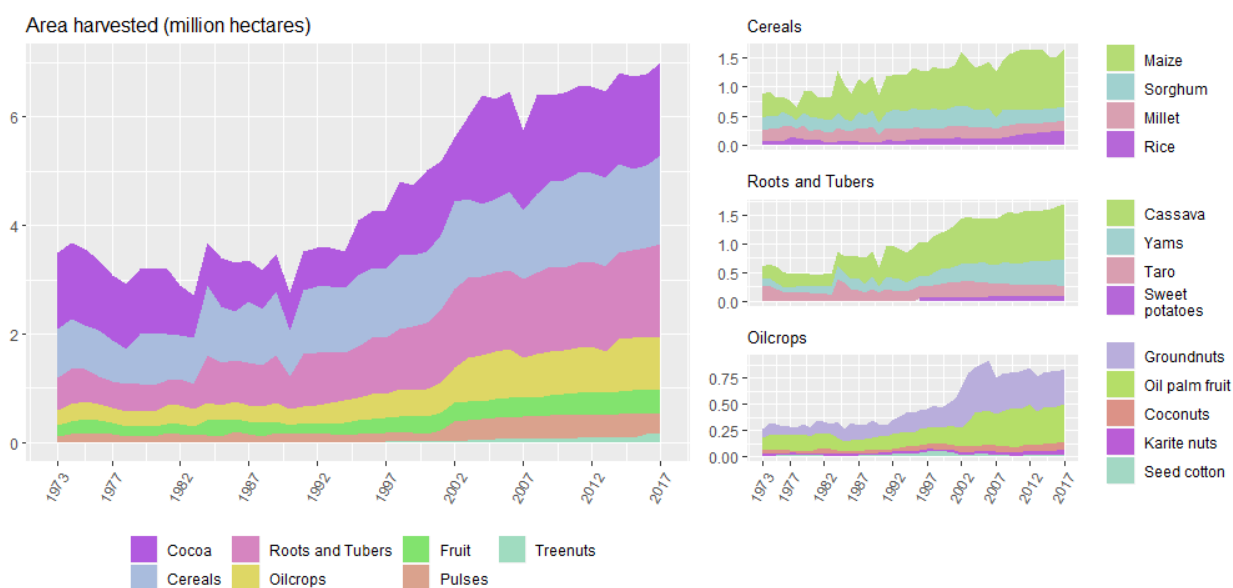
37. **Cereals and starchy roots constitute a large and increasing share of Ghana’s daily caloric intake and cultivated area (Figure 5).** Among the cereals, maize is predominant on most farms while cassava is the most prevalent of the root and tuber crops (Table 3, Figure 6). Despite domestic production, Ghana is dependent on imports to meet its internal cereal demand.

Figure 5: Calorie Consumption Per Capita Per Day in Ghana, 1973–2013, Most Recent Data



Source: FAO.

Figure 6: Harvested Area in Ghana, 1973–2017



Source: FAO.

38. **Primary agricultural commodities include cassava, yam, banana, maize, cereal, fruits, cocoa, and coconut.**⁵⁰ The main exports are cocoa, oil palm, and yam as shown in Table 4. While yams are

⁵⁰ Nutsukpo et al., “Chapter 6 – Ghana.”.

exported, they are also important domestically, and are an important source of calories in the Ghanaian diet.

Table 4: Import, Export, Production, and Total Demand for Key Commodities in Ghana⁵¹

	Export (tons, thousands)	Imports (tons, thousands)	Production (tons, thousands)	Total demand (mt, thousands)
Cassava	—	0	20845.90*	3673
Cashew	350.00*	—	110*	—
Cocoa	526	0	900*	837
Groundnuts	0.02*	0.27	521.00*	342.76
Maize	0.19*	81.71*	2,306.38*	1,429.25
Millet	0.03*	1.26*	181.56*	158.01
Oil palm	127.12	163.97	2,529.51	286.27
Plantains	0	0	4,050.63	2,422.14
Sorghum	0	0.03*	316.24*	168.18
Yam	17.28*	17.83	7,788.87*	3,570.38

Note: Darker colors show higher values for each indicator. Data resources vary from 2013 (oil palm) and 2015–17. A dash (—) indicates no data found; n.a. is not applicable

2.2 Climate Change in Ghana's Agriculture

39. **Climate change is apparent and widespread in Ghana.** Despite significant production gains in recent years, Ghanaian farmers are increasingly challenged by erratic rainfall patterns, longer periods of Harmattan, desertification, and shorter dry seasons.⁵² Coastal regions are threatened by flooding, water erosion, and waterborne disease risks. The north is an area of greater extremes (see Figure 7) with more flooding and droughts, wind erosion, temperature extremes, and loss of vegetation. Throughout the country, extreme precipitation events, droughts, and abnormal seasonal rainfall patterns are incapacitating long-held traditional weather prediction and timing practices.

40. **Ghana's agriculture is affected by erratic precipitation related to climate change, with overall trends showing declining rainfall.** Average annual and decadal precipitation has been declining significantly since the 1960s (Figure 8). Ghana is experiencing more frequent and extreme droughts and precipitation events,⁵³ and greater variability of precipitation across the country (Figure 9).⁵⁴ Extreme flooding in the north in October 2019 killed at least 28 people and destroyed 286 homes.⁵⁵ In 2015,

⁵¹ Bangmarigu Emmanuel and Artan Qineti, "Cocoa Production and Export in Ghana" (Nitra, Slovakia: Faculty of Economics and Management, Slovak University of Agriculture, 2018); S. Adjei-Nsiah and Owuraku Sakyi-Dawson, "Promoting Cassava as an Industrial Crop in Ghana: Effects on Soil Fertility and Farming System Sustainability," Research article, Applied and Environmental Soil Science, 2012, <https://doi.org/10.1155/2012/940954>; FAOSTAT, "Ghana"; Statistics, Research, and Information Directorate, "Agriculture in Ghana," Facts and Figures (Ministry of Food and Agriculture, October 2016), https://www.agrofood-westafrica.com/fileadmin/user_upload/messen/agrofood-westafrica/Brochure/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf; Index Mundi, "Ghana - Agricultural Land" Oil palm export figures includes all products and uses.

⁵² Murken et al., "Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agriculture Sector."

⁵³ Akudugu and Alhassan, "The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana."

⁵⁴ Murken et al., "Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agriculture Sector."

⁵⁵ Teo Blaskovic, "At Least 28 Killed, 286 Homes Destroyed as Severe Flooding Hits Upper East Region, Ghana," Daily News Service, The Watchers, October 18, 2019, <https://watchers.news/2019/10/18/flood-upper-east-region-ghana-october-2019/>.

flooding in Accra following a downpour left 159 people dead.⁵⁶ The 2007 floods, immediately followed by extreme drought, affected over 325,000 people.⁵⁷

Figure 7: Geographic Distribution of Floods and Droughts in Ghana⁵⁸

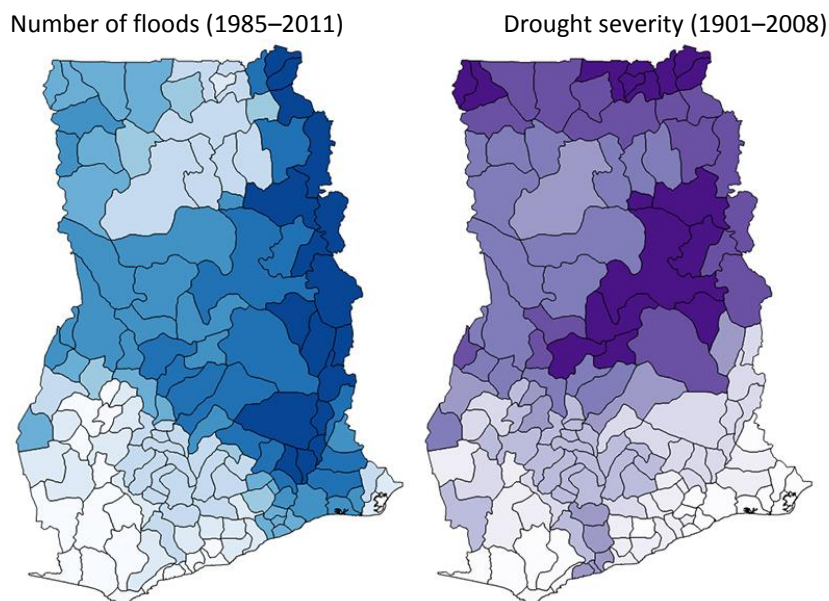
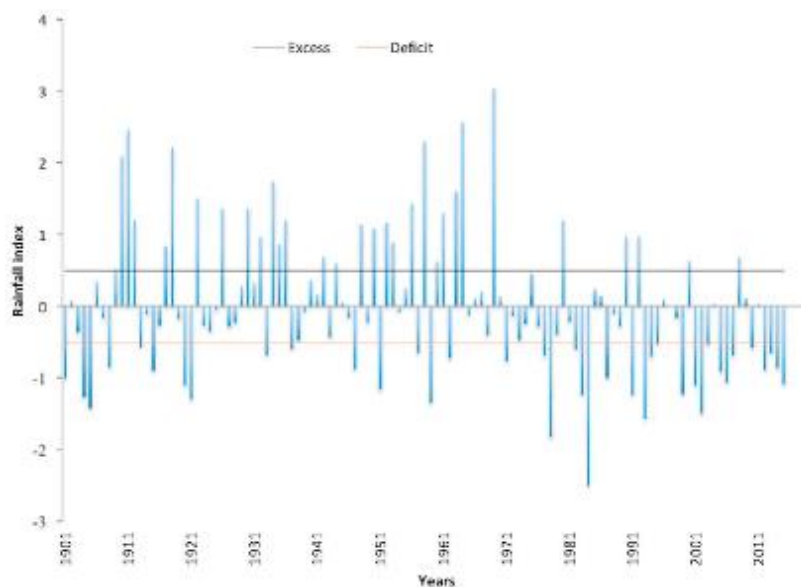


Figure 8: Annual Rainfall Excesses and Deficits Across Ghana, 1901–2014⁵⁹

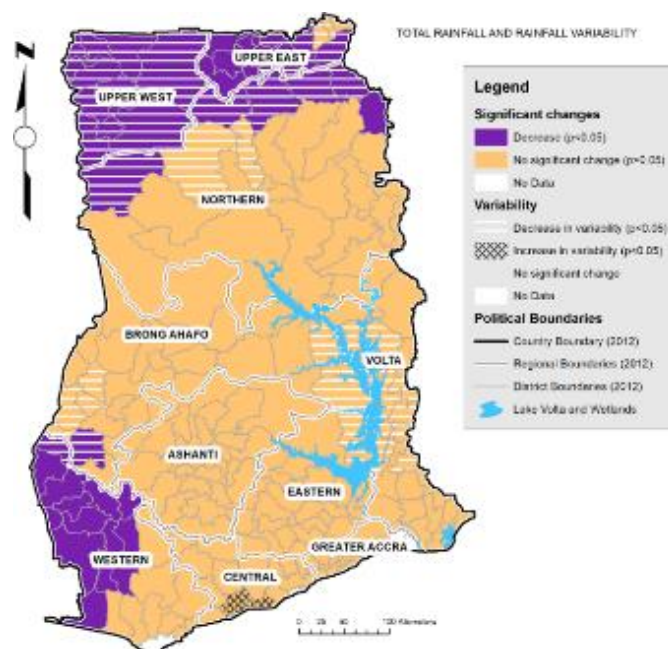


⁵⁶ Flood List, “Ghana--Accra Floods Again,” 2016, <http://floodlist.com/africa/ghana-accra-floods-june-2016>.

⁵⁷ GFDRR, “Country Program Update: Ghana.”

⁵⁸ Tanaka, Nuamah, and Geiger, “Ghana’s Challenges.”

⁵⁹ Abbam et al., “Spatiotemporal Variations in Rainfall and Temperature in Ghana Over the Twentieth Century, 1900–2014.”

Figure 9: Significant Changes in Rainfall as of 2014⁶⁰

41. **Temperatures, both average annual and decadal, have been increasing since the 1960s.** The average decadal temperature in the 1960s was 26.6°C while from 2006 to 2015 it was 27.4°C, with the greatest increases occurring in the north (Figure 10).⁶¹ The number of extreme heat days and nights increased by 13 percent and 20 percent, respectively, from 1960 to 2003, while the number of cold days and nights decreased by 3 percent and 5 percent, respectively.⁶²

42. **Ghana's current climate is the driest on record (since 1901)⁶³ and shows high geographic variability.** At the national level, the clear trend across time is toward increased temperatures and reduced precipitation (Figure 11). At the local level, extreme and unpredictable events, including prolonged droughts, violent floods, deadly heat waves, and erratic beginnings and ends to the rainy seasons, are the hallmarks of climate change impact. Distinct patterns become apparent within each of Ghana's agroecological regions (Figure 12).

⁶⁰ Abbam et al. 2018.

⁶¹ Abbam et al. 2018.

⁶² C. McSweeney, M. New, and G. Lizcano, "Ghana," Climate Change Country Profiles (United Nations Development Programme, 2010), http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Ghana/Ghana.hires.report.pdf.

⁶³ Abbam et al., "Spatiotemporal Variations in Rainfall and Temperature in Ghana Over the Twentieth Century, 1900–2014." 2018.

Figure 10: Significant Temperature Changes in Ghana Between 1900 and 2014⁶⁴

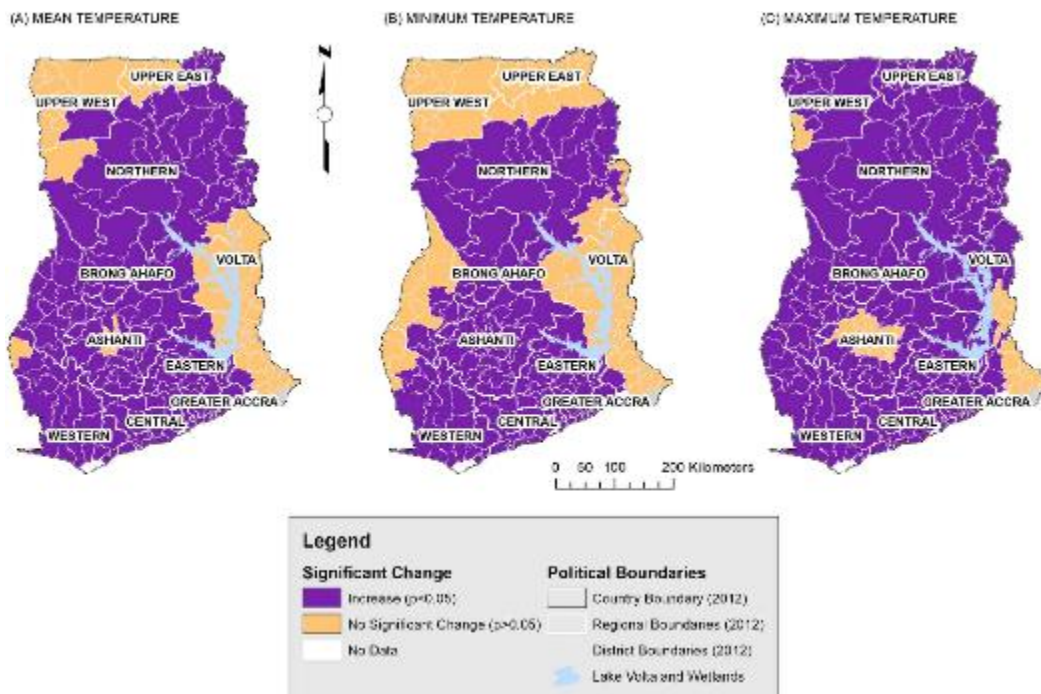


Figure 11: Mean Annual Average Rainfall and Temperature for Ghana (1901–2014)⁶⁵

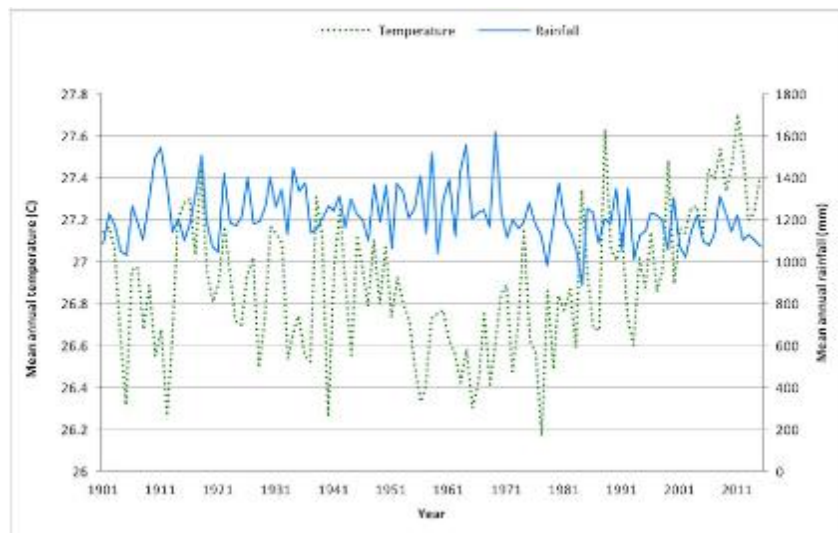
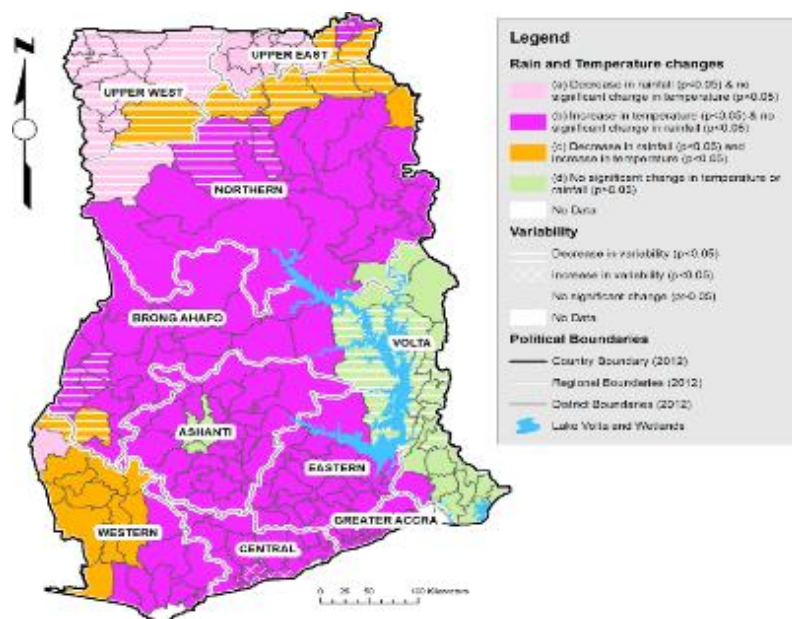


Figure 12: Significant Changes in Rainfall and Temperature as of 2014⁶⁶

⁶⁴ Abbam et al.

⁶⁵ Abbam et al. 2018.

⁶⁶ Abbam et al. 2018.



43. **The effects of climate change in Ghana will worsen. Overall, precipitation across Ghana is expected to keep declining, particularly from March to June.**⁶⁷ Projections vary widely, but a 4 percent decrease by 2040 is a commonly accepted estimate.⁶⁸ Across the country, temperature increases are expected to continue, particularly in the north, with 1.4–4.2°C increases and up to 90 percent of days exceeding 35°C by the end of the century.⁶⁹ In the north, the growing season may be shortened by delayed rains, while the temperature will increase. The north will also experience increased exposure to dust and dry winds, causing higher incidences of severe respiratory diseases, such as asthma and meningitis.⁷⁰ The frequency and intensity of extreme events, including droughts, floods, and heat waves will also increase, as will inter-annual variation.⁷¹ Coastal regions, including the capital of Accra, will face sea level rises of 13–45 cm over the next 100 years, with consequent flooding. Increased flooding will in turn increase waterborne illnesses, such as cholera and malaria, especially in coastal areas that hold densely populated temporary settlements with poor access to clean water and sanitation.⁷²

44. **The Ghanaian agriculture sector is very vulnerable to negative impacts from climate change.** High temperatures and reduced rainfall are expected to catalyze desertification, ecosystem deterioration, and concomitant losses of arable land. Higher temperatures, drought, intense rainfall, and standing water could instigate outbreaks of crop and livestock pests and diseases (see Box 1). Postharvest losses may increase due to erratic and unpredictable weather conditions.⁷³ Salinization of agricultural soils from sea level rise and tidal flooding will have detrimental impacts on productivity in coastal regions.⁷⁴ Ghana’s current low agricultural diversification intensifies its risk of crop failure. Climate change will also magnify

⁶⁷ Climate Service Center, “Benin-Ghana-Togo”; McSweeney, New, and Lizcano, “Ghana.”

⁶⁸ USAID, “Ghana,” Climate Change Risk Profile, 2017, <https://www.climatelinks.org/resources/climate-change-risk-profile-ghana>.

⁶⁹ Climate Service Center, “Benin-Ghana-Togo”; A. De Pinto et al., “Ghana Strategy Support Program: Climate Change, Agriculture, and Foodcrop Production in Ghana.” (IFPRI, 2012), <http://www.ifpri.org/sites/default/files/publications/gssppn3.pdf>; Ministry of Foreign Affairs of the Netherlands, “Ghana Climate Change Profile” (Reliefweb, April 2018).

⁷⁰ USAID, “Ghana.”

⁷¹ McSweeney, New, and Lizcano, “Ghana”; Climate Service Center, “Benin-Ghana-Togo.”

⁷² WHO and UNFCCC, “Climate and Health Profile: Ghana,” 2015, http://apps.who.int/iris/bitstream/10665/208862/1/WHO_FWC_PHE_EPE_15.08_eng.pdf?ua=1.

⁷³ Akudugu and Alhassan, “The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana.”

⁷⁴ Yaro, “Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana.”

the production vulnerability in the north, since the region is particularly hot and dry, has lower-quality agricultural lands, and is more susceptible to drought, soil erosion, and land degradation.⁷⁵

45. **Water issues will threaten Ghana's stability.** Ghana's agriculture sector is almost entirely rainfed; the country has only realized about 4 percent of its irrigation potential.⁷⁶ About 50 percent of the water used in Ghana originates from outside its borders through the rivers Volta, Bia, and Tano. Recent studies project that the Volta's flow could decline 24 percent in the next 30 years and 45 percent by 2100.⁷⁷ Ghana is already prone to droughts and extreme rain events (with rainfalls averaging just 44 mm per day) and this tendency is expected to increase over the coming years, generating significant threats of flooding, runoff, and erosion, particularly at the beginning of the rainy seasons.⁷⁸

46. **Climate change impacts on agriculture and forestry may undermine economic stability due to the importance of these sectors, with multiplier effects through Ghana's economy.** A majority of Ghanaians (70 percent) directly or indirectly depend on agriculture and forestry.⁷⁹ Ghana has made substantial investments to support the agricultural sector and agribusiness, and in 2019 it was beginning to see some growth resulting from policy reforms and investments.⁸⁰ While increased water stress and temperatures are projected to significantly reduce crop productivity in the coming decades, erratic weather could also threaten short-term gains in the sector. Cocoa is extremely sensitive to heat, drought, pests, and erosion; consequently, suitable production areas are expected to contract significantly by 2030.⁸¹ Some minor shifting in suitable production areas overall is projected; some parts of the north and east may become more suitable to cashew production.⁸² Ghana's substantial investments and policy reforms designed to bring about inclusive and sustainable growth in the medium to long term⁸³ could be undermined by climate change.

47. **Climate change could affect Ghana's political stability.** The Volta River feeds Ghana's only hydropower station, which produces 50–80 percent of the national electricity supply.⁸⁴ The predicted declines in the Volta River's flow would significantly amplify tensions with bordering countries over water withdrawal from the Volta.⁸⁵ Such tensions are likely to result in disputes over water allocation, which could worsen the effects of economic dependence on climate-susceptible crops in Ghana.⁸⁶ Desertification would push Fulani pastoralists' cattle from the dry Sahel into farming communities.⁸⁷ This might also lead to conflicts which might erode social networks, increasing societal vulnerability to climate risks.

⁷⁵ GFDRR, "Country Program Update: Ghana."

⁷⁶ Ghana Ministry of Agriculture, "Food and Agriculture Sector Development Policy (FASDEP II)," 2009.

⁷⁷ USAID, "Ghana."

⁷⁸ Nutsukpo et al., "Chapter 6 – Ghana."

⁷⁹ Jansen, "Transforming Agriculture for Economic Growth, Job Creation, and Food Security."

⁸⁰ The World Bank Group, "Ghana."

⁸¹ Yaro, "Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana.," World Bank, "Ghana Dashboard," Climate Change Knowledge Portal, 2017, http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=GHA&ThisTab=ImpactsVulnerabilities; USAID, "Ghana."

⁸² P. Laderach et al., "Predicting the Impact of Climate Change on the Cocoa-Growing Regions in Ghana and Cote d'Ivoire." (CCAFS & CIAT, 2011), http://www.eenews.net/assets/2011/10/03/document_cw_01.pdf.

⁸³ World Bank, "Enhancing Financial Inclusion," Economic Update, Ghana, June 2019, <https://www.worldbank.org/en/country/ghana/publication/ghana-economic-update-enhancing-financial-inclusion>.

⁸⁴ Dilys MacCarthy personal communication with Ghana VRA puts the figure at 50 percent; other sources give a higher estimate.

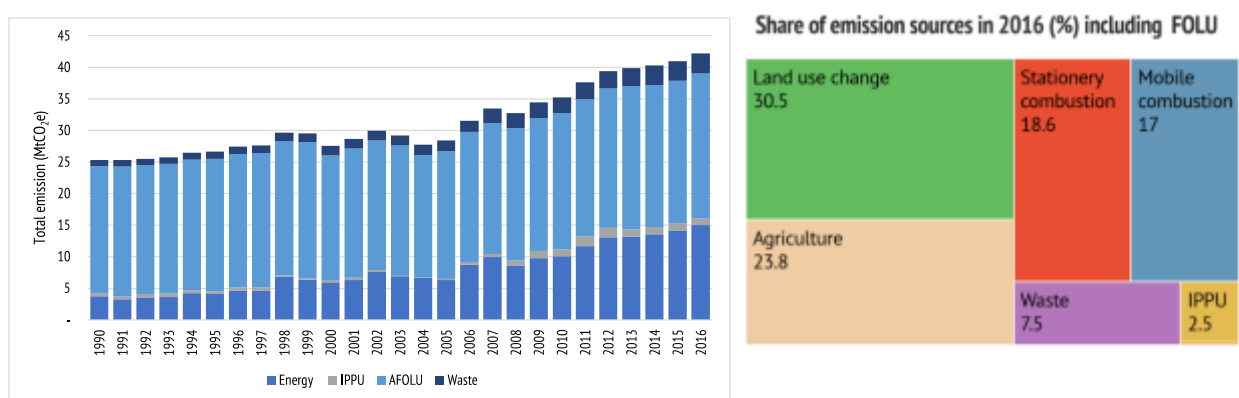
⁸⁵ USAID, "Ghana."

⁸⁶ De Pinto et al., "Ghana Strategy Support Program: Climate Change, Agriculture, and Foodcrop Production in Ghana."

⁸⁷ Akudugu and Alhassan, "The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana."

48. **Ghana contributes only 0.08 percent of global GHG emissions, ranking 151 out of 188 countries.**⁸⁸ Indeed, the country was a net consumer of GHG until the late 1990s. As of 1990, Ghana was sequestering 16.8 MtCO₂e annually (Figure 13).⁸⁹ By 2000, Ghana had become a net producer, emitting 107,700 ktCO₂e that year, or the equivalent of 0.97 tons/capita.⁹⁰ Methane and nitrous oxide—primarily from livestock enteric fermentation and inorganic fertilizers—were the top two GHG emissions until 2006, when they were overtaken by carbon dioxide from the growing energy sector. Nevertheless, energy sector emissions are declining as a result of improved technologies. Meanwhile, forest and grassland conversion rates continue to drive carbon dioxide emissions upward. Between 2017 and 2018, Ghana had the highest rate (60 percent) of increased deforestation in the world, with 70 percent of cleared forests in protected areas. Landfills, a growing livestock sector, and higher inorganic fertilizer use are also driving increases in methane and nitrous oxide emissions.⁹¹

Figure 13: GHG Emission Sources in Ghana⁹²



2.3. Climate Change Impacts on Ghana’s Food Security and Agricultural Economy

49. **Ghana is not well prepared to adapt to current and future climate change impacts.** The country ranks 103 out of 182 in climate vulnerability.⁹³ As described in this section, food security and agriculture will be challenged by climate change. Yet the country holds significant potential to develop effective climate adaptation techniques. For example, the growing agricultural sector, diverse agro-climatic zones, and significant geographic variation in crop production offer strong options for building resiliency.⁹⁴

50. **Food security will be negatively affected by the effects of climate change.** Approximately 6 percent of Ghana’s population is already food insecure (versus 16 percent of neighboring Togo)⁹⁵ and

⁸⁸ World Resources Institute, “CAIT Climate Data Explorer,” 2017, <http://cait2.wri.org/>; Actualitix, “Analysis of 2011 World Bank Dataset,” 2011, <https://en.actualitix.com/country/wld/co2-emissions-per-capita.php>; ClimateWatchData, “2020 NDC Tracker,” ClimateWatch, September 23, 2019, https://www.climatewatchdata.org/ndcs-enhancements?mkt_tok=eyJpIjoiTUxkaE5EVXpNalkwWkdNeSIsInQiOiJCVGZpZndURXBRY0VZlXhYn3pKM2hpQXBsQTh1bEFOT21NVnJHJzZ4ZWd4T0Nxd203bkNNb2lWbWkFhcWNSbjhtNktrTk11NFFzSDZhNmJya2hoazBvazFVZjUyaFdmV0VaTVArA1owVjZjbWtkQVpBSmJ1OFYzWUNCd0NZMnl2bCJ9&search=ghana.

⁸⁹ Felix Asante and Franklin Amuakwa-Mensah, “Climate Change and Variability in Ghana: Stocktaking,” *Climate* 3 (January 1, 2015): 78–99, <https://doi.org/10.3390/cli3010078>.

⁹⁰ World Bank, “Ghana Dashboard,” 2017; Environmental Protection Agency, “Ghana’s Fourth National Greenhouse Gas Inventory Report” (United Nations Framework Convention on Climate Change, February 2019).

⁹¹ Asante and Amuakwa-Mensah, “Climate Change and Variability in Ghana.”

⁹² Environmental Protection Agency, “Ghana’s Fourth National Greenhouse Gas Inventory Report.”

⁹³ NDC Support Programme, “NDC Facts,” UNDP, Ghana, 2018, <https://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/africa/ghana.html>.

⁹⁴ Murken et al., “Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana’s Agriculture Sector.”

⁹⁵ The World Bank Group, “Ghana.”

highly susceptible to further impoverishment. A 1°C rise in temperature represents a 4 percent reduction in real food consumption for the average adult.⁹⁶ Northern Ghana will feel the greatest climate change impacts, so people in there will likely suffer an outsized impact given poverty and limited access to alternative livelihoods. Increases in the hot, dry climate and decreases or changes to the mono-modal rainfall pattern will likely result in major crop losses and long hunger seasons. Total crop failure due to delayed rains or reduced total rainfall is projected to occur approximately once every five years in northern Ghana.⁹⁷

51. **While analyzing the impacts of climate change on biophysical suitability, most analyses hold management and technology constant at the current levels.** For example, some studies indicate that by 2050, cassava yields are expected to decline by 13.5 percent, yam by 30 percent, maize by 15 percent, and rice by up to 25 percent,⁹⁸ while groundnut yields in the south are estimated to increase by about 25 percent.⁹⁹ In reality, ongoing investments in agricultural research are not likely to completely stagnate. Farmers also exercise adaptive agency—intentionally switching to an improved variety or an alternative crop, changing levels of inputs or farming methods, and otherwise actively responding to shifting economic incentives induced by climate change. These techniques may bolster the resiliency of farmers, and the agricultural sector as a whole, to climate change.

52. **IMPACT modeling of climate change (see Annex D) shows it will negatively affect the yield of all staple crop groups, in both the medium and long term, under a variety of socioeconomic and representative carbon concentration scenarios.** Projected yields are shown for two scenarios and for two time periods in Table 5. Most cereals, especially maize, exhibit high vulnerability to climate change no matter what scenario is picked, from losses of 8–11 percent in 2030 to over 16–21 percent in 2050 compared to a no-climate change baseline. For other cereals, millet and sorghum show relatively smaller declines in the short term, but both have losses of around 4–6 percent by 2050. Rice, also a cereal, shows the lowest declines across all scenarios and time periods, remaining under 3 percent yield reductions from the baseline (Table 5).

53. **Cocoa, vital to Ghana’s economy, also exhibits considerable vulnerability,** with losses around 3 percent in the short term (2030) but up to 5–7 percent by 2050. Oil palm and its fruit, also a tree crop, shows impacts that are quite similar to cocoa. Plantains also fare poorly, although they do better than cocoa or oil palm. Groundnuts also show relatively steep losses in both the short and long term, from 3–4 percent in 2030 to 6–7 percent in 2050 based on IMPACT modeling. Note that the results from IMPACT may vary from other models, since IMPACT includes economic, demographic, and trade (among other factors) along with climate factors and crop responses. On a positive note, roots and tubers, such as cassava and yams, exhibit relative resilience under climate change modeling.

54. **Cultivated area is projected to be higher for most crops under climate change than under a no-climate change reference scenario.** This is not necessarily a good thing, as Ghana’s agricultural frontier has roughly doubled since the 1980s, resulting in high levels of forest clearing to meet the demand for farmland, even where the agricultural suitability is low. Accordingly, CSA practices that improve

⁹⁶ Prince Maxwell Etwire, “The Economic Impact of Climate Change on Farm Decisions and Food Consumption in Ghana” (Thesis, University of Otago, 2018), <https://ourarchive.otago.ac.nz/handle/10523/8413>.

⁹⁷ USAID, “Ghana.”

⁹⁸ J. Olesen, N. Chirinda, and S. Adiku, “Climate Change Impacts on Crop Productivity and Possible Adaptations in Ghana,” *Ghana Policy Journal Edition on Climate Change*, 2013, <http://dspace.africaportal.org/jspui/bitstream/123456789/34938/2/gpj-v5-n4.pdf?1>; R. Segoe, “Climate Change and Root Crop Production in Ghana” (EPA, 2006), http://www.nicap.net/fileadmin/NCAP/Countries/Ghana/ROOT_TUBERS_DRAFT_FINAL_REPORT.pdf.

⁹⁹ De Pinto et al., “Ghana Strategy Support Program: Climate Change, Agriculture, and Foodcrop Production in Ghana.”

intensification, in turn reducing land conversion and forest clearing, directly contribute to mitigation. Under both high- and low-emission scenarios (Table 6), groundnuts and palm oil have the greatest harvested area expansion, in both the short and long term, even though climate change will result in lower yields. Pulses will have a large decline and there will also be declines in vegetables. The area for rice is expected to expand—a positive development given its yield resilience to climate change. The IMPACT model also shows a decline in the overall cocoa area, in all scenarios and all time periods.

Table 5: IMPACT Analysis: Percentage Difference in Ghana Rainfed Yield

Percent Difference from No Climate Change Scenario	Yield			
	Low emissions		High emissions	
	2030	2050	2030	2050
Crop				
CER-Maize	-7.99	-15.55	-10.82	-20.73
CER-Millet	-1.91	-3.87	-3.04	-6.04
CER-Rice	-1.25	-2.60	-0.80	-1.71
CER-Sorghum	-1.88	-3.78	-3.13	-6.19
COT-Cacao	-3.33	-6.59	-2.80	-5.49
COT-Other	-1.85	-3.75	-1.29	-2.64
F&V-Plantain	-2.73	-5.43	-2.00	-4.00
F&V-Vegetables	-3.84	-7.84	-3.18	-6.51
OLS-Groundnut	-3.70	-7.34	-2.99	-5.87
OLS-Other Oilseeds	-2.87	-5.44	-3.60	-6.44
OLS-Palm Fruit	-3.66	-7.23	-3.17	-6.19
PUL-Other Pulses	-3.25	-6.43	-2.79	-5.41
R&T-Cassava	-1.25	-2.42	-0.70	-0.99
R&T-Other Roots	-1.63	-3.25	-1.05	-2.07
R&T-Yams	-1.06	-2.07	-0.50	-0.93

Note: Table shows differences in relation to a no-climate change reference scenario for 2030 and 2050, under high and low carbon emission scenarios (different representative carbon concentration scenarios), with BAU demographic and economic growth trajectories (SSP2) (see Annex D for methods)

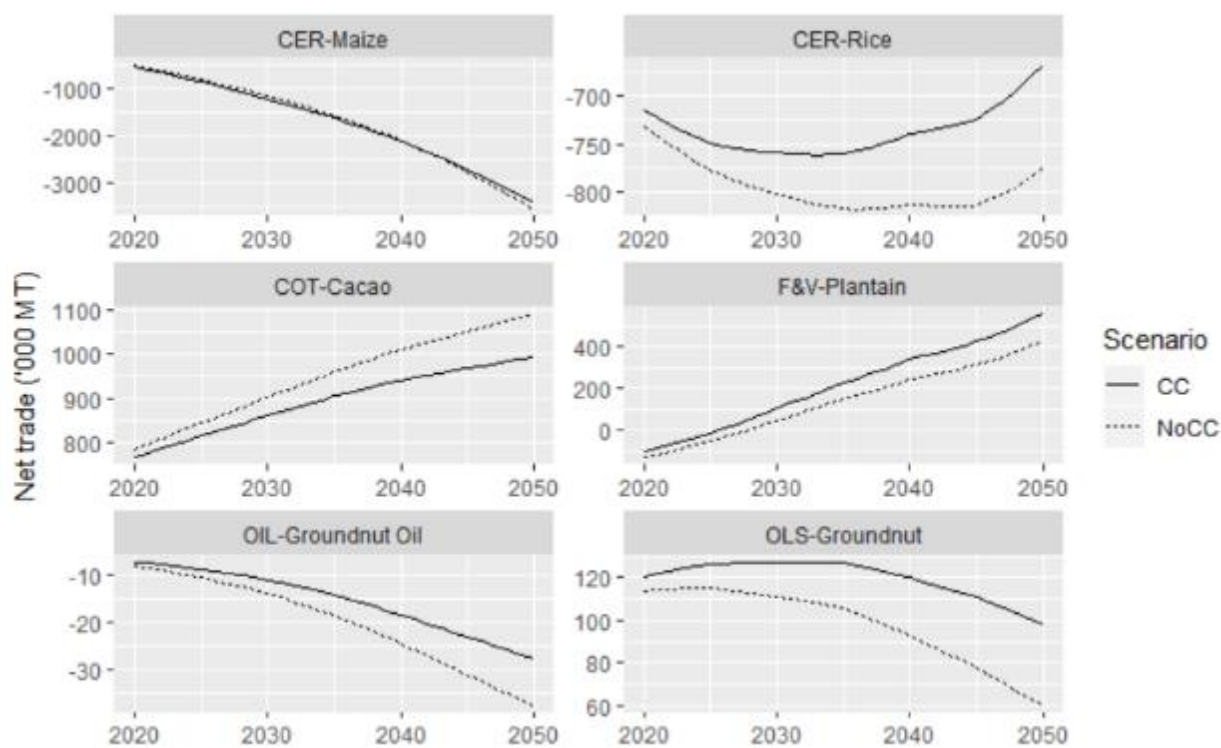
55. **Climate change will affect Ghana’s comparative trade advantage for different crops.** Climate change suitability and yield across countries also affects the complex international interplay of socioeconomic factors. Ghana’s rice, groundnut oil, and groundnut imports may decline (see Figure 14), as more of these crops are produced internally. The steepening trade deficit in maize shows little change under climate change scenarios. Ghana may also have a fledgling comparative advantage in plantain. On the **other** hand, climate change is projected to have a negative impact on Ghana’s comparative advantage in cocoa.

Table 6: IMPACT analysis: percentage difference in Ghana rainfed crop area.

Percent Difference from No Climate Change Scenario	Area harvested			
	Low emissions		High emissions	
	2030	2050	2030	2050
Crop				
CER-Maize	0.12	-0.36	0.60	0.25
CER-Millet	0.60	0.93	1.29	2.30
CER-Rice	1.19	2.29	1.81	3.63
CER-Sorghum	0.82	1.53	0.66	1.23
COT-Cacao	-0.05	-0.06	-0.03	-0.03
COT-Other	-0.74	-1.73	-0.55	-1.38
F&V-Plantain	0.93	1.91	1.31	2.56
F&V-Vegetables	-1.90	-4.03	-1.62	-3.49
OLS-Groundnut	3.26	7.06	4.28	9.35
OLS-Other Oilseeds	0.58	1.76	-0.13	0.33
OLS-Palm Fruit	2.15	4.20	2.16	4.18
PUL-Other Pulses	-8.19	-16.19	-8.91	-17.19
R&T-Cassava	0.35	0.79	0.27	0.72
R&T-Other Roots	0.20	0.50	0.35	0.80
R&T-Yams	0.38	0.90	0.38	0.92

Note: Table shows difference over a no-climate change reference scenario for 2030 and 2050, under high and low carbon emission scenarios (different representative carbon concentration scenarios), with BAU demographic and economic growth trajectories (SSP2).

Figure 14: IMPACT Analysis: Net Trade Projections to 2050. SSP2 RCP 8.5



2.4. The Potential for Digital Agricultural Solutions in Ghana

56. **Digital agriculture presents a new portfolio of potential solutions to the current challenges in agricultural systems.** Digital agriculture is the use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders to improve their products and processes.¹⁰⁰ Digital solutions can improve agricultural efficiency and resiliency by reducing financial and labor costs, providing timely decision-support information, decreasing losses, improving quality, supporting sustainable use of resources, and increasing productivity. The emergence of digital agricultural solutions presents a unique opportunity to spur sustainable economic growth and development.

57. **Digital agriculture innovations may target input suppliers, producers, distributors and consumers (that is, everyone between the producer and the consumer).** Some digital solutions serve as a broader cross-cutting framework, with multiple applications across various stakeholder groups. Regardless of the target stakeholder group, the positive effects of digital solutions tend to ripple throughout the value chain.

58. **Robust network infrastructure and affordable services and hardware (for example, mobile phones) are crucial prerequisites to digital solutions.** Ghana has invested heavily in network readiness in recent years, and the progress is apparent. Continuing this momentum will make Ghana's position stronger in implementing digital innovation. Ghana ranks 102 out of 139 on the Networked Readiness Index, ahead of neighboring Côte d'Ivoire but behind South Africa (67) and Rwanda (80).¹⁰¹ The country ranks 116 out of 176 on the 2017 Information Communication Technology Development Index with a score of 4.05, putting it in seventh place among African countries. Although this is an improvement on its 2016 score of 3.88, Ghana's rate of progress was relatively low compared to other countries. As such, the country's rank fell three places from 113 in 2016.¹⁰² While mobile connectivity has become widespread, internet costs remain high. The cost of 1 GB of data is about 2 percent of gross national income (GNI) per capita.¹⁰³

59. **As of 2017, there were 139 mobile subscriptions per 100 inhabitants.** This indicates that approximately 39 percent of individuals hold multiple subscriptions, typically representing an effort on the part of the individual to augment their coverage area or take advantage of improved rates when communicating with contacts across various service providers. Mobile subscription over-saturation tends to decline as coverage improves and costs decline. Of these mobile subscriptions, just over half (71 out of 139) are internet-enabled, mobile-broadband subscriptions. About 35 percent of Ghanaians use the internet.¹⁰⁴

60. **The most promising cross-cutting foundational technologies for Ghana's agricultural sector include big data, machine learning, remote sensing, Global Positioning System (GPS), barcoding, and blockchain.** Digital solutions for individual stakeholder groups will integrate with and rely on these foundational technologies to various degrees. For individual stakeholder groups, promising near-term solutions include SMS/IVR technology for delivering basic mobile money and information services, including weather and extension services.¹⁰⁵ Close collaboration with mobile service providers to ensure

¹⁰⁰ United Nations, "Digital Agriculture: Feeding the Future," Project Breakthrough, 2019, <http://breakthrough.unglobalcompact.org/disruptive-technologies/digital-agriculture/>.

¹⁰¹ World Economic Forum, "Networked Readiness Index," Global Information Technology Report 2016, 2016, <http://wef.ch/29cCKbU>.

¹⁰² International Telecommunication Union, "Global ICT Development Index," ITU, 2017, <https://www.itu.int/net4/ITU-D/idi/2017/index.html>.

¹⁰³ Alliance for Affordable Internet, "Affordability Index," 2019, <https://a4ai.org/affordability-report/data/>.

¹⁰⁴ International Telecommunication Union, "Global ICT Development Index."

¹⁰⁵ The World Bank Group, "Agriculture Observatory."

ease of use and transparency of costs is crucial to the success of such initiatives. The development of smartphone-adapted financial and information services, as well as peer network platforms (for example, knowledge sharing, marketing), can also begin in this timeframe. In the medium term, as foundational technologies improve, advanced solutions for larger farms can begin to come online, including precision farming, digitized farm records, secure certification systems, barcode product tracking, and GPS-equipped transportation. Finally, in the long term, the aforementioned services should become widely accessible to smallholders, particularly digitized farm records, which improve access to finance services by creating a credit history. Blockchain-enabled ‘trustless’ smart contracts and internet of things (IoT) capability will become feasible as technology systems become more robust.

61. In addition to network and hardware access, digital solutions face barriers in human capacity and resources. At the user interface, low literacy and digital literacy rates prevent full use of services; an outsized percentage of vulnerable populations—generally female and minority producers—are affected by literacy barriers. Low digital literacy also negatively affects the system level as decision-makers who have low understanding of how digital innovations might work are very unlikely to consider them as potential solutions. At the provider level, there is a dearth of qualified individuals to design, launch, and maintain service platforms, as well as to produce content for release via the platform. This challenge is further aggravated where many languages are spoken.

62. In the short term, these challenges can be addressed by integrating literacy and digital literacy components into programming, with an emphasis on gender-responsiveness and meeting stakeholders at their current level of capacity. These efforts should target producers as well as local and national decision-makers who have the power to bring digital innovations into solution development. In the medium term, training and deployment of national-level teams for design, launch, and maintenance of service platforms will be crucial. Simultaneously, building digital literacy into all levels of education will help minimize current digital literacy gaps and build long-term national capacity for innovating digital solutions.

2.5. Climate Change Impacts and Ghana’s Overall Risk and Resilience

63. A fundamental transformation of Ghana’s agricultural sector is needed to address the risks and challenges that climate change poses to food security and the overall agricultural sector. While this CSAIP focuses directly on the three CSA pillars, there are strong co-benefits offered by the proposed investments to help mitigate other risks and build resilience across multiple sectors. Many of the challenges posed by climate change affect multiple sectors and there are strong links across sectors and scales to mitigate risks and build resilience. A comprehensive analysis of all the ways this CSAIP supports risk and resilience would be extensive, but it is worth presenting a framework for considering how to view the proposed investments and their potential links with other sectors to build broader resilience.

64. Evidence shows that risks from climate change are increasing, as presented earlier in this chapter. However, the frequent prevalence of shocks, which in a fleeting moment seem to reduce all progress that has been made, is even more significant for poor rural farmers and countries. Actions to adapt to climate change, the very actions supported by CSA, provide positive ripples across the agricultural investment landscape and deal with some of these other shocks and risks. It is also important to differentiate between early interventions, designed to prevent potential risks from having an impact, and responses to risks. The CSA portfolio of actions constitutes an ex ante intervention; it takes stock of what the problems are and identifies solutions before potential problems turn into larger risks or shocks. By increasing stability for farmers and markets, even as climate change increases volatility, CSA supports

resilience. Box 2 provides a few examples of how to intentionally build on these synergies and co-benefits for increased resilience. The list is not intended to be complete but to provide a few examples of the overlaps of resilience between examples of CSA investments and how it provides resilience co-benefits to other categories of risks.

Box 2: Agricultural Risks¹⁰⁶ and Examples of Potential CSA Actions and Synergies with Other Sectors

Production Risks: Related to climate and weather (including drought, floods, extreme or erratic rainfall and changed timing of rain; temperature and heat extremes; wind and sandstorms); natural disasters; crops losses to wildlife; forest fire and bush fire

CSA Actions: While CSA cannot stop climate change (although it does help mitigate it), the on-farm context and trends for investments can be clearly analyzed in a site-specific way, using state-of-the-art trend data and information. This information on localized climate, changes in rainfall, likelihood of temperature increases provides a basis for minimizing management and operational risks.

Resilience Co-Benefits: In many local areas, access to sound information for disaster management planning is not available. Access to the information on climate extremes used for CSA can help with disaster mitigation planning for infrastructure, flood escape routes, windbreaks, firebreaks and other actions. It can also help identify how patterns have changed to so that other sectors (for example, schools) can decide if calendars should be shifted to reduce children’s exposure to extreme events, for example, rain.

Management and Operational Risks: Poor information for decision-making leading to forecast and planning errors; inadequate seeds; low awareness of optimal inputs; agricultural pests and disease; lack of preparedness for dealing with changes affecting production

CSA Actions: Farmers rarely have adequate access to seeds or animal stocks that are identified as being climate resilient. They often use what is available, or their best guess. Farmers also lack real-time information, such as that provided by the World Bank’s Agriculture Observatory, to know the right time to plant. CSA introduces the appropriate seeds, inputs, and the set of actions needed to maximize gains for productivity, adaptation, and mitigation.

Resilience Co-Benefits: Studies have shown that even farmers who are not project beneficiaries often adopt some or all new approaches. Also, broad use of new crops, aligned with integrated pest management (IPM), can reduce overall use of and exposure to pesticides. Better farm management and productivity lead to better overall household income and nutritional status, reducing childhood malnutrition and stunting while increasing disease resistance.

Personal Risks: Undernourishment; human health impacts caused by agriculture (for example, pesticide exposure); human disease, especially zoonotic, directly harming people or causing labor loss; security risks; displacement (for example, due to rising sea levels); political or social instability

CSA Actions: All projects increase productivity, supporting food security and improving human health. They all support poor farmers and help provide resilience against COVID-19 or other EIDs by supporting nutrition, jobs, and health across largely in rural areas. Some project interventions will reduce conflicts between pastoralists and farmers with livestock by improving forage supplies. Others support efforts to provide greater safety for women and children and reduce the number of hours spent collecting water or fuelwood.

Resilience Co-Benefits: Both OneHealth and EcoHealth approaches can easily be blended into capacity building, extension, and digital agriculture activities. Monitoring the health of livestock, poultry, and people can become part of the information flow used to pinpoint the spread of EIDs, zoonotic spread, and weather conditions, such as drought. These can be linked to develop an early warning and response capacity.

Financial Risks: How farms are financed, including obligations, loans, credit repayment, and insurance

CSA Actions: Many CSA interventions would not be possible without supported funding. In some cases, the on-farm costs of equipment are too high for individuals and credit is impossible to obtain, meaning that even innovative farmers cannot adopt new practices or try new crops because of the lack of support. The possibility of having 1.7 million beneficiaries with enhanced capacity to undertake on-farm activities will likely have broader effects through their households and communities.

¹⁰⁶ Jaffee, Siegel, and Andrews, 2008; Komarek, De Pinto, and Smith, 2020.

Resilience Co-Benefits: Private sector involvement with small farmers is often low, because no one wants to deal with the up-front costs. But without investment, it is hard to create the volume of products necessary to make vibrant value chains, so the multiplier effects of strong production do not happen. CSA investments act as an incubators or start-ups by creating sufficient capacity and supply for private sector involvement. Financial mechanisms such as farm insurance are essential to helping farmers build resilience.¹⁰⁷

Market Risks: Price, cost and market uncertainty related to international trade, major crises, or protectionism; price shocks from energy; input/energy price fluctuation; changes in inputs or outputs

CSA Actions: All investment priorities in these portfolios have been assessed by IMPACT, which considers several market risks and provides decision support based on low competitive risk for success.

Resilience Co-Benefits: Products for export, could, if trade shocks (such as economic problems or borders closed by EID or conflict) occurred, be consumed in-country. CSA investments improve what already exists: building on strong in-country knowledge of existing crops and commodities and demand helps counter future market uncertainty and risk. Also, stronger in-country production and diversification supports both rural producers and urban consumers in the case of potential shortages because exports are stopped, civil unrest, and so on.

Processing, Logistics, Operational Risks: Sanitation and processing problems; human illness; contamination and food safety issues; contaminating processing facilities; changing transport, energy, infrastructure, or service flows

CSA Actions: A key action is improving the phytosanitary conditions for food processing, with special attention in investments that deal with livestock, fisheries and aquaculture, or protein. These improvements support local confidence in food safety, and reduce the spread of potential diseases while creating new jobs, especially as food is moved from rural to urban areas.

Resilience Co-Benefits: Bushmeat frequently moves from rural to urban centers and may be processed in the same places as livestock. EcoHealth approaches can reduce the human disease burden, from extant concerns (for example, worms) to reducing the possibility of serious zoonotic infections (for example, Monkeypox). Monitoring on-site can also identify the source of disease origin, detecting, for example, an outbreak of bovine tuberculosis.

Institutional Risks: Policies or institutional changes; government or informal institutions (for example, producer cooperatives); enabling environment; civil unrest or conflict; implementation risks, uncertainty over fiscal and tax policies

CSA Actions: CSA priorities are defined by in-country expert stakeholders and have gone through multiple reviews both within and outside the country. They are driven by the demand of countries to transform their agricultural sectors, and they are produced with input from government officials representing different ministries and agencies. The CSAIP identifies policy gaps and barriers to implementation, as well as coordination issues to be addressed. In endorsing these proposals, governments gave definite paths forward to improve the institutional and policy context for CSAIP investment.

Resilience Co-Benefits: The World Bank assesses how easy it is to engage in agriculture in different countries, synthesizing a variety of factors from seed supplies and sustaining livestock to protecting plant health to finance, in *Enabling the Business of Agriculture*.¹⁰⁸ The information presents indicator scores that benchmark countries against regulatory good practices that affect farmers. CSAIP actions will engage in policy discussions, and implementation, and it is likely that they will provide leverage to support doing business in the agricultural sector.

65. **By enhancing production/productivity, adaptation/resilience and mitigation to climate change, CSA supports a wide range of co-benefits to reduce other risks and build overall resilience within the agricultural sector.** During the design phase, a strategic assessment of co-benefits and the relevant actors

¹⁰⁷ Adzawla et al, 2020.

¹⁰⁸ World Bank 2019b.

can be used to identify which of the co-benefits are most valued, which are the easiest to implement, and which have the most impact. The current global challenge presented by COVID-19, while terrible, opens the door to push for strategic investments that will support recovery efforts, and minimize future risks to Ghana.

CHAPTER 3: ASSESSING PRIORITIZED INVESTMENTS FOR CLIMATE-SMART AGRICULTURE PORTFOLIO IN GHANA

66. **The long list of 22 investments was reduced to 9 investments for Ghana at a priority-setting workshop.** Participants used an iterative, qualitative, and quantitative prioritizing process to review each of the 22 initial proposals. Specifically, eight clusters of criteria were used to identify the nine final investment priorities (see Annex C). These criteria are:

- (a) **On-farm value:** economic; nutritional; food security
- (b) **CSA smartness:** productivity; resilience; mitigation
- (c) **Investment objective:** growth in a new sector; resilience in a crop/sector that is already important
- (d) **Boosting agriculture:** agriculture value diversification; infrastructure and connectivity
- (e) **Climate risks, climate mitigation, and productivity:** addresses key climate risks; increases agricultural productivity; provides and builds resilience to climate risks; reduces GHG emissions (absolute emissions or emissions intensity)
- (f) **Finance and private sector engagement:** improve access and affordability of finance for CSA; improves competitiveness of the agriculture sector through infrastructure, incentives, and other means; provides private sector investment and business opportunities (including public-private partnerships [PPPs]); long-term sustainability of investment and adoption of interventions
- (g) **Policies and institutions:** align with national CSA policies; improves institutional capacities (economic, financial, natural resource management, and local government); engages and

strengthens farmer networks/organizations; improves extension (public and/or private); improves research and development to support CSA.

- (h) **Social benefits and safety nets:** provides job creation opportunities; enhances gender equity and engages the youth; protects the poor and vulnerable through social safety nets; improves access to clean water and sanitation

67. **Names used in this report, especially in tables, have been shortened from the names identified at the prioritizing workshop.** Investment titles were simply too long to easily fit in a table, so for the purposes of this CSAIP, names are often shortened (as shown in Table 7), so that ‘Climate-Resilient Ruminant Production and Genetic Resource Conservation’ appears as ‘ruminant production’. Use of these shorter names does not detract from the fact that they represent from the full names or practices to support CSA; the shorter names are needed for the tables and simplicity.

Table 7: Complete and Shortened Names of Proposed Project Investments

Full Name	Short
Knowledge systems and advisory services supporting climate-smart agriculture	KNOWLEDGE AND ADVISORY
Integrated water resource management for rice	WATER MANAGEMENT
Cereal-legume integration	CEREAL-LEGUME INTEGRATION
Climate-smart cocoa production	COCOA PRODUCTION
Climate-smart poultry	POULTRY PRODUCTION
Climate-resilient ruminant and genetic resource conservation	RUMINANT PRODUCTION
Sustainable fisheries and aquaculture	SUSTAINABLE FISHERIES & AQUACULTURE
Diversified tree crop	TREE CROP PRODUCTION
Roots and tubers-livestock integration	ROOT-TUBER-LIVESTOCK

68. **All of the prioritized investments include both cutting-edge and proven technologies and practices for CSA (Table 8 and Table 9).** Each of the nine priority investments was selected based on the criteria given above, and for their importance either to Ghana as a whole, or to the specific region where they would be implemented. The investment packages are shown in Table 7. Table 8 shows the investments, their importance to Ghana, and assumptions of what would happen without the projects.

Table 8: Final List of Prioritized CSAIP Investments

CSA Investment	CSA Investment Package	Commodities	Location
1. Knowledge systems and advisory services supporting CSA	Supporting evidence-based research, extension agents, and information and communication technology (ICT) advisory services	All crop commodities, fish, and livestock	National
2. Integrated water resource management for rice	Irrigation facilities and water management for rice	Focused on rice, with possible expansion to other commodities	National
3. Cereal-legume integration	Improving crop varieties (heat- and drought-tolerant, disease-resistant); soil fertility management	Maize, sorghum legume	Coastal savannah; savannah
4. Climate-smart cocoa production	Improving cocoa growing area suitability; planting new resilient cocoa strains (heat- and drought-tolerant, disease-resistant);	Cocoa	Forest; transitional

CSA Investment	CSA Investment Package	Commodities	Location
	replacing old trees; cocoa IPM; integrated soil fertility management		
5. Climate-smart poultry	Improving poultry feed and manure management; enhancing genetic resources	Chicken, guinea fowl	Transitional; savannahs; forest
6. Climate-resilient ruminant and genetic resource conservation	Introducing water harvesting technologies; irrigation for growing feed; establishing fodder banks, grazing, and watering pathways for livestock; improving breed varieties (heat stress- and disease-resistant)	Cattle, sheep and goat	Transitional; savannah; forest
7. Sustainable fisheries and aquaculture	Introducing heat- and disease-resistant fish varieties; improving feed for aquaculture; culture-based fisheries	Tilapia, catfish, shrimps, mussels, and clams	Transitional; coastal savannah, forest
8. Diversified tree crop	Agroforestry; improving tree crop varieties (heat- and drought-tolerant, disease-resistant); integrated soil fertility management	Cashew, oil palm	Forest; transitional
9. Roots and tubers-livestock integration	Improving crop varieties and livestock species (heat- and drought-tolerant, disease-resistant); integrated soil fertility management	Roots and tubers (cassava and yam)	Coastal savannah; transitional; savannah

Table 9: Investments, Their Importance, Scenarios, and Objectives

Climate Impact	Project Importance	Scenario WITHOUT Investment	Scenario WITH investment
Knowledge systems and advisory services supporting CSA			
Resilient	Foundational: leverage all CSA objectives to transform knowledge and extension by creating two-way information flow to identify emerging problems	Farmers make short-term decisions when facing uncertainty or high risk, perpetuating the poverty cycle, degrading resources, and increasing vulnerability. Local knowledge is less helpful with sudden shocks from climate or other factors.	Strong flow of good information on CSA suite of interventions supporting improved practices and productivity. Awareness and demand are driven by project. Project supports OneHealth, allows early action for pests, drought, and so on.
Integrated water resource management for rice			
Resilient	Shows links for managing water and crop production (rice)	Rice imports increase while prices increase globally; environmental resources continue to be degraded while water scarcity increases; crop failure.	Efficient water capture and management allows Ghana to use rice resilience to meet its own demand and possibly to export rice.
Cereal-legume integration			
Highly vulnerable	Optimize existing cereal-legume farm practices to increase yields and improve soils	In 10 years, maize yields drop 8–11%; millet and sorghum drop 2–3%; soil degradation reaches critical levels, forcing people to move and clear land, increasing emissions.	Cereals are resilient; productivity increases; groundnut exports are supported; there is a 40% yield boost to 200,000 farm families; diversified on-farm crops increase resilience to shocks.
Climate-smart cocoa production			
Vulnerable	Transform a well-established sector with CSA practices to reverse declining yields	Old trees and climate impacts lead to yield declines; continued deforestation exacerbates climate impacts, causing additional yield declines.	Sector is transformed by climate-resilient practices that reduce encroachment on forest areas & boost yields.

Climate Impact	Project Importance	Scenario WITHOUT Investment	Scenario WITH investment
Climate-smart poultry			
Vulnerable	Make sector climate-resilient; create jobs; lower costs & sale prices; reduce imports; improve phytosanitary conditions and monitoring	Climate-related diseases, heat, and feed costs accelerate sector shut-down; the native, resilient stock is ignored, and Ghana becomes reliant on imports; potential for avian disease vectors increases.	Resilient domestic poultry sector provides jobs, income, and protein while reducing import demand and meeting demand for local poultry. Mitigation benefits are achieved, and value chains are increased.
Climate resilient ruminant and genetic resource conservation			
Vulnerable	Make sector climate-resilient; to augment food security & income, build economic sector; monitor ruminant health.	Reduced productivity as feed sources decline while heat stress and mortality increase. Pastoralist-smallholder conflict increases as does reliance on bushmeat.	Crop-livestock integration and resilient breeds with improved health boosts productivity for income and consumption, enabling climate resilience; established water sources and corridors reduce conflict.
Sustainable fisheries and aquaculture			
Vulnerable	Make a highly profitable sector sustainable and climate-resilient, build value chains to create jobs and grow sector.	Climate shocks affect the sector; overharvesting and poor resource management impact productivity; prices increase; protein intake suffers. Jobs and value chains decline.	A burgeoning sector is built on climate-resilient and sustainable feeds, breeds, and practices to ensure long-term profitability and well-developed value chains. Export market, jobs, and economic growth are enabled.
Diversified tree crop			
Vulnerable	Leverage agroforestry practices in profitable export sectors to ensure continued food production and reduce forest encroachment.	A 3–4% drop in oil palm yields; forest and soil health decline as does income; forest clearing; a significant decline in food production leads to increased prices, food insecurity, and reliance on imports.	Resilient agroforestry practices ensure long-term productivity of export tree crops and reduce forest loss; enhanced ecosystem services mitigate climate change impacts; food production and security is maintained or improved.
Roots and tubers-livestock integration			
Mixed	Integrate two key farming systems to foster resiliency, increase productivity, reduce costs in both, and monitor livestock health.	Climate impacts further reduce feed availability and increase mortality; overgrazing exacerbates soil degradation; low crop and livestock productivity creates poverty trap; smallholder-pastoralist conflict is increased.	Resilient varieties, new feed resources, and relevant value chains bring climate resiliency and increase productivity, resulting in increased incomes, new jobs, productivity, and relevant sectoral growth.

69. **To assess across the prioritized investments, this CSAIP considered the investments from multiple perspectives**, including (a) geographic distribution; (b) number of beneficiaries; (c) CSA pillars: productivity; resilience, and mitigation; (d) economic and financial assessments including project cost, NPV with and without risks and for different carbon values, ROI, and benefit-cost ratio (BCR) (with and without risks); (e) climate modeling; (f) alignment with Ghana’s NDC; (g) design and implementation issues; (h) partnership; (i) financing; and (k) key investment objectives.

The methodologies for the analyses presented below are described as part of the assessment; details can be found in respective Annexes C, D, and E.

3.1. Assessing Geographic Distribution of Ghana’s Priority Investments

70. **The investments are well distributed across Ghana to maximize their impact.** Two investments are national in scope, while the other seven are well distributed across four agroecological zones. More projects are located in the poorer areas in the central transitional and northern savannah zones. In these zones, poverty is relatively higher, climate impacts are greater, and there are fewer alternatives to

agriculture (Table 10). Five of the investments (cereal-legume, fisheries and aquaculture, and root-tuber-livestock) are located in coastal savannah. While it only occupies 2 percent of Ghana’s total land area, including the Accra metropolitan area, the Coastal Savannah has Ghana’s highest population, and has high concentration of the youth, making these projects important to the region. The forest area (6 percent of land area and where cocoa production is centered) has six investment projects, two of which build on forest resources, two alternatives livelihood, and two of which are linked to project with national coverage. The transitional area benefits from projects with the forest area (to its south), the drier and poorer savannah (to the north), and the national scale.

Table 10: CSAIP Investments by Agroecological Zones in Ghana

FOREST (6)	TRANSITIONAL (7)	SAVANNAH (7)	COASTAL SAVANNAH (5)
		Cereal-Legume Integration	
Cocoa Production			
Resilient Poultry			
Ruminant Production			
Diversified Tree Crop			
Root-Tuber-Livestock			
Sustainable Fisheries and Aquaculture		Sustainable Fisheries and Aquaculture	Sustainable Fisheries and Aquaculture
Water Management			
Knowledge system and advisory services			

3.2 Assessing Beneficiaries and Benefits of Ghana’s Priority Investments

71. **Investments benefit different numbers of people** (see Table 11 and Annex E). The knowledge and advisory investment reach the greatest number of people, 500,000, but the magnitude of its impact will be lower. Both the cereal-legume integration and the root-tuber-livestock investments aim to reach a projected 200,000 farmers, but both are large projects trying to leverage major changes in existing production systems to enhance climate smartness. Poultry, small ruminant, cocoa, and water management for rice production are the four projects with beneficiary’s coverage that ranges between 140,000–160,000 small farmers. Tree crop production reaches 120,000 farmers. The fisheries and aquaculture project intend to reach the fewest farmers, 70,000.

Table 11: Beneficiaries in Each Project

Investment	Targeted beneficiaries
Knowledge and Advisory	500,000
Ruminant Production	150,000
Root-Tuber-Livestock	200,000
Cereal-Legume Integration	200,000
Poultry Production	160,000
Cocoa Production	150,000
Tree Crop Production	120,000
Water Management	140,000
Sustainable Fisheries and Aquaculture	70,000
Total beneficiaries	1,690,000

3.3. Assessing Climate-Smart Agriculture Pillars (Productivity, Resilience, Mitigation) of Ghana's Priority Investments

72. **Climate smartness comprises improving productivity, resilience, and mitigation.** Results from assessing these core components of CSA for the nine priority investments are presented below. Methodologies are described in Annex E.

A Productivity

73. **All CSA priority investments increase productivity by at least 20 percent** “with project support scenario”. Sustainable fisheries and aquaculture show the highest yield increase, nearly 60 percent, while both water management and cereal-legume integration increase yields over 40 percent (Table 12). Not surprisingly, knowledge and advisory leads to a smaller change, as its impact is less direct, while tree crop production has similarly low yield gains at 20 percent.

Table 12: Percentage change in yield.

Investment	Change in Yield (%, SD) ¹
Sustainable Fisheries & Aquaculture	59% (30%)
Water Management	44% (4%)
Cereal-Legume Integration	40% (31%)
Cocoa Production	32% (20%)
Poultry Production	27% (52%)
Ruminant Production	27% (19%)
Root-Tuber-Livestock	27% (14%)
Knowledge & Advisory	21% (40%)
Tree Crop Production	20% (20%)

¹ Average percentage change between beneficiaries with vs without project

Note: The values in brackets are the standard deviations (SD).

Resilience and Risk

74. **The nine investments show a high degree of resilience, even when climate and pest risks are included.** This investment plan and its economic analysis allow for a direct targeting of investments regarding the climate and pest risks threatening productivity and growth in the future. This guards against an overly optimistic analysis of performance when risks are excluded from economic analysis.

75. **One way of showing the resilience of projects is by understanding the risks, and then using the probability of a positive NPV as an indicator of resilience.** As shown in Table 13, all investments have a better than 50 percent chance of a positive NPV even in the face of uncertain climate and pest risks. This suggests that the entire investment plan is robust for tomorrow's environmental conditions. Four investments (tree crops, cocoa, water management, and cereal-legume) appear especially robust with an 85 percent or higher chance of a positive NPV. Three projects (fisheries and aquaculture, ruminants, and root-tuber-livestock) have between 50 and 54 percent likelihood of a positive NPV, indicating higher risk and less resilience. If risks are excluded, the chances of a positive NPV increase in all investments. For the projects with a higher chance of a positive NPV, there is only a small difference in results with and without risk. In contrast, for some of the projects where the probabilities are lower, especially the root-tuber-livestock investment, there is greater sensitivity to potential risks (for example, 23 percent), showing a

higher sensitivity and lower resilience. For this analysis of risk and resilience, over 100 model runs were done for each investment.

76. **Overall, the chance of a positive NPV are good.** The mean impact for each of the investments suggests a high probability of positive return. However, the reality is that risks make the likelihood of success with any given individual investment uncertain. Where there are extreme values (especially negative ones), it is important to consider the risks of the investments. Simply put, there is the possibility that investments may not perform as planned and that they may not produce positive results when implemented. Uncertainty in performance is inherent to investments in agricultural development. An evaluation of 86 projects by the World Bank found that 41 percent had non-positive outcomes.¹⁰⁹ Climate change will only add to this uncertainty. Methodologically extreme values and the large variation in predicted results are produced from consideration of joint effects of multiple uncertain parameters. While these models are based on the best available information at the time of development, information on costs, benefits, and performance is scarce and uncertain. The modelling approach used here attempts to account for, and make explicit, that reality and in so doing provide all the necessary information on which to base a sound decision.

Table 13: Chance of a Positive NPV With and Without Climate and Pest Risks

Investment	Chance Positive NPV (%) ²	WITH RISKS	WITHOUT RISKS
		Positive NPV (%) ²	Positive NPV (%) ²
Tree Crop Production		92%	94%
Cocoa Production		89%	93%
Water Management		89%	90%
Cereal-Legume Integration		85%	89%
Poultry Production		71%	77%
Knowledge & Advisory		58%	61%
Root-Tuber-Livestock		54%	77%
Ruminant Production		51%	65%
Fisheries & Aquaculture		50%	63%

Emissions

77. **The entire portfolio reduces Ghana’s overall emissions and would sequester 7.31 MtCO₂ if all the priority investments were implemented.** The Ghana CSAIP investments will be both sources of and sinks for GHGs. Five of the investments (see Table 14) produce low levels of additional emissions; this is unsurprising since four of the investments are focused on meeting Ghana’s future protein needs with livestock (cows and small ruminants), poultry, fisheries and aquaculture. For example, improving livestock productivity typically increases the GHGs produced, for example, through enteric fermentation and methane from cattle or increased amounts of manure being handled from poultry. The cereal-legume integration produces a very small emissions increase. (See Annex E for methodologies.)

¹⁰⁹ World Bank, “Ghana Dashboard,” Climate Change Knowledge Portal, 2017, http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCCode=GHA&ThisTab=ImpactsVulnerabilities.

Table 14: Emissions from Priority Investments (MtCO₂), Based on Analysis Using FAO’s EXACT¹¹⁰ GHG Calculator

		Mt CO ₂	
		Emitted	Sequestered
Cereal-Legume Integration	-0.02	Tree Crop Production	3.4
Fisheries & Aquaculture	-0.35	Cocoa Production	3.2
Poultry Production	-0.39	Water Management	2.35
Root-Tuber-Livestock	-0.39	Knowledge & Advisory	0.23
Ruminant Production	-0.72		
Subtotals	-1.87	Subtotals	9.18

78. **Even though some investments may lead to small emission increases, they reduce emission intensity, and their increases must be weighed against the multiple benefits they provide.** For example, the five projects with emission increases (tCO₂e) lead to increased consumption of animal-sourced foods, a critical nutrition intervention to combat childhood stunting and wasting. Additionally, several investments that emit CO₂ also support intensification which could potentially reduce forest-clearing. These secondary benefits were not quantified, but they increase the overall mitigation benefits of the entire CSAIP. The water management project shows positive sequestration potential, as do both diversified tree crops and cocoa because they increase the amount of biomass and carbon stored therein. Lastly, the entire portfolio reduces overall emissions.

79. **Of the nine priority investments, some stand for their strong support of the fundamental CSA pillars.** A summary of the top five investments for each of the three CSA pillar categories is shown in Table 15. Of the nine investments, cocoa production, water management, and cereal integration appear in the top five in each of the categories, while tree crops and poultry production each appear twice. These five investments are the climate-smartest—that is, they most fully address all three CSA Pillars.

Table 15: Climate Pillars: Ranking the Top Five Investments in Each CSA Smartness Category.

PRODUCTIVITY	RESILIENCE	EMISSIONS
Sustainable fisheries and aquaculture	Tree crop production	Tree crop production
Water management	Cocoa production	Cocoa production
Cereal-legume integration	Water management	Water management
Cocoa production	Cereal-legume integration	Knowledge and advisory
Poultry, ruminants, root-tuber-livestock	Poultry production	Cereal-legume integration

3.4. Economic and Financial Assessment of Ghana’s Priority Investments

80. **The nine investments are predicted to provide significant benefits for Ghanaian farmers.** To allow the potential magnitude of foreseeable risks to be understood, the cost-benefit analysis (CBA) (see Table 15) is presented both with and without risks. Without risks included in the model, NPV (20 years) ranges from US\$28.5 million with the aquaculture program to more than US\$231 million with the program focused on CSA cocoa production. Differences in the estimated productivity are due to inherent variation in the costs of interventions, the number of target beneficiaries, and the relative speed at which interventions reach scale (that is, adoption rate). When considering the realities of inter-annual weather

¹¹⁰ “FAO EXACT,” n.d.

fluctuations, pest outbreaks, and social and political drivers of adoption, the estimated NPV of the investments drops by about 50 percent.

81. **All investments are expected to improve the productivity and income of farmers.** Investment in improved agricultural practices increases farm outputs, whether by introducing new breeds of livestock, drought-tolerant seeds for crops or by providing information for better farming decisions (for example, knowledge, advisory, and climate services). How well these on-farm improvements translate to overall investment productivity varies because of the variable costs of interventions (Table 16). In some cases, such as aquaculture and rice irrigation, the upfront investment is significant, so a slower pace of adoption is expected. On the other hand, the knowledge and advisory investment reaches many beneficiaries quickly but its potential to change farmers' productivity is lower. Common types of interventions that are the result of receiving information, such as on-time planting, have a relatively low impact on average yields (that is, 4–8 percent) compared to planting at a suboptimal time. Of course, when poor planting decisions occur, they create crop failures in households not participating in the program. The relative changes in production can be more substantial and are captured in the tails of distributions used in the models.

Table 16: Assessing Economic and Financial Performance of the Nine Priority Investments (With and Without Climate and Pest Risks)

CSA INVESTMENT	ESTIMATED PROJECT BUDGET (US\$)	Mean NPV (US\$, millions)		Mean ROI		Mean BCR (SD)	
		WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT
Cereal-Legume Integration	32,000,000	109.0	208.8	4.04	7.77	2.63 (5.54)	5.04 (6.96)
Cocoa Production ¹¹¹	54,000,000	188.8	231.3	4.15	5.10	2.72 (3.96)	3.33 (4.33)
Poultry Production	32,000,000	81.6	119.3	3.19	4.63	1.97 (4.90)	2.88 (5.70)
Ruminant Production	37,500,000	38.1	88.5	1.43	3.07	0.77 (7.26)	1.78 (7.74)
Fisheries & Aquaculture	35,000,000	9.6	28.5	0.29	0.93	0.21 (0.92)	0.62 (1.24)
Water Management	70,000,000	143.7	171.1	2.32	2.78	1.54 (2.36)	1.84 (2.47)
Knowledge & Advisory	50,000,000	198.1	331	4.74	7.90	2.99 (14.31)	4.99 (17.12)
Root-Tuber-Livestock	50,000,000	24.2	75.9	0.52	1.74	0.36 (2.39)	1.15 (2.76)
Tree Crop Production	29,040,000	204.2	217.6	8.24	8.79	5.30 (7.85)	5.64 (8.00)

Note: NPV = Net Present Value, ROI = Return on Investment¹¹², BCR = Benefit Cost Ratio with standard deviations (SD). NPV and ROI are average of 100 model runs.

82. **Each investment will present positive returns relative to their costs, based on the analysis.** In some cases, the ROI is expected to reach as high as 9x (for example, with the tree crop program) indicating that these investments have potential to create large impacts at scale over the 20-year period (Table 16). Even accounting for risks, ROI and BCR remain positive. BCR for practically all the investments are within

¹¹¹ Note: A CSAIP reviewer in Ghana felt that the performance of the proposed cocoa sector project was low, compared to Ghana Cocoa Board (COCOBOD) financial estimates. This is likely because of different input numbers and methodologies used (see Annex E).

¹¹² ROI here is expressed as a ratio between discounted net benefit and discounted costs.

the range of the investments identified by the Global Commission on Adaptation,¹¹³ suggesting that these programs are consistent with and equally good investments as those identified in other initiatives.

83. **The equivalent of a sensitivity analysis was performed for NPV, using two levels of carbon pricing (low and high), both with and without climate and pest risks.** The mean NPV shows a high sensitivity to high carbon prices for the three investments that strongly support mitigation (tree crops, cocoa, water management), even when risks are considered. A few projects show a large change (that is, the NPV doubles) if risks are excluded, for example, the cereal-legume integration project (Table 17). Other projects are sensitive to higher carbon pricing and risk. This analysis shows that the financial and economic analyses are highly sensitive to some of the model assumptions, providing a strong rationale for careful and cautious analysis of both future carbon pricing and risk calculations within agricultural sector investments.

Table 17 : Comparison of Mean Investment NPV (US\$, millions) Under Carbon Price and Risk Scenarios

Investment	No Risk - Low C Price	No Risk - High C Price	With Risks - Low C Price	With Risks - High C Price
Knowledge & Advisory	318.4	331.0	185.5	198.1
Cereal-Legume Integration	209.4	208.8	109.6	109.0
Poultry Production	137.5	119.3	99.8	81.6
Ruminant Production	122.7	88.5	72.3	38.1
Tree Crop Production	55.8	217.6	42.4	204.2
Root-Tuber-Livestock	94.2	75.9	42.3	24.2
Cocoa Production	79.2	231.3	36.7	188.8
Water Management	59.2	171.1	31.8	143.7
Fisheries and Aquaculture	45.3	28.5	26.3	9.6

3.5. Climate Modeling Assessment of CSAIP Priority Investments

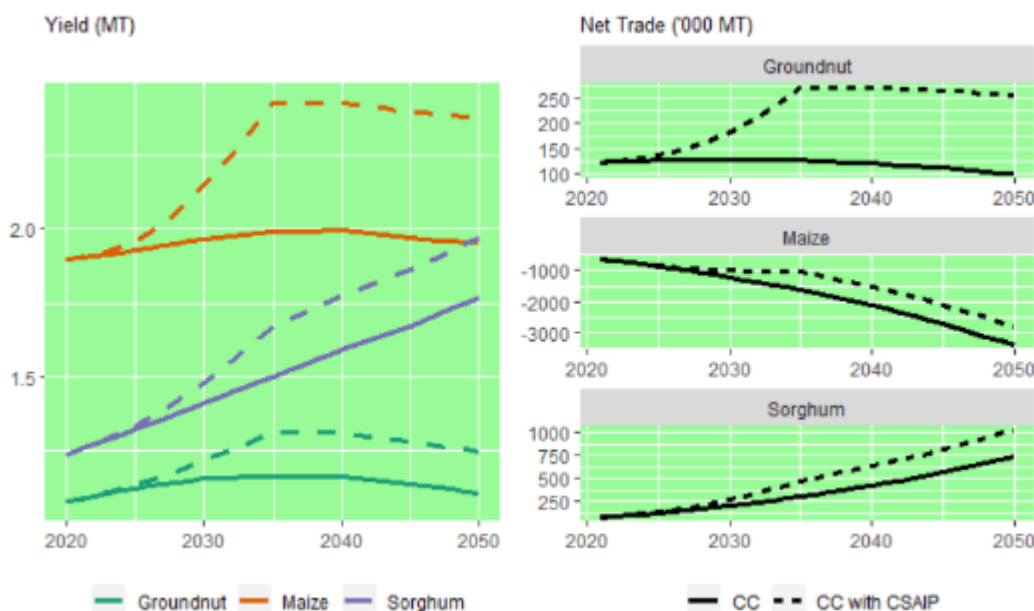
84. **The CSA investment plans are built upon the strengths of commodities that exhibit resilience under climate change, while simultaneously offsetting potential damages to commodities exhibiting vulnerability.** We assessed the potential impact of the CSAIP on yield, food security, and trade trajectories in Ghana out to 2050 under climate change, given different demographic, economic, and emissions assumptions over this period. This analysis identified the crops that exhibit resilience or vulnerability under climate change and focused on how the CSAIPs can leverage resilience and offset vulnerability. For this analysis, the team considered yield shocks, expected time horizons, and adoption rates associated with each of the CSAIPs. Inputs came from experts familiar with these technologies and practices. The IMPACT scenarios below show ‘with CSAIP’ and ‘without CSAIP’ future climate change scenarios out to 2050, for different plausible demographic and economic growth scenarios (SSPs), and different assumptions about future GHG concentration scenarios (RCPs).

85. **The modeling suggests that the cereal-legume integration CSA intervention has considerable potential to improve maize, sorghum, and groundnut yield and trade trajectories.** Climate modeling

¹¹³ Global Commission on Adaptation, “Adapt Now: A Global Call for Leadership on Climate Resilience,” September 13, 2019, https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf; World Resources Institute, “CAIT Climate Data Explorer,” 2017, <http://cait2.wri.org/>.

suggests that the cereal-legume investment plan could offset this dependence. CSA actions make a substantial difference in maize yield, with a clear departure over the baseline by 2030, which generally increases and then plateaus by 2035. Under BAU scenario, maize yield rise slightly and then decline. Sorghum levels increase in both the BAU and worst-climate scenarios, but CSA actions improve yields. In contrast, groundnut yield shows a decline over time under BAU, but the CSA package extends the timing before the decline begins and outperforms the BAU on yield. The net trade data show that the cereal-legume investment plan would produce more maize to offset imports, while simultaneously enhancing Ghana’s comparative advantage in trade in groundnut and sorghum (Figure 15).

Figure 15: Potential Impact of Cereal-Legume Integration CSA Interventions on Maize, Sorghum, and Groundnut Yields and Balance of Trade



Note: Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic representative carbon concentration scenario (RCP 8.5).

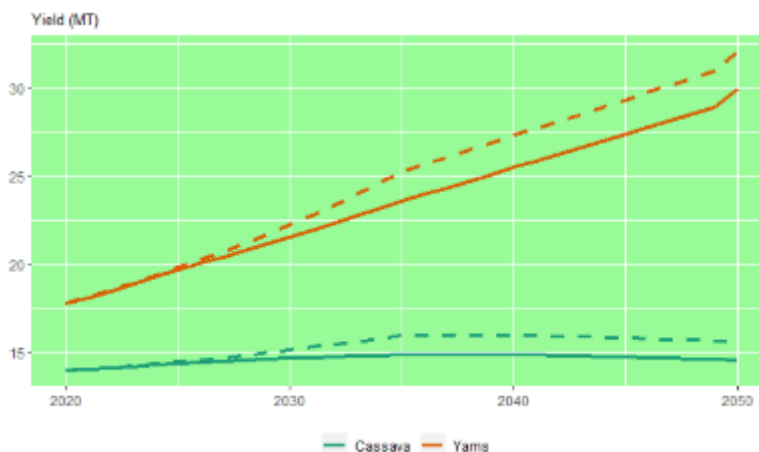
86. **The roots, tubers, and livestock integration CSA intervention is poised to build on the projected resilience of yams and cassava while offsetting potential damages to livestock production.** The latter is generally considered more vulnerable to climate change (Figure 16). Cassava yields remain low, but they are resilient to climate change; the CSAIP investment package increases cassava yields and maintains these yields over time. Yams show an improved yield under BAU and the CSAIP investment, with the CSAIP investment producing a noticeable difference in yield by 2030 and maintaining the yield advantage and resilience over time.

87. **Modeling suggests that the cocoa production CSAIP could offset potential damages to Ghana’s cocoa production and sustain its competitive edge in critically important cocoa exports** (Figure 17). Cocoa exhibits considerable vulnerability to climate change (Table 5). Cocoa production investments increase overall cocoa yields and begin showing improved net trade before 2030. As Ghana’s main export crop, this increase in cocoa yield and trade has strong and positive ripple effects through the economy.

88. **The water harvesting and irrigation CSAIP is poised to capitalize on rice’s resilience under climate change** (Figure 18). Both for overall yield and for net trade, the CSA investment package leads to

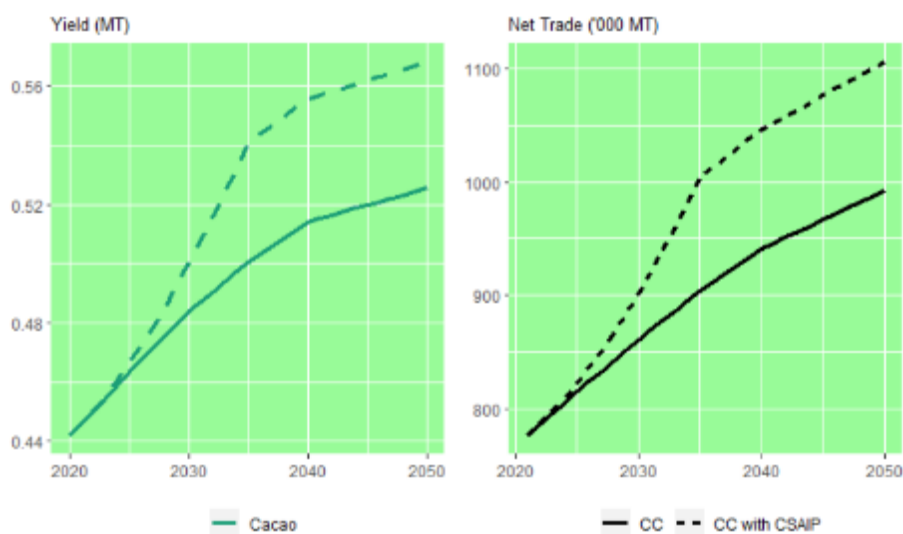
improved yields by 2030 that continue over time. By improving yields as part of CSA, rice production will increase, leading to reduced, if still likely extant, imports, as shown in Figure 18. If this initial rice production showed a high success rate, it could further encourage domestic rice production.

Figure 16: Potential Impact of the Roots and Tubers-Livestock Integration CSA Intervention for Yields and Balance of Trade

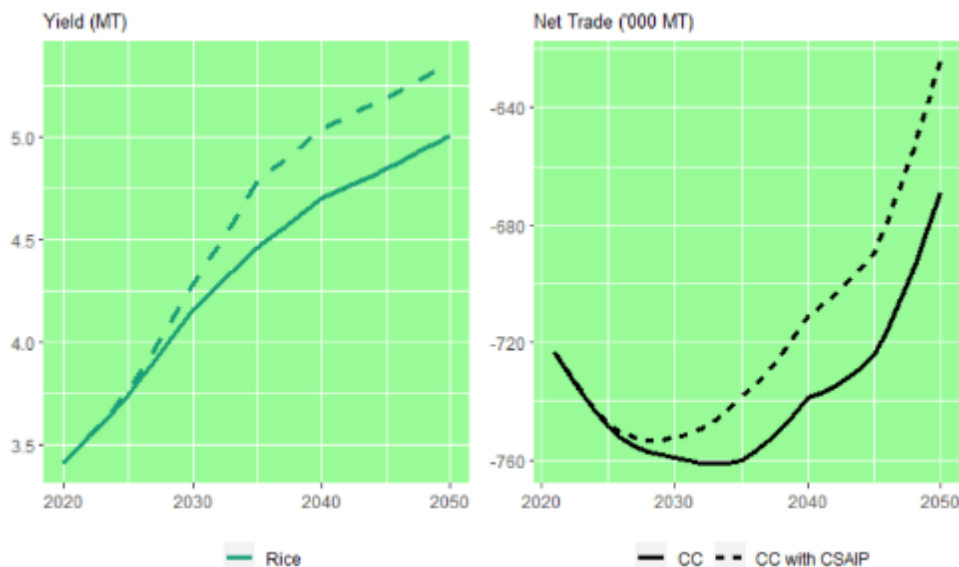


Note: Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic representative carbon concentration scenario (RCP 8.5).

Figure 17: Potential Impact of the Cocoa Production CSAIP on Rainfed Cocoa Yields and Balance of Trade



Note: Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic representative carbon concentration scenario (RCP 8.5).

Figure 18: Potential Impact of the Water Harvesting Technologies and Irrigation CSAIP on Irrigated Rice Yields and Balance of Trade

Note: Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic representative carbon concentration scenario (RCP 8.5).

3.6. Assessing CSAIP Investment Alignment with Ghana's Nationally Determined Contribution

89. **Ghana's extant policies and programs offer broad and strong recognition of the importance of CSA and the need for investments.** Ghana, and especially its agriculture sector, has experienced significant economic growth over the past several decades. The government has given high priority to investments in agricultural innovation and it has put in place new policies supporting agriculture and agribusiness.¹¹⁴ Stakeholders recognize that these gains are threatened by climate change impacts. The Ghanaian government has put forth NDCs to the Paris Climate Agreement and has recently committed to upscale its actions by 2020 as part of the new Climate Ambition Alliance. Ghana's commitment to a climate-smart future and recent (September 23, 2019) intent to further enhance their 2020 NDC commitments demonstrates their understanding and leadership.¹¹⁵ Their actions are supported by the international community, including the United Nations, the African Agricultural Alliance, Economic Community of West African States, and donors such as the Bill and Melinda Gates Foundation, the World Bank, and the European Commission.¹¹⁶

90. **This CSAIP is clearly aligned with Ghana's NDCs, both on high-level objectives and specific investment activities.** The World Bank is supporting Ghana's development of this CSAIP in alignment with and under the auspices of the NDC. It will be crucial to ensure that this alignment and support continues as the intended NDC enhancements are put in place in 2020 and these CSAIP programs are developed. The NDC high-level objectives include, among others:

¹¹⁴ Rodger Voorhies, "OPINION: How to Stop Climate Change Robbing African Farmers of a Brighter Future," *Property Rights*, n.d., 20.

¹¹⁵ Prensa Presidencia, "Climate Ambition Alliance: Nations Push to Upscale Action by 2020 and Achieve Net Zero CO2 Emissions by 2050," Gobierno de Chile, September 23, 2019, <http://prensa.presidencia.cl/comunicado.aspx?id=102021>.

¹¹⁶ World Resources Institute, "RELEASE: At UN Summit, New Commitments of Over \$790 Million to Support Climate Adaptation for Over 300 Million Small-Scale Food Producers," September 23, 2019, <https://www.wri.org/news/2019/09/release-un-summit-new-commitments-over-790-million-support-climate-adaptation-over-300>.

- Sustainable land use, including food security
- Sustainable forest management
- Climate-proof infrastructure
- Equitable social development

91. **The CSAIP makes robust contributions to these objectives at the national scale.** For example, the knowledge and advisory services investment establishes a sound basis for all four of these NDC objectives by broadening and strengthening the means for disseminating technology and innovation to the farm level. Introducing CSA into the national extension system supports reduced emissions, climate resiliency, and equitable development via sustainable intensification and natural resource management. The water harvesting and irrigation, aquaculture, poultry, and ruminant investments also address all four objectives by increasing productivity, reducing expansion, creating climate-resilient infrastructure, and promoting inclusive social development.

92. **Many proposed adaptation activities in the NDC are also strongly supported by the CSA crop and livestock investments.** Five of the NDC project areas are directly relevant to agriculture: (1) sustainable utilization of forest resources; (2) building resilience in climate-vulnerable agriculture landscapes; (3) value-added forest resources; (4) strengthening equitable water distribution and access; and (5) increasing climate resilience and livelihood diversity for women and vulnerable populations. These five project areas lay out a total of twelve project goals. The entire CSAIP supports all twelve of these goals and proposes actions that directly address nine of the twelve. The COVID-19 shock to Ghana and its potential impacts on human health and the economy show the necessity of the second and fifth areas listed above by building resilience in climate vulnerable landscapes and for the most vulnerable populations. CSA activities play a critical role to ensure food security and strengthen the resilience and preparedness of the agriculture sector broadly and rural households individually. Many of the investments are targeted to support rural farmers who could potentially become food insecure. They also aim to reduce the impacts of future shocks by increasing production, introducing more resilient crops and breeds, increasing income, replacing food imports with domestic products, and improving knowledge transfer and communication to provide early warning and advice on potential shocks.

93. **The CSAIP project concepts are fully integrated with these NDC project goals.** For instance, the climate-smart poultry investment proposes postharvest storage and processing innovations, increased livestock productivity, and livelihood diversification for women and vulnerable populations. The water harvesting and irrigation program directly addresses equitable water distribution and access, seeks to increase the productivity of crops and livestock, and actively manage natural spaces, while supporting drylands wildfire management. The climate-smart cocoa investment proposes enforcement of felling standards, governance reform for forest biodiversity conservation, emission reductions from cocoa landscapes, active management of natural spaces, and reforestation and conservation agriculture within the agroforestry context. All of these directly support NDC project goals (Table 18).

94. **The adaptation approaches specified by the NDC are of crucial importance.** The Ghanaian NDCs integrate all three pillars of CSA: productivity, adaptation, and mitigation. Given unavoidable, continuing, erratic, and variable climate change impacts and the potential shocks that can result from climate and other factors (for example, disease outbreak, global recession), an additional focus on adaptation and resilience is warranted to ensure continued productivity. As such, the NDCs emphasize increasing climate resilience and decreasing vulnerability through adaptation approaches explicitly informed by these key elements:

- Good governance

- Intersectoral coordination
- Capacity building
- Science, technology, and innovation
- Adequate finance (from both domestic sources and international cooperation)
- Promoting outreach; informing, educating, and communicating with individuals
- Accountability via monitoring and reporting

Table 18: Alignment of CSAIP with NDC

Investment Directly Addresses NDC Goal	Investment Supports NDC Goal												Little or No Alignment Between Investment and NDC Goal
	Reforestation/afforestation	Enforce felling standards	Enrichment planting	Cocoa emission reduction	Wildfire management	Conservation agriculture	Postharvest storage and processing	Livestock and aquaculture productivity	Governance reform	Actively manage natural spaces	Water distribution and access	Livelihood diversity	
Poultry Production													
Root-Tuber													
Livestock													
Ruminant Production													
Cereal-Legume Integration													
Cocoa Production													
Tree Crop Production													
Knowledge & advisory													
Water Management													
Fisheries & Aquaculture													

95. **These are pivotal elements necessary for Ghana’s successful implementation of CSA practices.** As such, every component of the CSAIP repeatedly emphasizes and prioritizes these approaches to climate adaptation. Good governance, intersectoral coordination, capacity building, finance, research, and outreach are named as the foundational components to the success of every project concept. Each plan also proposes monitoring and evaluation methods for measuring and reporting project impact. The degree to which these foundational elements are supported and assessed in Ghana will form the basis for project plan development and be the primary predictor of the CSAIP’s long-term impact and success.¹¹⁷

¹¹⁷ World Bank, “Transforming Agriculture for Economic Growth, Job Creation and Food Security”; International Food Policy Research Institute (IFPRI), “Public Agricultural Spending and Growth in Ghana.”

3.7. Policy Coherence: Alignment, Gaps, and Distortions with Other Policies, Strategies, and Commitments

96. **The CSAIP addresses and supports the goals of multiple national policies and strategies**, including the National Climate Change Policy and Adaptation Strategy, the National Climate-Smart Agriculture and Food Security Action Plan, the IFJ (medium-term plan for agriculture), the PFJ Campaign, Planting for Export and Rural Development, Rearing for Food and Jobs, Tree Crops Policy, Ghana Irrigation Policy, and the Green Economy Learning Strategy, among others (Table 18 and Annex C). The CSAIP also strongly supports several main components of the Forest and Wildlife Policy (FWP), the National Water Policy (NWP), the Ghana Shared Growth and Development Agenda (GSGDA), the Cocoa and Forest Initiative, and other policies key to maintaining the agricultural sector's growth and contribution to the national economy. Also, by promoting and expanding the adaptation approaches previously discussed, the CSAIP builds resilience within national institutions, thus having a positive impact on myriad aspects of national policy. These investments further support Ghana's current national policies and its future developments in agriculture and food security in the face of climate change.

97. **Implementation of the CSAIP will make significant strides toward meeting several of Ghana's international commitments.** In addition to the NDCs, Ghana is signatory to other international commitments, including:

- SDGs
- Comprehensive Africa Agriculture Development Program (CAADP)
- Malabo Declaration on the Transformation of Agriculture
- African Union 2063 Agenda
- African Forest Landscape Restoration Initiative (AFR100)

98. **The CSAIP will move Ghana closer to meeting all of these international commitments.** The proposed investments address the poverty reduction and environmental conservation aims of the 2030 SDGs¹¹⁸ and the African Union 2063 agenda for inclusive and sustainable development.¹¹⁹ Ghana is estimated to have completed 57 percent of the CAADP process.¹²⁰ Adopting this CSAIP will put the country well into the third phase, *Development of Investment Program*, which supports partnerships and alliances by designing investment programs and turning priorities into programs for action components.¹²¹ The CSAIP also paves the way for two other components of the third phase, *Development of Alliances with Public and Private Investors* and *Development of Intersectoral Perspectives and Partnerships*, by providing concrete recommendations for the same. Implementing the investments in this CSAIP will complement Ghana's effort to meet its Malabo Declaration commitment to dedicate 10 percent of the national budget to agriculture. Finally, these investments will significantly augment Ghana's contribution to AFR100's goal of restoring 100 million ha of deforested and degraded landscapes across Africa by 2030.¹²²

99. **Several national policies recognize climate change and support adaptation and mitigation through CSA.** The National Climate Change Policy, the National Climate Smart Agriculture Food and Security Action Plan, and the National Climate Change Strategy offer strong coherence and alignment with

¹¹⁸ UN Communications Groups, "The Sustainable Development Goals in Ghana" (United Nations Development Programme, November 2017).

¹¹⁹ African Union, "Agenda 2063: The Africa We Want," The African Union Commission, 2019, <https://au.int/en/agenda2063/overview>.

¹²⁰ AUDA-NEPAD, "Tracking Progress: Ghana."

¹²¹ AUDA-NEPAD, "The CAADP Country Process," 2019, <https://www.nepad.org/caadp/publication/caadp-country-process>.

¹²² Afr100, "Home," African Forest Landscape Restoration Initiative, 2018, <https://afr100.org/>.

the NDCs, and concomitantly this CSAIP (Table 18). Strong coordination between these and other relevant policies for implementation will help ensure that Ghana's CSA goals are achieved.¹²³

100. **Ghana's government recognizes the crucial role of gender equality in climate resilience and national development.** Ghanaian smallholder adaptive capacity varies with education and gender. Female farmers have significantly lower economic resources, technology access, and overall knowledge and awareness, implying that women farmers have lower capacity to respond to climate change impacts.¹²⁴ Climate change responses generally reflect larger power and political dynamics at both the local and national levels, including gender biases. Leveraging policies to continue promoting gender sensitivity and power dynamics on all levels will significantly augment national climate resiliency and economic potential. These biases and the need to overcome them are formally recognized and addressed in national policies, including the Gender and Agriculture Development Strategy and the Food and Agriculture Sector Development Policy II (FASDEP). There is strong coherence across national policies for mainstreaming of gender issues¹²⁵ and supporting Ghana's international alliances and commitments, including the African Union Agenda and SDGs.

Policy Gaps and Distortions

101. **Investments in CSA design and implementation, climate change resilience, and mitigation may be constrained by the existing policy context** (Table 19). Possible barriers to the investment for all the CSAIP's projects are: (a) the absence of intersectoral and interdepartmental collaboration; (b) policy misalignment; (c) policy distortion; (d) weak institutional capacity; and (e) donor unwillingness to support investments. Not only are these potential threats to investment, but they are also directly related to the policy context.

102. **Both risks that derive directly from climate change and those that do not are often rooted in or aggravated by national policies.** Risks and potential barriers of medium significance to CSA identified within the CSAIP for different investments include: (a) extreme weather conditions, including drought and resultant wildfires, shortened rainy season or intense or poorly timed rains, floods, and extreme temperatures; (b) pests and disease; (c) poor farmer information access and capacity building; and (d) mitigation-skewed policy. Risks from climate and pests are incorporated into the economic models (see Annex E).

103. **While climate stresses cannot be ignored, there are climate adaptation efforts underway, from farmers changing planting times or varieties to national-scale efforts to promote adaptation within larger sectors.** The CSAIP portfolio helps reduce both risks and shocks to the agricultural sector, especially with the national-scale investments for finance and capacity. These begin to address some of the policy gaps that are fundamental to building resilience across the sector. Addressing impacts from COVID-19 to Burkina Faso and building responses, including CSA, offer an entry point to reducing a variety of risks and building resilience across the agriculture and other sectors. These projects can help policy makers devise coordinated approaches to holistic climate-smart development goals that also support OneHealth and risk reduction objectives. Impacts and risks will be quite different in urban and rural contexts, which will determine the extent to which persons are affected. The IMPACT modeling reflects the differences

¹²³ NCD Support Programme, "Ghana," UNDP, accessed September 15, 2019, http://www.gh.undp.org/content/ghana/en/home/projects/ndc_sp_gh.html.

¹²⁴ Majeed Abdul-Razak and Sylvia Kruse, "The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana," *Climate Risk Management* 17 (2017): 104–22, <https://doi.org/10.1016/j.crm.2017.06.001>.

¹²⁵ Philip Antwi-Agyei, Andrew Dougill, and Lindsay Stringer, "Assessing Coherence between Sector Policies and Climate Compatible Development: Opportunities for Triple Wins," *Sustainability* 9, no. 11 (November 18, 2017): 2130, <https://doi.org/10.3390/su9112130>.

between urban and rural impacts and risks, including in the context of global trade competitiveness given changing advantages in the agricultural sectors of different countries.

Table 19: Alignment of CSAIPs with Policy Gaps and Distortions

CSA Investment Plans	Tenure, Management, Enforcement Issues	Low Extension	Need Funding	Low Capacity	Policy Conflicts	Short-term Gain (US\$)	Low Coordination of Govt and Private Sector
Sustainable Fisheries & Aquaculture	✓		✓	✓	✓		✓
Tree Crop Production	✓	✓		✓	✓	✓	✓
Water Management			✓		✓	✓	✓
Cocoa Production	✓	✓		✓	✓	✓	✓
Cereal-Legume Integration	✓	✓	✓				
Poultry Production		✓		✓	✓		✓
Ruminant Production	✓	✓		✓	✓		
Root-Tuber-Livestock	✓	✓		✓		✓	✓
Knowledge & Advisory	✓	✓	✓				✓

Note: The cells colored white imply little or no support in terms of policy on the area of CSA investments (see cases).

104. **Several pro-CSA policies are not fully implemented due to weak collaboration between sectors and governmental ministries.** Multiple Ghanaian policies outline CSA goals without specifying precisely how they will be achieved or by whom. As a result, there is poor coherence between sectoral policy documents and approaches. Competition and weak collaboration between sectors and ministries exist rather than strong alliances supporting common goals.¹²⁶ This has been recognized as a major limiting factor to development by the Ministry of Food and Agriculture (MoFA) and other key stakeholders.¹²⁷ Defining of roles, synergies, compromises, and trade-offs between stakeholders—particularly state institutions—will be a vital step toward implementing and improving the effectiveness of existing pro-CSA policies, particularly given limited resources and budgets.¹²⁸ Better coordination across government entities, or even a single unit designated to coordinate between the government and private sector could increase the currently limited private sector engagement in Ghanaian CSA programs.¹²⁹

105. **Some national policies give inadequate attention to climate change issues; there is significant opportunity to better align agricultural policies with national objectives.** The National Climate Change Policy, the National Climate Change Strategy, the GSGDA, and the NDCs address the threat of climate change to agriculture in considerable detail. Yet the FASDEP II and Medium-Term Agricultural Sector Investment Plan (METASIP) were not developed specifically to address climate change (see Annex B). There is only partial coherence between FASDEP II and NWP, and limited coherence between FASDEP II and the FWP.¹³⁰ The Ghanaian government recognizes the need to revise existing legal frameworks for

¹²⁶ A Belén Cárdenas et al., “Policy Coherence for Climate-Sensitive Planning in Ghana,” n.d., 7.

¹²⁷ Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture.” 2018a.

¹²⁸ M. Akhtar-Schuster et al., “Improving the Enabling Environment to Combat Land Degradation: Institutional, Financial, Legal and Science-Policy Challenges and Solutions.” *Land Degrad. Dev.*, no. 22 (2011): 299–312.

¹²⁹ Naaminong Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture” (World Bank, 2019).

¹³⁰ Antwi-Agyei, Dougill, and Stringer, “Assessing Coherence between Sector Policies and Climate Compatible Development.”

better alignment with NDC objectives.¹³¹ Identifying the specific coherent and conflicting elements of these policies with climate-smart initiatives¹³² can help policy makers devise coordinated approaches to holistic climate-smart development goals.¹³³

106. **Based on information from the Ghana stakeholders meeting and analysis, it is evident that the distortions of some pro-CSA policies and subsidies are creating potential barriers to CSA implementation.** Overall national food production decreases, with a concomitant increased reliance on imports. National crop diversity also declines, and the agricultural economy relies more on the yield of any single crop in a given year. All these scenarios increase smallholder and national vulnerability to climate impacts. Similarly, large-scale subsidy programs have had significant distortionary effects in agricultural spending.¹³⁴ Careful design and implementation of policies and a legislative understanding that policies will be monitored and revised as they are implemented can resolve these unintended policy consequences. Maximizing policy coherence is crucial to achieving all agreed national objectives.¹³⁵

107. **Some national CSA climate change policies are oriented toward mitigation.** Adaptation-focused programming is critical for resource-poor smallholders for adjusting their farm management and livelihood decisions to increase climate resilience.¹³⁶ However, some policies—especially in energy, forestry, and wildlife—are heavily skewed toward mitigation.¹³⁷ While mitigation is important, there is a growing international call to focus efforts on preparing smallholders to be resilient in the face of climate change impacts.¹³⁸ Refocusing mitigation-focused policies to include climate adaptation and productivity efforts will have an outsized positive effect for climate-vulnerable households, national food security, and the agricultural economy. Ghana’s government has recognized the importance of focusing on productivity and resilience rather than solely mitigation; approximately 55 percent of its NDC efforts will be focused on productivity and 45 percent on adaptation and mitigation.

108. **Enhancing institutional capacity will be foundational to meeting Ghana’s national climate-smart goals.** Stakeholders, including the MoFA, have repeatedly highlighted the need for investments in capacity building as a prerequisite for coordinating and implementing national planning priorities. The Ghanaian government aims to identify opportunities for continuous up-skilling and expanding the technical capacity of its staff.¹³⁹ Enhanced institutional capacity would prepare ministries for the realignment of existing policy frameworks necessary to achieve coherence between policies and establish coordinated efforts across departments, ministries, and sectors.¹⁴⁰ In particular, the Environmental Protection Agency (EPA) of Ghana serves as a focal point on climate change with the mandate to spearhead capacity-building

¹³¹ Government of Ghana, “Ghana’s Intended Nationally Determined Contribution,” 2015, 16.

¹³² Government of Ghana. 2015.

¹³³ Antwi-Agyei, Dougill, and Stringer, “Assessing Coherence between Sector Policies and Climate Compatible Development”; Philip Antwi-Agyei and Andrew Dougill, “SRI Briefing Note Series No.13,” no. 13 (n.d.): 8.

¹³⁴ Tanaka, Nuamah, and Geiger, “Ghana’s Challenges.”

¹³⁵ A. Chandra and A. Idrisova, “Convention on Biological Diversity: A Review of National Challenges and Opportunities for Implementation,” *Biodiversity Conservation*, no. 20 (2011): 3295–3316; Organization for Economic Cooperation and Development, “A Comparative Analysis of Institutional Mechanisms to Promote Policy Coherence for Development.” (Institutional Approaches to Policy Coherence for Development OECD Policy Workshop, Paris, 2004).

¹³⁶ Cárdenas et al., “Policy Coherence for Climate-Sensitive Planning in Ghana.”

¹³⁷ Antwi-Agyei, Dougill, and Stringer, “Assessing Coherence between Sector Policies and Climate Compatible Development.”

¹³⁸ World Resources Institute, “RELEASE.”

¹³⁹ Government of Ghana, “Ghana’s Intended Nationally Determined Contribution”; Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture.”

¹⁴⁰ Antwi-Agyei, Dougill, and Stringer, “Assessing Coherence between Sector Policies and Climate Compatible Development”; Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

programs and establish appropriate mechanisms to ensure collaboration between climate-relevant sectors.¹⁴¹ Yet they need greater financial support for cross-sectoral planning.

109. **Most Ghanaian smallholders rely on traditional techniques and indigenous knowledge to forecast near-term weather and seasonal climate.** Traditional knowledge such as when birds migrate, when plants germinate, and changes in cloud cover and wind patterns have historically guided farmers' decision-making. However, the erratic weather conditions brought by climate change have made such knowledge and practices increasingly unreliable.

110. **Climate information services are limited, and Ghanaian farmers have limited access to the knowledge, economic, and agronomic resources that support innovation.** The 2018–2021 National Agricultural Investment Plan acknowledges that low transfer and uptake of science, technology, and research findings; low genetic material quality; inadequate mechanization, quality standards, infrastructure, and water management systems; and lack of disease surveillance are major limiting factors for the development of the Ghanaian agricultural sector.¹⁴² Advisory and information sharing systems are crucial to Ghana's agricultural development.¹⁴³ Furthermore, they allow the pivotal reporting that supports risk mitigation measures, such as early warning systems and advice for pest outbreaks or identifying livestock disease outbreaks and mitigating them with early action. Such services, coupled with financial services, would allow farmers to invest in innovation and vastly improve their capacity to make informed farm management decisions.¹⁴⁴

111. **Current agricultural extension services need to be improved to take better advantage of research, technology, or science innovations.**¹⁴⁵ The current national extension model is costly to implement and has not yet scaled to reach most farmers. Farmers respond to this lack of information by delaying farming decisions, hoping they will receive some useful information later. Delayed decision-making, combined with erratic weather patterns, often results in farmers missing crucial windows for field management activities. Climate and knowledge services can fix this gap by providing timely and reliable agricultural forecasting if all stakeholders are involved in both producing and disseminating climate information.¹⁴⁶ Climate and knowledge must be available and designed to reach smallholders via a variety of channels and formats. For example, the CCAFS has been a leader in participatory production of climate services that integrate farmer knowledge and experiences with meteorology.¹⁴⁷ Furthermore, the World Bank Agriculture Observatory uses existing global data to provide near-real time data to help farmers receive information relevant to their current situation, allowing extension agents and farmers to implement tailored and fast solutions to emerging risks.

112. **Investing in innovation is disincentivized by current tenure regimes, input costs, and land-use planning practices.** The Ghanaian government has recognized tenure insecurity and poor marketing systems as major limiting factors to national agricultural development.¹⁴⁸ Private land ownership is quite

¹⁴¹ Antwi-Agyei, Dougill, and Stringer, "Assessing Coherence between Sector Policies and Climate Compatible Development."

¹⁴² Ministry of Food and Agriculture, "Investing for Food and Jobs: An Agenda for Transforming Ghana's Agriculture."

¹⁴³ Abdul-Razak and Kruse, "The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana"; Francis Z.

Naab, Zaid Abubakari, and Abubakari Ahmed, "The Role of Climate Services in Agricultural Productivity in Ghana: The Perspectives of Farmers and Institutions," *Climate Services* 13 (January 2019): 24–32, <https://doi.org/10.1016/j.cliser.2019.01.007>.

¹⁴⁴ Samuel T. Partey et al., "Developing Climate-Smart Agriculture to Face Climate Variability in West Africa: Challenges and Lessons Learnt," *Journal of Cleaner Production* 187 (June 2018): 285–95, <https://doi.org/10.1016/j.jclepro.2018.03.199>.

¹⁴⁵ Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund," Emission Reduction Programme Document (World Bank, April 21, 2017).

¹⁴⁶ M.C. Lemos and B.J. Morehouse, "The Co-Production of Science and Policy in Integrated Climate Assessments," *Global Environmental Change* 15, no. 1 (2005): 57–68, <https://doi.org/10.1016/j.gloenvcha.2004.09.004>.

¹⁴⁷ Naab, Abubakari, and Ahmed, "The Role of Climate Services in Agricultural Productivity in Ghana."

¹⁴⁸ Ministry of Food and Agriculture, "Investing for Food and Jobs: An Agenda for Transforming Ghana's Agriculture."

uncommon, and most land is held communally in the trust of chiefs under customary land tenure systems. Public lands held in trust by the government are also prevalent. The cost of inputs to improve productivity on existing lands often exceeds the cost of agricultural expansion, especially for cocoa production, leading to forest clearing. There is a complete lack of rural land-use planning policy and practices. Furthermore, forest conservation laws are difficult to enforce given the minimal resources and low capacity of the Forestry Commission.¹⁴⁹

3.8. Assessing Design and Implementation Opportunities in CSAIP Priority Investments

Opportunities: Building on Existing CSA Activities

113. **Momentum from existing programs and initiatives can be used to leverage continued growth and development in Ghana’s agricultural sector.** Over 80 programs and initiatives (Table 20), funded by both the Ghanaian government and international donors, have driven agricultural sector growth.¹⁵⁰ Most projects have focused on enhancing productivity, sustainability, and rural livelihoods; some projects also include capacity development.¹⁵¹ Several government-funded initiatives focus on fostering an enabling environment for private sector actors in various commodity value chains.¹⁵² Participatory studies of projects in Ghana indicate that those focusing on economic resources, awareness, and capacity development have the greatest impact on preparing smallholders to adapt to climate change.¹⁵³ Programs focusing on infrastructure, social capital, and institutions have the least impact on smallholders’ adaptive capacity,¹⁵⁴ which remains low, particularly in northern Ghana.¹⁵⁵ All programs, in addition to meeting the broader goals of the NDCs, should contribute to building farmers’ adaptive capacity to maximize benefits given climate change.¹⁵⁶

114. **Continued climate-smart innovation in Ghana requires support from many sectors, including Ghana’s government, non-profits, the private sector, and international organizations.** Bilateral and multilateral donors have been the primary programs funders to date and have recently committed to strong continued support, particularly of climate adaptation efforts.¹⁵⁷ The Government of Ghana has also been the sole funder of several programs.¹⁵⁸ Non-profit organizations have played a key role in program implementation.

115. **The West African Alliance for Climate-Smart Agriculture, one of several international alliances to which Ghana is signatory, is a key opportunity for Ghana to develop water management infrastructure.** Launched in 2015 by the Economic Community of West African States, this alliance serves as a platform to actively promote CSA mainstreaming, particularly for the resilience of vulnerable populations. As an alliance member, The West African Monetary and Economic Union contributes to developing both water resource infrastructure and financial and policy mechanisms related to irrigation

¹⁴⁹ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund.”

¹⁵⁰ Ghana Statistical Service, “Provisional 2017 Annual Gross Domestic Product.”

¹⁵¹ Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

¹⁵² Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture.”

¹⁵³ Partey et al., “Developing Climate-Smart Agriculture to Face Climate Variability in West Africa.”

¹⁵⁴ Abdul-Razak and Kruse, “The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana.”

¹⁵⁵ Abdul-Razak and Kruse.

¹⁵⁶ Government of Ghana, “Ghana’s Intended Nationally Determined Contribution.”

¹⁵⁷ Global Commission on Adaption, “Adapt Now: A Global Call for Leadership on Climate Resilience,” September 13, 2019.

¹⁵⁸ Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

for agriculture. This is closely aligned with Ghana’s NDC plan. Given the predictions of future water scarcity in Ghana, water management in the context of climate change is key to continuing agricultural sector growth. Careful coordination at the national level will help engage these multinational actors behind a climate-resilient Ghanaian agenda.

Table 20: Select Current CSA Projects in Ghana¹⁵⁹

Fund	Project	CSA Relevance	(US\$, millions)	Term
World Bank	West Africa Agricultural Transformation Program (WAATP)	Strengthens regional agricultural innovation systems to enhance adoption of climate-smart practices	277.00	2018–2022
	Ghana Commercial Agriculture Project	Increases access to inputs for climate resilience	50.00	2019–2020
	Ghana Forest Investment Program (FIP)	Reduces forest loss and degradation	19.39	2019–2023
African Development Bank (AfDB)	Ghana Cocoa Sector Investment Project	Improvement of cocoa value chain through productivity enhancement programs, storage, processing, and promoting local consumption	600.00	2018–2024
Department for International Development	Africa Agriculture Development Company (AgDevCo)	Provides capital and technical assistance in rural areas, and contributes to farmers' resilience to climate change	190.17	2013–2023
European Union, German Government	Market Oriented Agriculture Project	Creates an environment for agricultural investments	175.38	2017–2021
International Fund for Agricultural Development (IFAD)	Adaptation for Smallholder Agriculture Program (ASAP)	Enhances profitability and resilience to climate change among smallholder farmers	113.00	2012–2023
International Fund for Agricultural Development	Ghana Agricultural Sector Investment Program	Promotes and mainstreams climate change resilient approaches	77.99	2014–2021
Global Environmental Fund (GEF) Trust Fund	Sustainable land and water management - Second additional financing (Food IAP)	Expands area under sustainable land and water management practices	12.77	2015–2020
Dutch embassy	HortiFresh Project	Enhances competitiveness of fruit and vegetable sector for inclusive economic growth	9.90	2018–2021
Adaptation Fund	Increased resilience to climate change in northern Ghana through water	Enhances resilience and adaptive capacity of communities around water resources against climate risks	8.30	2016–2020

¹⁵⁹ Ministry of Foreign Affairs of the Netherlands, “Ghana Climate Change Profile”; NCD Support Programme, “Ghana”; Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture”; Climate Investment Funds, “Engaging Local Communities in REDD+/Enhancement of Carbon Stocks,” March 15, 2018, <https://www.climateinvestmentfunds.org/projects/engaging-local-communities-reddenhancement-carbon-stocks>; Global Environment Facility, “Preparation of Ghana’s Initial Biennial Update Report to UNFCCC,” June 4, 2016, <https://www.thegef.org/project/preparation-ghanas-initial-biennial-update-report-unfccc>; World Bank, “Ghana Climate Innovation Center,” Text/HTML, February 2016, <https://projects.worldbank.org/en/projects-operations/project-detail/P145765>.

Fund	Project	CSA Relevance	(US\$, millions)	Term
	resources management and diversification of livelihoods			
Mondelēz International Cocoa Life	Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II) project	Adopts sustainable environment and climate change cocoa production and conserves natural resources	1.85	2016–2020
United Nations Development Program (UNDP), Government of Germany	NDC Support Program	Advances implementation of Paris agreement on climate change	1.70	2017–2020
Danish International Development Agency	Climate-Smart Cocoa Systems for Ghana (CLIMCOCOA)	Assesses the role of agroforestry as a model for CSA in cocoa production	1.48	2016–2020
Japanese government	Climate resilience and food security through sustainable agroforestry cocoa production within Ghana	Promotes sustainable biodiversity, and reclaims mined/degraded lands among smallholder cocoa farmers	0.80	2019–2020
Food and Agriculture Organization	Promotion of conservation agriculture and IPM for sustained soil fertility and	Enhances sustainability of natural resource base specifically soils	0.41	2019–2021

Note: See Annex B, Section C for past projects.

Design and Implementation Opportunities

116. **There are a number of opportunities that were identified for the priority investments that potentially offset the challenges noted above** (Table 21). The strongest by far is the research capacity, knowledge base, and expertise that exists in Ghana. There is a strong network of universities and research institutions, as well as leadership in agricultural sciences. For example, well-established national research facilities and programs and multiple university programs training agricultural professionals, including researchers already exist for ruminants, supporting the design and implementation of this investment. While there might be room for improvement, the research capacity was noted as an opportunity in eight of the nine potential investments. Local support of some type, whether generally or because of knowledge of some part of the investment, was cited as important for six of the nine investments. For example, many farmers already have knowledge about some cereal-legume interactions, even if they do not know the optimal mix for their area. For the root-tubers-livestock investment, most smallholders already own livestock in partial integration with crop systems. High potential for profit was an incentive to encourage people to participate in four of the investments. Each project concept in Annex A contains a fuller description of opportunities.

Table 21: Opportunities Supporting CSAIP Investment, Design and Implementation

Area of Investments	Research/ Knowledge/ Expertise	Local Support/ Demonstrated	High Profit Potential	Trade/Intl. Investment	Enabling Policy
Sustainable Fisheries and Aquaculture	✓		✓	✓	✓
Cocoa Production	✓	✓	✓	✓	
Tree Crop Production		✓	✓	✓	✓
Water Management	✓				✓
Cereal-Legume Integration	✓	✓			
Poultry Production	✓		✓		
Ruminant Production	✓	✓			
Root-Tuber-Livestock	✓	✓			
Knowledge and Advisory	✓	✓			

Note: The cells in white color code implies that there is little or no support on the area of investments.

3.9. Assessing the Potential for Supporting Collaboration and Partnerships and Institutionalizing CSAIP Investments

117. **Partnerships and the number of potential collaborators can contribute benefits or complexity, depending on what the arrangements are with specific partners.** Clarifying obligations up front is vital to strong partnerships, by allowing a consideration of how well partners can operationalize to support project design and implementation (for example, what they bring) versus the obligations inherent in partnerships (what partners expect). There are also huge differences in the level of involvement of partners, especially in the areas of support and expertise, funding, and legal requirements. Projects with many partners need to prioritize and clarify the roles and responsibilities of all partners at the outset. This can be particularly challenging when public sector partners are involved, necessitating clear identification of lead agencies, funding flows and responsibilities, which ministries or agencies have authority, and how to resolve any policy conflicts.

118. **Many of the projects noted entail a variety of potential public sector partnerships (Table 22); only those public sector entities that were mentioned at least twice appear here, so some projects could be more complex.** The Ministry of Agriculture and the EPA were the most frequently mentioned collaborators, suggesting that as the CSAIP moves forward, special channels should perhaps be opened to facilitate support with them. Links with Ghanaian universities was also prioritized by six of the investments. Again, this suggests that special facilitation and tracking in these projects might support collaboration. Finally, with regard to institutional complexity, both the tree crop production and water management projects mentioned at least five government entities for collaboration, suggesting a clear need to carefully plan how this collaboration will proceed and what the government entities will facilitate.

119. **Many of the proposed investments involve a of international and national NGO collaborators, ranging from research institutions to Ghanaian NGOs.** The collaborators identified in Annex A for each investment serve as a preliminary list, since others will be identified during the design and implementation process. The ruminant investment had the greatest number of potential collaborators identified (eight overall), while cocoa, cereal-legume, and root-tuber-livestock each identified seven potential partners. Again, this level of engagement has both benefits and costs, and the greater the number of collaborators,

the more important it is to have a clear plan for what the collaboration entails. Tree crops, water management, fisheries and aquaculture, and knowledge and advisory all identified five potential collaborators. Poultry production had the smallest at two.

Table 22: Most Frequent Key Public Institutional Collaborators Identified by Investment

	Key Public Institutional Collaborators							
	Min Ag (7)	Min Land & Nat Res (3)	EPA (7)	Forestry Comm (3)	Redd++ (2)	Min Fish & Aqua (2)	Fish comm (2)	Ghanaian Universities & Research Organizations (9)
Tree Crop Production	✓	✓	✓	✓	✓			✓
Water Management	✓		✓			✓	✓	✓
Sustainable Fisheries & Aquaculture			✓			✓	✓	✓
Cocoa Production		✓	✓	✓	✓			✓
Cereal-Legume Integration	✓	✓	✓	✓				✓
Ruminant Production	✓		✓					✓
Root-Tuber-Livestock	✓		✓					✓
Poultry Production	✓							✓
Knowledge & Advisory	✓							✓

120. **Engaging both public and NGO collaborators offers potential mechanisms for institutionalizing CSAIP objectives, both for specific investment and for the overall CSAIP.** However, this will not happen spontaneously and must be purposefully planned. Stakeholders and technical experts consistently identify several foundational elements that must be firmly established to institutionalize CSAIP in Ghana. Key elements, summarized below, underlie the primary opportunities and key barriers to the success of CSA in Ghana:¹⁶⁰

- Broad acknowledgement of the cross-cutting and significant impacts of climate change, and broad support and mechanisms for institutional responses to it
- Acknowledging climate change and its impacts while developing and realigning policies and frameworks to form a cohesive and supportive national policy framework
- Collaboration and coordination across agencies, ministries, sectors, and stakeholders to achieve the agreed-upon objectives to address climate change issues

¹⁶⁰ Antwi-Agyei and Dougill, “SRI Briefing Note Series No.13”; Akhtar-Schuster et al., “Improving the Enabling Environment to Combat Land Degradation: Institutional, Financial, Legal and Science-Policy Challenges and Solutions.”; Abdul-Razak and Kruse, “The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana”; Antwi-Agyei, Dougill, and Stringer, “Assessing Coherence between Sector Policies and Climate Compatible Development”; Cárdenas et al., “Policy Coherence for Climate-Sensitive Planning in Ghana”; Government of Ghana, “Ghana’s Intended Nationally Determined Contribution”; Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture”; Naab, Abubakari, and Ahmed, “The Role of Climate Services in Agricultural Productivity in Ghana”; Voorhies, “OPINION: How to Stop Climate Change Robbing African Farmers of a Brighter Future”; Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture.”.

- Expanding institutional capacity and human resources to make the changes necessary to establish coherence, collaboration, and coordination toward meaningful action and outcomes
- Strong funding support from the Ghanaian government, the private sector, international donors, and multilateral organizations

3.10. Assessing Financing in CSAIP Priority Investments

121. **Finance remains a major issue for implementing climate actions in Ghana.** Smallholders have been investing their meagre financial resources in adapting to climate change over the years.¹⁶¹ Now, more funding streams are needed to take changes to scale and meet Ghana’s NDC commitments. Ghana’s government¹⁶² and other stakeholders acknowledge financing as the cornerstone of meeting NDC and other national climate-related objectives, yet most climate actions are limited by inadequate funding for research, capacity building, and program implementation.¹⁶³ Doubling the share of the total public budget invested in agriculture would more than double sectoral growth rates, with direct impacts on household and national prosperity.¹⁶⁴

122. **A significant portion of Ghana’s NDC commitments are contingent on international funding support.** The Ghanaian government estimates that US\$22.6 billion will be needed to finance its NDC commitments. Approximately US\$6.3 billion can be mobilized domestically—US\$1.4 billion from the national budget, US\$1.7 billion from corporate social responsibility, and US\$3.2 billion from commercial facilities. This implies that 72.12 percent of the total estimated cost must be sourced internationally. Given this international support, Ghana expects to be able to triple its emissions reduction—from 15 percent to 45 percent relative to business as usual—by 2030.¹⁶⁵

123. **Mobilization of sustainable domestic funding is crucial to sustaining long-term change.** Robust institutional capacity will be key to establishing the necessary structures and mechanisms.¹⁶⁶ Two major foci of the 2018–2021 IFJ program are creating an enabling environment for private sector engagement and increasing public sector funding to at least 10 percent of the national budget, as specified by the Malabo Declaration.¹⁶⁷ As part of the CSAIP development, stakeholders identified the following as high-potential funding frameworks for supporting sustainable climate action in Ghana:

- Multi-level coordinating units on CSA investments
- Including CSA investment expenses in national budget planning
- Passing legislation for CSA investment funds like GETFUND, to be monitored by a multisectoral technical committee, and responsible for:
 - Ensuring flexibility and availability of funds
 - Ensuring coordinated use of funds
 - Integrating sources of finance to engage and attract local private sector investors

¹⁶¹ Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

¹⁶² Government of Ghana, “Ghana’s Intended Nationally Determined Contribution.”

¹⁶³ Antwi-Agyei and Dougill, “SRI Briefing Note Series No.13”; Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

¹⁶⁴ Aragie Emerta, Artavia Marco, and Pauw Karl, *Strategic Public Spending: Scenarios and Lessons for Ghana* (Intl Food Policy Res Inst, n.d.).

¹⁶⁵ Government of Ghana, “Ghana’s Intended Nationally Determined Contribution.”

¹⁶⁶ Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

¹⁶⁷ Ministry of Food and Agriculture, “Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture”; AUDA-NEPAD, “Tracking Progress: Ghana.”

- A centralized system for fund-related decision-making representing government, development partners, civil society, and other stakeholders

124. **Financing costs and needs are well within the scope of reasonable projects that are financed by a range of institutions and organizations.** There are a range of different approaches to funding for the nine investments, from multilateral and bilateral organizations, foundations and donors (for example, Gates Foundation) to national budgets, NGO support, and private sector financing (see Table 23). Six of the priority investments will mainly target multilateral and donor organizations for financing. In contrast, there is the perception that the investment in cocoa production could come primarily from the private sector. Financing for ruminants, fisheries, and tree crops will draw on a mix of public and private sector funds. There are large differences in the overall cost of projects, from a high of US\$70 million for water management to a low of US\$29 million for tree crop production. These overall costs can be balanced against the cost per beneficiary: both water management and fisheries and aquaculture have the highest costs (US\$500 per beneficiary) while knowledge and advisory has the lowest cost (US\$100 per beneficiary). Yet overall budgets and costs per beneficiary are simply that. A BAU scenario, where the international community fails to support Ghana’s desire to increase capacity, productivity, and resilience as part of transforming the overall sector, would suggest the costs of inaction are high.

Table 23: Financing Needed and Key Identified Potential Sources

CSA Investment	Estimated Project Budget (US\$)	Beneficiaries	Cost per Beneficiary (US\$)	Potential Sources of Funding
Water Management	70,000,000	140,000	500	Multilateral and donor organizations (for example, World Bank, AfDB, UK’s Department for International Development (DFID), Gates Foundation)
Cocoa Production	54,000,000	150,000	360	Private sector funds (for example, large processors such as Nestle and Cadbury)
Knowledge & Advisory	50,000,000	500,000	100	Multilateral and donor organizations (for example, World Bank, EU) and NGOs (for example, Innovations for Poverty Action (IPA), Farm Radio)
Root-Tuber-Livestock	50,000,000	200,000	250	Multilateral and donor organizations (for example, World Bank, AfDB, Gates Foundation, IFAD)
Ruminant Production	37,500,000	150,000	250	Public and private sector funds such as the Global Climate Fund, national budgets, and so on.
Fisheries and Aquaculture	35,000,000	70,000	500	Public and private sector funds such as the Global Climate Fund, national budgets, and so on.
Cereal-Legume Integration	32,000,000	200,000	160	Multilateral and donor organizations (for example, World Bank, AfDB, Gates Foundation)
Poultry Production	32,000,000	160,000	200	Multilateral and donor organizations (for example, World Bank, AfDB, Gates Foundation)

CSA Investment	Estimated Project Budget (US\$)	Beneficiaries	Cost per Beneficiary (US\$)	Potential Sources of Funding
Tree Crop Production	29,040,000	120,000	242	National Budgets, Private Sector, Multilateral & donor organizations (for example, United States Agency for International Development [USAID], World Bank, AFD (France), KfW (German Development Bank), World Cocoa Foundation)

125. **An operational framework to guide CSA programming into practice will help ensure that funding is focused on priorities crucial to project success.** Effective frameworks support planning and implementation by producing concrete information. There are many potential private, public, and international funders and financing instruments, as shown in Table 23 and in Annex B, Section 4. Developing financing strategies specifically for priority investments, or creating packages tailored to specific donors can help secure funding. Specific targeting and proposed partnerships with the private sector, where appropriate, are also vital.

3.11. Key Objectives of CSAIP Priority Investments

126. **The CSAIP investments build on Ghana’s own policy priorities.** Specifically, Ghana has sought to create jobs, improve value chains, reduce food imports, and increase exports. We have added another way to assess investments: whether it has the potential, as a demonstration project, to leverage change and begin to transform a sector (Table 24). This is done by examining whether the investment was aligned with any of the following national priorities:

- Supporting Food and Nutritional Security
- Building Agricultural Sector Resilience
- Creating Jobs and Value Chains
- Improving the Balance of Trade
- Supporting Mitigation
- Supporting Agricultural Sector Transformation

127. **Investments such as diversified tree crops, irrigated rice, aquaculture and cocoa are critical to implement because of their importance in transforming specific sectors.** Many of these investments are targeted in national strategies and have strong national support. Aquaculture, irrigation and rice, cocoa and diversified tree crops (due to their value chains and jobs) are crops and strategies directly identified in the IFJ plan. Several are also mentioned in the ‘Planting for Export and Rural Development’ plan. These plans may have higher costs because they use new technologies, infrastructure, breed or seed varieties, or other components that require greater initial investment. However, they are intended to maintain a sector that is important to the country but declining, ensuring its climate resilience (for example, cocoa), or to introduce new technologies and practices for resilience and sustainability (for example, aquaculture) while supporting value chains or build new infrastructure (for example, water management and irrigation for rice) that can reduce flooding and support production.

Table 24: Objectives of Investments - Main Benefits from Each Investment

	Food security	Resilience	Value Chains	Trade	Mitigation	Transform Sector
Cereal-Legume Integration						
Knowledge & Advisory						
Poultry Production						
Tree Crop Production						
Cocoa Production						
Water Management						
Root-Tuber-Livestock						
Fisheries & Aquaculture						
Ruminant Production						

Note: Mitigation only refers to projects that sequester carbon, even though other projects reduce emissions intensity).

128. **The Global Commission on Adaptation¹⁶⁸ identifies four key and high-priority recommendations to help countries adapt to climate change that emphasize supporting small-scale farmers.**

- Improve smallholder productivity
- Help small producers manage risks from increased variability and climate shocks
- Address the challenges of the most climate-affected and vulnerable
- Achieve policy coherence by making agriculture interventions climate-smart

129. **All investments support smallholder productivity and help small producers manage and reduce risks from climate change impacts and other shocks.** From extension agents providing timely and accurate information (for example, what to do in case of a drought), to resilient seeds and animal breeds, increasing resilience and decreasing or managing risks is integral to this portfolio. The portfolio also targets the vulnerable in different ways. Through geographic focus on Ghana’s poorest regions, investments in farm systems used by Ghana’s poorest farmers, and investments that support women and youth by creating new jobs and value chains, this portfolio supports those most in need. While policy interventions are not a focus of the CSAIP, having a strong portfolio of CSA investments that demonstrate supportive and barrier policies helps achieve policy coherence and furthers CSA across the policy arena.

130. **Taken together, these investment opportunities represent a well-balanced portfolio.** The investments span different sectors of the country, have different levels of risk, target divergent groups of beneficiaries, and introduce a wide range of well-demonstrated CSA technologies and practices (see Annex A for details). All the investments support risk reduction and resilience, support CSA pillars, and contribute to meeting the objectives, as identified in Ghana’s national plans, that are fundamental to addressing its future.

¹⁶⁸ Global Commission on Adaptation 2019; WRI, 2019

CHAPTER 4: SUMMARIES OF THE NINE PRIORITIZED CSAIP INVESTMENTS FOR GHANA

131. **This CSAIP includes two national-scale investments and seven regional climate-smart crop and animal investments.** The national investments are designed to provide information, capacity building, infrastructure, and national-level services to enable CSA to be practiced across Ghana. The regional investments are focused on productivity, resilience, and GHG emissions of specific crops and animals in specific regions of the county. The section below presents the summaries of the nine investments. The full concept notes can be found in Annex A.

4.1 KNOWLEDGE SYSTEMS AND ADVISORY SERVICES SUPPORTING CSA

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: National

BENEFICIARIES: 500,000 small farmers and their families

PDO: Establish robust research and extension services, leveraging appropriate information communication technologies, to augment farmer productivity, adaptivity, and mitigation in the face of climate change.

HIGHLIGHTS: National-scale program; foundational to CSA, and sound agricultural progress across Ghana; supports all three CSA pillars; strong economic and financial support; highly aligned with national needs and strategies

KEY INVESTMENTS:

- Evidence-based research
- Extension services
- ICT advisory services, particularly climate information services
- Capacity building

JUSTIFICATION AND KEY INVESTMENTS

Strong agricultural research and extension networks are the primary predictor of agricultural productivity growth in Sub-Saharan Africa. Extension programs in Ghana have increased farm income by 11–111 percent, household income by 23–85 percent, and per capita income by 21–110 percent. Climate information services are particularly helpful to farmers facing erratic weather patterns. In Ghana, 85 percent of farmers are willing to register at a cost of GHS 1; 50 percent would register for GHS 2; but just 19 percent would register for GHS 3. Access to and use of a mobile phone significantly improve farmers' livelihoods. An estimated 87 percent of farmers own mobile phones, versus just 38 percent in 2014. Farmers use mobile phones to negotiate bulk input and sale prices and sell their produce beyond their own communities. About 80 percent self-report that owning a mobile makes it easier to communicate with intermediaries and other customers; 68 percent report selling at higher prices; and 89 percent report improved incomes. Farmers contact extension agents to inquire about onset of rains, planting times, input sources, and input availability or to report pests and diseases.

Increasing demand and limited resources have strained Ghana's free public extension services despite efforts to revitalize the services. Both men and women farmers rate mobile phone-based dissemination of information as a useful alternative to the conventional agent-based extension services in northern Ghana. Farmers must be encouraged to access extension services using mobile phones irrespective of age, sex, education, experience, and size of holdings. Extension agents need to meet the demand for these services using the best available science and CSA practices.

KEY PROJECT INVESTMENTS

- Evidence-based research; extension services; ICT advisory service, particularly climate information services; capacity building

POTENTIAL PROJECT IMPACTS

PRODUCTION	Increase in farmers' productivity
RESILIENCE	Services are foundational to providing farmers with the real-time and longer-term data necessary to overcome climate shocks and build resilience
MITIGATION	Small mitigation benefits accrue by supporting CSA practices, estimated at 0.23 MtCO ₂ e sequestered over the project's 20 years
COST	Cost of US\$100 per beneficiary or a total cost of US\$50,000,000
YIELD	Increases yield of 500,000 farmers by 21 percent, also farmers share info locally

ECONOMIC AND FINANCIAL ANALYSIS

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in Yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
500,000	21	198.1	58	4.74	2.99 (14.31)
Without Climate and Pest Risks					
500,000	21	331.0	61	7.90	4.99 (17.12)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Robust research network
- University degree programs in agricultural studies produce qualified agricultural extension experts
- Good mobile phone penetration
- Strong informal community networks and the opportunity to leverage them for advisory services
- Strong alignment to seven NDC goals: cocoa emission reduction; conservation agriculture; postharvest storage and processing; livestock and aquaculture productivity; governance reform; water distribution and access; livelihood diversity
- Supportive to five NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; wildfire management; actively manage natural spaces
- Commitment of policy makers and implementers at all levels of governance

KEY RISKS

- Segregation, particularly in gender, for both advisory services and capacity to use ICT
- External circumstances that dissuade or prevent farmers from implementing recommendations, including restrictive land tenure; unreliable access to profitable markets; lack of safe harvest storage; dearth of financial services such as loans and credit
- Strong social and cultural norms that limit adoption of innovative practices
- Barriers such as technology cost, synergy with government plans, finance, gender inclusivity, lack of support from government and other organizations

FINANCING

Public Financing Opportunities

- Blended finance opportunities via the MoFA and public research institutions and investments in the extension system

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency, for example, USAID, FAO, World Bank

Private Financing Opportunities

- Private sector actors are invested in providing funding for the advisory services in their particular value chain to ensure continued productivity as an investment in their own business profitability

Most Promising Supporting Digital Agriculture Technologies

- Mobile finance services, digitized farm records, and smart contracting
- Mobile extension and climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support management decisions
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

4.2 INTEGRATED WATER RESOURCE MANAGEMENT FOR RICE

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: National

BENEFICIARIES: 140,000 small farmers and their families

PDO: Fully leverage Ghana's water resources in sustainable ways to improve productivity, nutritional security, climate resiliency, and ecological health.

HIGHLIGHTS: Rice is nutritious, in high demand, and is resilient to climate impacts; it needs water and improved farming techniques; project increases small farmer income by 44 percent; project provides the basis for introducing new water management strategies into rice production

KEY INVESTMENTS:

- Water harvesting and irrigation systems
- Capacity building and water management
- CSA rice production

JUSTIFICATION

The vast majority of Ghana's agriculture depends on rainfall, which is becoming increasingly erratic and difficult to predict with climate change. Pollution, population growth, high evapotranspiration, and environmental degradation have reduced water availability. Water harvesting or irrigation are not appropriate interventions across all scenarios: the feasibility and potential impacts of such programs vary widely across geography, time (given growing climate change impacts), the population served (economies of scale), and the type of water harvesting/irrigation system used. Robust extension and finance services are crucial to the success of water harvesting and irrigation systems. In some cases, improved use efficiency of existing water sources removes the need for new technologies. For example, rice farmer training in northern Ghana increased labor efficiency by 7.3 kg/worker/day, and total output by 797 kg. Fully utilizing reservoir storage capacity, maintaining infrastructure, reducing water conveyance network losses, and optimizing field-level management has been shown to improve water use efficiency by 58–68 percent in existing Ghanaian irrigation systems.

Deliberate water management, conservation, and resource-use efficiency are necessary to create resiliency in the face of climate change-induced droughts, floods, and land degradation. Robust infrastructure, effective farmer training, good farmer access to financial services, augmented institutional capacity to deliver extension services, and strong inter-ministerial and intersectoral collaboration will be crucial components of successful efforts. Farmer capacity building through extension, along with enough institutional resources for maintaining and improving infrastructure, are crucial to fully leveraging existing systems and technologies. Flood recession agriculture, widely practiced in other arid regions of West Africa, may be particularly promising for water- and fertilizer-constrained farmers in flood-prone areas. Integrating aquaculture with water harvesting and irrigation systems could offer synergetic benefits to both systems. There are also synergies between national gender equality goals and irrigation policy goals as yet largely untapped.

POTENTIAL PROJECT IMPACTS

PRODUCTION	CSA investments boost rice yields
RESILIENCE	Project supports rice, which is already a relatively resilient crop
MITIGATION	Benefits by supporting CSA practices are estimated at 2.35 MtCO ₂ e _q sequestered over the 20 years
COST	Cost of US\$500 per beneficiary, or a total cost of about US\$70,000,000
YIELD	Increased by 44 percent for 140,000 small farm families

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks

Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
140,000	44	143.7	89	2.32	1.54 (2.36)
Without Climate and Pest Risks					
140,000	44	171.1	90	2.78	1.84 (2.47)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana’s NDCs and many other national policies
- Abundant national water resources
- Governmental support for integrated water management strategies
- Research community engagement in water management innovation
- Strong synergies between national gender equality policy and national water management policy

KEY RISKS

- Competition for resources (for example, urban areas, aquaculture)
- Erratic and extreme precipitation due to climate change
- Capital-intensive nature of water management technologies
- Poor access to farmer-focused extension and finance services that support effective water management
- Limited institutional capacity to maintain infrastructure and provide crucial services to farmers
- Traditional cultural norms and taboos
- High variability in suitable interventions across time, space, and economies of scale
- Low financial commitment by farmers for maintenance

FINANCING

Public Financing Opportunities

- The Government of Ghana is investing in strategies to improve water resource management

International Financing Opportunities

- Several international donors and NGOs are investing in improving water management in Ghana

Private Financing Opportunities

- Collaboration with aquaculture and rice industry stakeholders may offer private sector resources

Most Promising Supporting Digital Agriculture Technologies

- Mobile finance services and digitized farm records to support credit line establishment for investing in small scale water harvesting technology
- Smart contracting for transparent and equitable land tenure processes, enabling farmers to secure land on which to install water harvesting technology
- Mobile extension and climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making
- Remote sensing, drones, GPS, IoT, and GIS for informing the establishment and management of water reservoirs and monitoring water resources

4.3 CEREAL-LEGUME INTEGRATION

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Savannah, Transitional

BENEFICIARIES: 200,000 farmers and their families

PDO: Introduce and optimize current cereal-legume rotations by developing climate-resilient crop varieties and introducing the best soil fertility management practices.

HIGHLIGHTS: Raises income for 200,000 poor farming families by 40 percent; CSA actions reverse projected climate change maize yield losses, support sorghum resilience, and double groundnut yield; project has a positive NVP of 93 percent demonstrating high likelihood of success; CSA actions increase yields, build cropping resilient systems at household scales, improve soil quality, reduce land degradation, increase food security, and provide a basis for groundnut exports

KEY INVESTMENTS:

- Heat-, drought-, and disease-resistant or tolerant crop varieties
- Integrated soil fertility management, including the use of organic and inorganic fertilizers, mulching, intercropping, and reduced tillage

JUSTIFICATION

Cereals are a mainstay of the Ghanaian diet and critical for food security. Legume-grain rotations dominate the Ghanaian savannah, providing vital household nutrition and income. However, current crops deplete soils, require management techniques that are not climate resilient, and are often low yield. Improved legume and cereal varieties are needed to create resiliency given climate impacts. Legume-cereal systems can improve soils and productivity. Current soil fertility levels strongly influence the benefits realized and soil fertility levels vary significantly both across the savannah zones and between farms. There is a dramatic opportunity to increase overall legume and soybean production and resilience. This will mitigate agricultural expansion, improve household nutritional and economic outcomes, and foster national food supplies and economic stability.

This CSA integration builds on existing systems and improves the components—rather than building a different system—tailoring existing legume-grain systems for improved soil quality and economic outcomes. Site-specific tailoring is vital to optimize production, and most farmers are unaware of opportunities to tailor legume-cereal systems to their particular region, soils, and farm management goals. Specific legumes may also be better suited to certain savannah subregions. Research suggests that benefits may vary significantly based on the selected legume variety.

POTENTIAL PROJECT IMPACTS

PRODUCTION	Will increase yields for all crops over climate baseline, especially for maize and groundnuts
RESILIENCE	Cereal-legume systems greatly improve food security and soil quality, supporting both crop and household resilience to climate extremes
MITIGATION	Intensification and slowing land conversion accrue sequestration benefits across approximately 20 years
COST	Cost of US\$160 per beneficiary, with a total cost of about US\$32,000,000
YIELD	Increased by 40 percent for 200,000 small farming families

ECONOMIC AND FINANCIAL ANALYSIS

Cereal-legume CBA with and without climate risks

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
200,000	40	109.0	85	4.04	2.63 (5.54)
Without Climate and Pest Risks					
200,000	40	208.8	89	7.77	5.04 (6.96)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana's NDCs and many other national policies
- Strong in-country and international expertise on the CSA approaches and activities needed
- Good base of research throughout Ghana on tailoring these to specific agro-zones, soil conditions, and given farming context
- Broad grassroots support for cereal-legume integration practices
- Previous projects provide foundational lessons and capacity
- Strong institutional network of collaborators, government, research, universities, farmer organizations, NGOs, and international organizations

KEY RISKS

- Poor farmer access to advisory services and climate services
- Poor access to labor-saving technologies for soybean and groundnut harvesting
- Other barriers include irrigation water supply; gender inclusivity; gaps in finance and labor resources; land tenure; technology cost; market access; farm mechanization; and information and input access.

MOST PROMISING SUPPORTING DIGITAL AGRICULTURE TECHNOLOGIES

- Mobile extension, soil, and climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision making
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support input supply and product markets

FINANCING

Public Financing Opportunities

- Blended finance opportunities via the Ministry of Agriculture and public research institutions

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency, for example, USAID, FAO, World Bank

Private Financing Opportunities

- There are limited private financing opportunities for this investment; in-kind collaboration for provision of climate and advisory services is the most promising avenue for private sector engagement

4.4 CLIMATE-SMART COCOA PRODUCTION

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Forest, Transitional

BENEFICIARIES: 150,000 small farmers and their families

PDO: Given climate change, sustain and expand Ghana's agricultural economy through climate-smart innovations in the production of the country's top agricultural commodity.

HIGHLIGHTS: Climate impacts will be high and negative on the sector, but CSA efforts show remarkable ability to reverse losses; individual farmer benefits are high; project is expensive, but justified given demonstration and leverage potential

KEY INVESTMENTS:

- Improve suitability of cocoa growing areas using agroforestry techniques
- Identify new and suitable areas for future cocoa expansion
- Provide heat- and drought-tolerant, disease-resistant planting materials
- Reduce diseases through IPM and cocoa spraying

JUSTIFICATION

Cocoa is a primary driver of the Ghanaian agricultural economy. Over 12 million people rely on the cocoa-producing regions of Ghana for their livelihoods. Cocoa accounts for 1.6 percent of the national GDP and 8.1 percent of the agricultural GDP. Climate change poses significant threats to the Ghanaian cocoa industry and negative impacts on the cocoa economy would have major repercussions for the national economy, rural livelihoods, and development. Current cocoa production practices in Ghana exacerbate these threats and minimize farmers' ability to adapt to the impacts of climate change. Cocoa production drives one of the highest deforestation rates in Africa—3.2 percent annually. Transformation of this sector is required to become sustainable and climate resilient.

Climate-smart agroforestry practices have proven to improve cocoa yields both in Ghana and elsewhere. Yield in most cocoa production areas will show decline from climate change, while some small areas will increase in suitability for cocoa production. In Ghana's cocoa-growing regions, each agroecological subregion is threatened by climate change in distinct ways and to varying degrees. This requires responses and solutions tailored to be region-specific. Digital agricultural innovations show significant promise as over 90 percent of Ghanaian cocoa farmers use mobile phones. Timely, practical push-SMS services to cocoa farmers significantly increases productivity across both large populations and multiple production years. The cocoa sector also holds great sway over livelihoods and ecological sustainability in Ghana; hence domestic and international NGOs, bilateral, and multilateral international donors are also heavily involved in cocoa production in Ghana.

POTENTIAL PROJECT IMPACTS

	This investment will hold yields steady or potentially even double them if the sector is transformed
PRODUCTION	
RESILIENCE	This investment can transform the cocoa sector improving its resiliency and decreasing deforestation.
MITIGATION	Benefits by supporting CSA practices are estimated at 3.20 MtCO ₂ equivalente sequestered over the 20 years (with additional benefits from reducing deforestation)
COST	Cost of US\$360 per beneficiary, or a total cost of about US\$54,000,000
YIELD	Raise incomes for 150,000 cocoa farmers and their families by a projected 32 percent

ECONOMIC AND FINANCIAL ANALYSIS

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
150,000	32	188.8	89	4.15	2.72 (3.96)
Without Climate and Pest Risks					
150,000	32	231.3	93	5.10	3.33 (4.33)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana’s NDCs and many other national policies, such as investing in food and jobs and the Ghana Cocoa and Forests Initiative National Implementation Plan
- Strong grassroots support from community leaders and cocoa farmers
- Strong support from the federal government of Ghana
- Proven high productivity of climate-smart agroforestry cocoa practices
- High profitability of the industry
- Private sector and international investment in continued cocoa productivity in Ghana

KEY RISKS

- Assuring strong collaboration and clear institutional arrangements given numerous actors in the sector, and the need for increasing transparency and efficiency of current policy practices
- Limited farmer and forester access to knowledge, economic, and agronomic resources to support innovation
- Farmer and forester decisions are driven by economic and policy constraints

FINANCING

Public Financing Opportunities

- Blended finance opportunities appear to be the most promising; all financing solutions must necessarily be integrated with the Cocoa Board

International Financing Opportunities

- Emissions Reductions Payment Agreement via Forest Carbon Partnerships Facility Carbon Fund

Private Financing Opportunities

- Many private sector actors are ready to engage in ensuring the sustainability of the cocoa economy in Ghana due to its profitability on the international market.

Most Promising Supporting Digital Agriculture Technologies

- Mobile climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to disseminate research and development outputs and support crop management decisions
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support input supply and product markets
- Smart contracting for transparent, streamlined, and equitable land tenure processes

4.5 CLIMATE-RESILIENT POULTRY PRODUCTION

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Transitional, Savannah, Coastal

BENEFICIARIES: 160,000 smallholder farmers and their families

PDO: Revitalize the Ghanaian poultry sector with climate-smart approaches in feed production and genetic resource enhancement.

HIGHLIGHTS: A vital sector for protein with high and rising demand; climate risks high for maize and for poultry; CSA builds resilience for both maize and poultry sector; increases production to reduce imports; high value chain and private sector potential

KEY INVESTMENTS:

- Improved poultry genetic resources for climactic resiliency and disease resistance
- Information and advisory services on poultry production
- Optimized poultry feed including termite collection innovation, insect protein in poultry feed, and increased national productivity of yellow maize.
- Improved varieties, advisory services for weed control and planting density, and improved access to inputs and advisory services, including for fertilizer and IPM

JUSTIFICATION AND KEY INVESTMENTS

Ghana is capable of self-sufficiency in poultry. Ghanaian consumers prefer domestic poultry products to imported and are willing to pay a premium for the same. Feed represents approximately 82 percent of the cost of poultry production. Maize constitutes 50–60 percent of the total feed formulation, yet 85 percent of the country's maize is grown on farms of less than 2 ha. Maize, without CSA practices, will be the crop that is the hardest hit by climate change impacts. The poultry sector relies on small and medium producers of local breeds and is highly gender segregated. Chickens and guinea fowl are the most commonly produced poultry. Medium- and small-scale poultry producers (fewer than 10,000 birds) comprise 80 percent of national production. Producers, who have the highest ROI and value addition, are predominantly men, while traders and processors are primarily women. The Ghanaian poultry sector has been in steep decline. For example, 80 percent of broilers were domestically sourced in 2000, but by 2010 this had fallen to just 10 percent. Nearly all (98 percent) of birds are local breeds; there is considerable genetic diversity in local chicken breeds, but genetic diversity of guinea fowl is low.

Extreme climactic conditions, such as high temperature, excess rainfall, and drought, lead to heat and water stress, affecting bird health, increasing mortality, and decreasing productivity. There is inadequate access to veterinary services, including vaccinations. Poor infrastructure, market access, and postharvest processes further aggravate these challenging circumstances. Degree of access to financial services has also proven to be particularly important: the sustainability and higher performance of the industry significantly depends on access to financial services. A suite of actions is needed to introduce climate-resilient poultry, feed stocks, and other practices.

POTENTIAL PROJECT IMPACTS

PRODUCTION	Will increase productivity in the poultry industry; increase yields for the relevant crops, especially; and provide opportunity for exploiting alternative protein sources such as insects
RESILIENCE	Neither poultry nor maize, their main feed, are resilient; investment will boost resilience of these commodities
MITIGATION	CSA practices reduce poultry emissions, by 0.39 MtCO ₂ equivalent emitted
COST	Cost of US\$200 per beneficiary, or a total cost of about US\$32,000,000
YIELD	Increased by 27 percent for 160,000 small farming families

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
160,000	27	81.6	71	3.19	1.97 (4.90)
Without Climate and Pest Risks					
160,000	27	119.3	77	4.63	2.88 (5.70)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana's NDCs and many other national policies
- Consumer preference for domestic poultry products and willingness to pay a premium for the same
- Potential for 250–300 percent increase in maize productivity with existing technologies
- Availability of termites and other insects as a low-cost and nutritious source of feed

KEY RISKS

- There is currently a nationwide competition between human food supplies and poultry feed production which may be best alleviated through policy changes.
- Lack of proper animal health facilities and welfare for poultry
- Price and availability of poultry feed
- Collapse or near-collapse of major players
- Poor maize and poultry farmer access to information and inputs

FINANCING

Public Financing Opportunities

- This investment aligns well with any program invested in poultry and maize productivity and national food security

International Financing Opportunities

- This investment aligns well with any program invested in poultry and maize productivity and national food security, for example, FAO, World Bank, IFAD

Private Financing Opportunities

- The private sector has high interest in revitalizing the domestic poultry market; various large-scale producers are prepared to invest

Most Promising Supporting Digital Agriculture Technologies

- Pest and disease early warning systems—enabled by weather stations, big data, machine learning, and mobile technology
- Mobile extension services and mobile market platforms—enabled by big data, machine learning, and mobile technology

4.6 CLIMATE-RESILIENT RUMINANTS

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Forest, Transitional, Savannah

BENEFICIARIES: 150,000 small farmers and their families

PDO: Use climate-smart techniques to increase the resource-use efficiency and climate resiliency of ruminant production.

HIGHLIGHTS: Most Ghanaian farmers have ruminants; this suite of actions increases resilience to climate change, boosts smallholder income and nutritional security, and diminishes risk.

KEY INVESTMENTS:

- Irrigation for growing feed
- Establish grazing and watering corridors for livestock
- Establish browsing stands as fodder banks
- Heat-stress and disease-resistant ruminant varieties
- Manure as an alternative fertilizer

JUSTIFICATION

The diversity of integrated crop-livestock production systems makes them synergistically more productive and resilient than either system alone. Most smallholders' rear ruminants for income; all smallholders produce crops. Small ruminants offer significant benefits to Ghanaian smallholders. Small ruminants have short gestation period, high prolificacy, rapid growth rate, high feed conversion efficiency, high disease resistance capacity, and easy marketability. Small ruminant manure is also an important alternative source of fertilizer, with similar chemical characteristics to synthetic fertilizer. A majority of Ghanaian smallholders already own small ruminants: in northern Ghana, 86–97 percent of smallholders' own goats, 50–88 percent own sheep, and 17–43 percent own cattle. Ruminants in Ghana are primarily fed via free-range grazing and crop residues, and about 90 percent of farmers feed crop residues to their livestock.

The primary constraints on livestock productivity in Ghana include feed scarcity, limited grazing land, theft, high incidence of disease and mortality, poor housing, and high veterinary costs. Methods for increasing feed availability, including shrub browsing stands are necessary to support animal health and productivity. Climate extremes, increasing in prevalence, are exacerbating livestock mortality. Heat- and disease-resistant breeds are increasingly important for maintaining household nutritional and economic security. Improved varieties of ruminants offer significant potential for resource-use efficiency and climate resiliency. Existing technologies in livestock management, breeding, and health could sustainably develop the livestock industry to close the animal protein gap. Livestock corridors can help build resiliency for pastoralists in search of pasture and water resources. There is significant opportunity to align policy with national goals in climate resiliency, productivity, and economic growth. Policies designed to encourage integrated crop-livestock systems and provide the necessary inputs to support adoption of the same will help spread risk and promote farm efficiency and resiliency.

POTENTIAL PROJECT IMPACTS

PRODUCTION	Productivity is increased when these systems improve breeds, feed sources and supplements, and pasture
RESILIENCE	More resilient ruminants and feed sources greatly improve food security, diminish risk, and enhance on-farm and climate resiliency of ruminant production
MITIGATION	Emissions of 0.72 MtCO ₂ e equivalent are generated over 20 years
COST	Cost of US\$250 per beneficiary, or a total cost of about US\$37,000,000
YIELD	Increased by 27 percent for 150,000 small farming families

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks (No CSA practices)					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
150,000	27	38.1	51	1.43	0.77 (7.26)
Without Climate and Pest Risks (CSA practices)					
150,000	27	88.5	65	3.07	1.78 (7.74)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Strong policy alignment, including with the NDC and Ghana Livestock Development Policy and Strategy
- The majority of smallholders already own small ruminants in partial integration with crop systems
- Some local breeds of small ruminants demonstrate heat resistance
- Well-established national research facilities and programs
- Multiple university programs training agricultural professionals, including researchers

KEY RISKS

- Competing interests of pastoralists and farmers
- Historic availability of fodder resources has resulted in low farmer interest in irrigation fodder systems and browsing stands under new climate scenarios
- The amount of labor required for using manure as fertilizer as alternative under extensive grazing system
- Lack of financial and risk mitigation services deters farmers from innovations
- Minimal animal production and health services support systems available
- Lack of coordination between communities and district/national level organizations
- Minimal government investments and policy frameworks in the livestock sector

FINANCING

Public Financing Opportunities

- None identified

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency and food security, for example, USAID, FAO, World Bank

Private Financing Opportunities

- There are potential private financing opportunities for this investment including the African Fertilizer and Agribusiness Partnership, commercial feed producers, and commercial livestock processors

Most Promising Supporting Digital Agriculture Technologies

- Climate services, pest and disease early warning systems, and mobile extension services enabled by weather stations, big data, machine learning, and mobile technology
- Remote sensing, drones, GPS, IoT, and GIS for informing the establishment and management of corridors and water reservoirs and monitoring water resources

4.7 SUSTAINABLE FISHERIES AND AQUACULTURE

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Transitional; Coastal Savannah, Forest

BENEFICIARIES: 70,000 along the entire value chain (small farmers, medium fishers, processors and their families)

PDO: Ensure the continued growth of the Ghanaian aquaculture industry by using climate-smart practices to establish the sustainable production of fish species such as tilapia, catfish, and shrimp.

HIGHLIGHTS: Important possibility of reshaping aquaculture sector to be resilient and meet growing demand; meet growing protein requirements in country; provide jobs and value-added in supply chain; high beneficiary gains; high start-up cost for project although it could leverage the whole sector

KEY INVESTMENTS:

- Improved fish seed (stress and disease-resistant varieties)
 - Improved feed, meeting commercial standards and at lower cost
 - Environmental planning to increase climate resiliency of culture-based fisheries
 - Needs-based research and dissemination of innovation through capacity building
 - Postharvest processing development with a focus on gender integration
-

JUSTIFICATION

The Ghanaian government and World Bank have prioritized innovation in the aquaculture industry and as a result, the sector has grown from 10,200 tons in 2010 to over 57,400 tons in 2016. Yet the industry produces far below its capacity, and consumer demand is high. Aquaculture accounts for about 3–5 percent of the national GDP and employs about 10 percent of the labor force. It is also a nutritional security mainstay: fish provides about 60 percent of the nation's protein. There are outstanding untapped opportunities in Ghana's aquaculture sector: 26 percent of technical potential has yet to be realized, even in the absence of innovations such as producing live feed, marine fish culture, shellfish culture, integrated fish farming, producing native species, and feed innovation. Fish feed accounts for 40–70 percent of the total variable production costs of an aquaculture operation and represents a primary limiting factor for growth of the industry.

Ghanaian aquaculture's current profitability is threatened by serious sustainability challenges. Extreme climate weather events, including erratic rainfall, extreme temperatures, floods, and drought have been shown to decrease small-scale operators' fish supplies by 25 percent and revenue by 53 percent. This creates a direct relationship between climate change and poverty. There is an urgent need to build environmental adaptive resilience via mapping of flood zones, tree planting, dyke systems, and water storage facilities. Climate-smart policies and sustainable resource-use strategies will also play a key role in upholding the aquaculture sector. The aquaculture postharvest value chain remains relatively underdeveloped with opportunities for value addition in reducing postharvest losses, minimizing handling costs, producing higher value products, involving women more, and improving livelihoods.

POTENTIAL PROJECT IMPACTS

PRODUCTION	Higher yield to meet protein demand and limit shocks
RESILIENCE	Highly vulnerable sector that can be made sustainable and climate resilient
MITIGATION	Benefits are relatively low, with 0.35 MtCO ₂ equivalente emitted over 20 years
COST	Cost of US\$500 per beneficiary, or a total cost of about US\$35,000,000
YIELD	Increased by 59 percent for 70,000 small farming families

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
70,000	59	9.6	50	0.29	0.21 (0.92)
Without Climate and Pest Risks					
70,000	59	28.5	63	0.93	0.62 (1.24)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana's NDCs and many other national policies.
- Strong in-country and international expertise on CSA approaches and activities
- High consumer demand with significant growth opportunities and high sector profitability
- Established research centers, associations, councils, and other organizations to integrate value chains
- Strong institutional network of collaborators, government, research, universities, investors, farmer organizations, NGOs, and international organizations

KEY RISKS

- High cost of imported feed and low quality and supply of domestically produced feed
- Poor capacity building and innovation dissemination networks
- Vulnerability of sector to climate change impacts
- Additional barriers include finance and reliability of water supply, cost of technology, support from government and other organizations, land tenure system, market access, availability of resources, and mechanization

FINANCING

Public Financing Opportunities

- Blended finance opportunities via the Ministry of Fisheries and Aquaculture Development and the Fisheries Commission

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency, for example, USAID, FAO, World Bank

Private Financing Opportunities

- Commercial fish feed producers
- Commercial fish seed/fingerling producers
- Large-scale aquaculture operations

Most Promising Supporting Digital Agriculture Technologies

- Smart contracting, blockchain, and barcoding for sustainability certification, labelling, and product tracing
- IoT and remote sensing for monitoring water resources
- Extension and climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making in the face of extreme weather events
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

4.8 DIVERSIFIED TREE CROPS

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Forest, Transitional

BENEFICIARIES: 120,000 small farmers and their families

PDO: Employ agroforestry techniques to make cashew, oil palm, and possibly plantain production climate smart.

HIGHLIGHTS: Agroforestry can sustainably support high-value crop mixes; slowing the rate at which lands are converted to plantations or crop fields; project can help Ghana integrate cashew and oil palm into sustainable agroforestry approaches

KEY INVESTMENTS:

- Agroforestry: Diversification, Intensification, including heat-and drought-tolerant, disease-resistant cashew and oil palm varieties
 - Management of soil fertility, land, and water
 - Advisory systems to promote agroforestry practices
 - Realigning policy with national goals to support profitability and sectoral sustainability
-

JUSTIFICATION

Agroforestry offers many benefits that directly translate to improved productivity, household livelihoods and food security, national economic growth, and domestic food supplies. Ghanaian farmers are also incentivized to practice agroforestry through grants, farming inputs, capacity training, public nurseries, and improved access to markets. Agroforestry represents an important opportunity to more fully engage women and youth in the Ghanaian agricultural sector. Over 85 percent of female Ghanaian farmers already practice agroforestry via alley cropping, scattered trees on farmland, taungya, and home gardens. These women farmers are highly engaged in all farm management activities except applying agrochemicals. Thus, training women in agroforestry and/or as agroforestry focal farmers could significantly enhance agroforestry practices and extension services. Cashew trees offer particular benefits for livelihoods and nutritional security; the cashew harvest occurs in the ‘lean months’ of other major food crops and can provide timely supplementary income.

International demand for oil palm and cashew products is increasing, and Ghanaian farmers are producing for the export market with government support. Yet the cashew and oil palm value chains are rife with environmental issues that threaten the sustainability and ongoing profitability of these industries. Low yields aggravate agricultural expansion, decrease nutritional stability, and exacerbate poverty. For example, Ghanaian oil palm farms yield an average 7 tons/ha/year, even though more than 20 tons/ha/year is achievable with existing management and extraction technologies. Technical inefficiency among producers is strongly correlated with lack of training, experience, and land security. Catalyzing improved productivity through robust extension support would particularly benefit smallholders, with potential yield increases of 1,400 percent and economic increases in excess of US\$1 billion. Cashew and oil palm expansion is a driver of forest loss and has been at the expense of food crops. CSA practices focused on intensification rather than expansion of tree cropping are foundational to climate change mitigation, national nutritional security, and continued socioeconomic development.

POTENTIAL PROJECT IMPACTS

PRODUCTION	Huge potential yield gains are possible with CSA investments
RESILIENCE	Oil palm is not a resilient crop, but CSA can boost resilience through agroforest systems
MITIGATION	Benefits by supporting CSA practices are estimated at 3.40 MtCO ₂ equivalent sequestered over the 20 years (with additional benefits from reducing deforestation)
COST	Cost of US\$242 per beneficiary, or a total cost of about US\$29,040,000
YIELD	Increased by 20 percent for 120,000 small farming families - especially women

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks (No CSA practices)					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
120,000	20	204.2	92	8.24	5.30 (7.85)
Without Climate and Pest Risks					
120,000	20	217.6	94	8.79	5.64 (8.00)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana's NDCs and many other national policies, such as the Ghana Forest Plantation Strategy (2016–2040)
- High profitability of the industry
- Private sector and international investment in continued oil palm and cashew productivity in Ghana
- Proven improved productivity of agroforestry systems
- Strong engagement of female farmers in agroforestry

KEY RISKS

- Lack of institutional resources to enforce forest conservation laws; integrated management and traceability systems; commitment and support from government, private sector, and non-profit stakeholders; and research outputs on best agroforestry practices in Ghanaian oil palm and cashew production
- Institutional culture discourages collaboration between implementing governing bodies and sectors and inertia discourages increasing transparency and efficiency of current policy practices
- Limited farmer access to knowledge, economic, and agronomic resources to support innovation
- Prioritization of cash crops can decrease nutritional security and cause land conflicts

FINANCING

Public Financing Opportunities

- Blended finance opportunities via the Ministry of Agriculture and public research institutions

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency, for example, USAID, FAO, World Bank, and Emissions Reductions Payment Agreement via Forest Carbon Partnerships Facility Carbon Fund
- Possible interest of Bill and Melinda Gates Foundation, German Development Agency (GIZ), Technoserve

Private Financing Opportunities

- The profitability of the oil palm and cashew sectors imply private sector interest in the continued productivity and yields of these crops.

Most Promising Supporting Digital Agriculture Technologies

- Mobile finance services, digitized farm records, and smart contracting
- Mobile extension and climate services enabled by big data, machine learning, and mobile technology
- Mobile platforms to support peer knowledge exchange, input supply, and product sales at market rates

4.9 ROOTS AND TUBERS-LIVESTOCK INTEGRATION

(See full concept note with greater analysis and sources in Annex A)

PROJECT SUMMARY

REGIONS: Transitional, Savannah, Coastal

BENEFICIARIES: 200,000 small farmers and their families

PDO: Decrease production costs and increase climate resiliency using integrated root-tuber-livestock systems.

HIGHLIGHTS: improving food security and building resilient systems; increasing income and savings of poor farmers; increasing on-farm efficiencies; supporting improvement of smallholder sector; potential to boost exports for yams; adding new value chains

KEY INVESTMENTS:

- Reduced cost and improved accessibility of high-quality livestock feeds
- Improved resource-use efficiency and economic resiliency using crop residues as livestock feed
- Optimized crop productivity through integrated soil fertility management using manures
- Heat-tolerant, drought-tolerant, fast-growing, and disease-resistant cassava and yam varieties

JUSTIFICATION

The diversity of integrated crop-livestock production systems makes them synergistically more productive and resilient than either system alone. Most Ghanaian smallholders already own livestock. Most livestock are free-range, and about 90 percent of farmers also feed crop residues to their livestock; agro-industrial by-products (such as bran) are another common feed supplement. Cassava and yams are widely grown staple food crops in Ghana, and both will do well with climate change, especially yams. Cassava is the main staple food crop of Ghana; it is grown by over 90 percent of farmers and contributes over 20 percent of the agricultural GDP. It is very tolerant of poor growing conditions; even with poor soil, droughts, and frequent disease, it can yield about 13 tons of tubers per hectare. Yams contribute more than 15 percent of the agricultural GDP and account for about 11 percent of total annual calories consumed. Unlike cassava, however, yams require good rainfall and fertile soils; however, they have much higher nutritional value.

There is significant untapped opportunity for improved heat-tolerant, drought-tolerant, and disease-resistant varieties of both crops, especially for short-duration, fast-growing cassava. Livestock feed is a high-potential use for yam and cassava crop root and peel residues, as well as for foliage and shoots that can be harvested several times through the year. These can be used as feed for cattle, sheep, goats, pigs, rabbits, broiler and layer poultry, and fish without adverse effects on growth or productivity, and in many cases a great benefit. A lack of access to fertilizer and other inputs is a major constraint of agricultural productivity in Ghana, and one of the primary causes of agricultural encroachment on natural spaces. Significantly greater fertilizer access and use, including from livestock, is needed to support national goals of improved productivity and resilience in the Ghanaian agricultural sector.

POTENTIAL PROJECT IMPACTS

PRODUCTION	High potential to greatly increase yields in these resilient systems
RESILIENCE	This widespread system is vital for food security and soil quality, supporting crop, animal, and household resilience to climate extremes
MITIGATION	This project will increase emissions by 0.39 MtCO ₂ equivalent
COST	Cost of US\$250 per beneficiary, or a total cost of about US\$50,000,000
YIELD	Increased by 27 percent for 200,000 small farming families

ECONOMIC AND FINANCIAL ANALYSIS

CBA with and without climate risks

With Climate and Pest Risks					
Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
200,000	27	24.2	54	0.52	0.36 (2.39)
Without Climate and Pest Risks					
200,000	27	75.9	77	1.74	1.15 (2.76)

ENABLING ENVIRONMENT

KEY ENABLING FACTORS

- Close alignment with Ghana's NDCs and many other national policies
- The vast majority of smallholders already own livestock in partial integration with crop systems
- Some local crop varieties already demonstrate heat, drought, and disease resistance
- Well-established national research facilities and programs
- Multiple university programs training agricultural professionals, including researchers

KEY RISKS

- Historic availability of fodder resources has made improved fodder systems a low priority for farmers, despite significant advantages under climate change scenarios
- High land insecurity and low finance and risk mitigation services deter farmers from investing in soil quality
- High labor intensity of using manure as fertilizer alternative under extensive grazing system
- Current land tenure regime incentivizes expansion over investments in current land
- Current markets make fertilizer inputs scarce, expensive, and of unreliable quality
- Institutional priority for supporting innovations in cash cropping rather than food cropping

FINANCING

Public Financing Opportunities

- Unknown

International Financing Opportunities

- Multiple international donors (see Annex A)

Private Financing Opportunities

- There are multiple potential private sector collaborators and financing opportunities through commercial feed producers, livestock processors, breweries, and fertilizer and agribusiness partnerships.

Most Promising Supporting Digital Agriculture Technologies

- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best practices and disseminate research and development outputs
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support management decisions
- Mobile peer-to-peer platforms—enabled by big data, machine learning, and mobile technology—to support knowledge exchange, middleman reduction, economies of scale, input supply, and product sales at fair market rate

CHAPTER 5: MONITORING AND EVALUATION: ASSESSING OUTCOMES AND IMPACTS

5.1. Context

132. **A robust and practical monitoring and evaluation (M&E) plan is an integral component of Ghana's CSAIP.** This M&E plan aims to provide CSAIP implementers—particularly the government—with a manageable system that facilitates generating, collecting, and analyzing standardized data to assess the success of portfolio investments and inform operational and strategic decision-making. The M&E plan establishes and illustrates links between the plan's objectives (expected outcomes and impacts) and its inputs and activities (projects). It also identifies key requirements for implementing the plan.

133. **M&E activities create a mechanism for tracking progress against targets.** There are opportunities in M&E for learning lessons; increasing accountability; raising flags when adaptive action may be necessary; and telling data-driven stories of success by government agencies, financial institutions, subnational agencies, communities and other decision-makers. M&E plans and activities need to be dynamic and can be revised and adjusted as lessons emerge from their implementation. Key M&E terms are defined in Box 3.

Box 3: Defining Key M&E Terms

- **EVALUATION:** Occasional and in-depth data collection for assessing the outcomes and impact of the intervention strategy (that is, effectiveness)
- **IMPACT:** High-level objectives identified by stakeholders during the development of the Investment Plan (that is, the project development objective)
- **INDICATORS:** Information documenting current state and changes of activities, outputs, outcomes, or impact
- **MONITORING:** Continuous data collection tracking implementation of budgets and activities (planned vs. achieved)
- **OUTPUTS:** Tangible products of project activities including trainings, publications, partnerships, new technologies, policies, and infrastructure (for example, weather stations)
- **OUTCOMES:** Changes in behavior including knowledge, attitudes, and skills of stakeholder groups that result from project activities and outputs
- **RESULTS FRAMEWORK:** A graphic summary and management tool summarizing the expected results from particular interventions such as investments, development plans, or policies
- **THEORY OF CHANGE:** A description or diagram of why and how the desired change and objectives will occur

5.2 Theory of Change

134. **The CSAIP strongly focuses on improving Ghana’s food and nutritional security by sustainably increasing agricultural productivity and building the resilience of farms, farmers, ranches, landscapes, and the food systems.** Ghana’s CSAIP emphasizes productivity and resilience because (a) Ghana’s agriculture, forest, and land-use sector (AFOLU) has been a low contributor to global carbon emissions; and (b) the program is designed to address national food security priorities. Improving productivity and food and nutrition security while increasing farmers’ income and resilience helps Ghana achieve targets for at least eight of the seventeen SDGs¹⁶⁹ that are included in the MTNDPF (2018–2021) and its associated results framework. This CSAIP increases impact in the six above-mentioned development areas, while the M&E plan will support the government in harmonizing reporting systems related to global commitments (SDGs, NDCs).

135. **This CSAIP also contributes to climate change mitigation, the third pillar of CSA, and to national mitigation commitments in the NDC via climate change mitigation co-benefits.** Many of the interventions—particularly the ones focused on livestock and small ruminants—will decrease GHG emissions per unit of product (known as GHG intensity). Investments in diversified tree crops systems also sequester carbon and reduce emissions from farms and landscapes.

136. **Adaptation needs to happen at multiple scales, across both sectors and landscapes, to meet development goals.** This encompasses farming practices, institutional policy, markets, and the private sector. The CSAIP aims to work with diverse beneficiaries across the food system, located in different agroecological zones (AEZ) of the country (see Chapter 3). Investments are directed toward crop farmers and livestock keepers as well as smallholders engaged in aquaculture and fisheries. The CSAIP also plans activities that affect the functioning of markets and value chains with the private sector. Support for government institutions in establishing crucial support frameworks for CSA is included, and addresses policy setting and implementation, research, knowledge development, and capacity building. This broad

¹⁶⁹ SDG 1 (No poverty), SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation), SDG 12 (Responsible consumption and production), SDG 13 (Climate action), and SDG 15 (Life on land).

support ensures that all the major types of actors in the food system will be engaged by and benefit from the CSAIP, catalyzing transformative change.

137. **Four key action areas are embedded into the theory of change (TOC) of the entire CSAIP and of individual investments** (Figure 20).

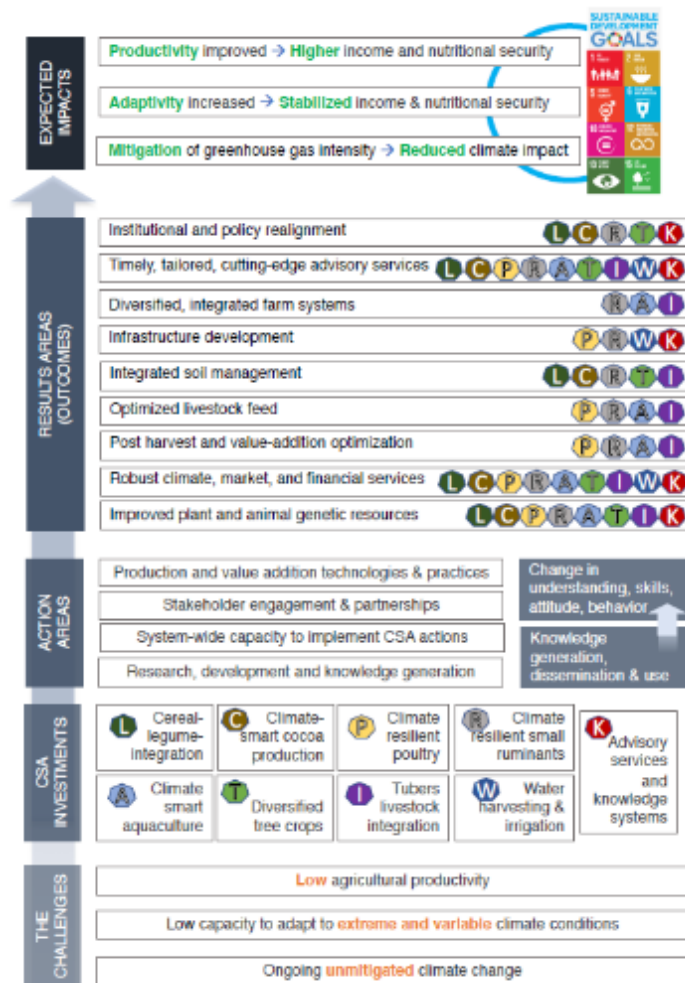
- (a) robust research and development (R&D)
- (b) uptake of climate-smart production technologies and value-added practices
- (c) stakeholder engagement and partnerships
- (d) system-wide capacity to implement CSA actions

Robust R&D is needed to facilitate introducing improved crop varieties and livestock breeds adapted to new climate conditions (particularly drought). On-farm actions that target production and value addition are key steps for creating a sustainable food system. Stakeholder engagement and partnerships are needed to foster concerted action, particularly in the area of information exchange and learning (advisory services). Moreover, system-wide human, technical, and financial capacity is critical to implement CSA actions (technologies, services, policies) across the agriculture decision-making spectrum.

138. **The TOC assumes that increased use of CSA will be facilitated by knowledge development and dissemination, and also by its accessibility and usability by the end-users (farmers, extension staff, private sector actors, decision-makers, and so on).** The TOC assumes that use of relevant knowledge and timely information will lead to changes in attitudes, awareness levels, skills, opinions, and behavior (in the short term); increases in productivity and incomes (in the medium term); and to improved food security, nutrition and resilience (in the long term).

Figure 20: How CSAIP Investments and Implementation Lead to Benefits

The key action areas apply to all nine investments, enabling different types of outcomes. Outcomes are investment specific. Medium-term and long-term changes (outcomes and impacts, respectively) contribute to the attainment of multiple SDGs.



5.3 Results Framework and Core Indicators

139. A core component of the CSAIP M&E plan is the results framework, which is built from fundamental data characterizing farm, household, and value-chain activities. It will track productivity, resilience, and adaptive capacity to quantify the adaptation and mitigation benefits from the program investments. This approach allows it to be extended to agricultural interventions outside the CSAIP. It includes core indicators agreed upon by investment stakeholders that need to be collected and monitored at national and regional (investment zone) levels and reported on a regular basis. Each project will be monitored separately using guidelines that will be established at project inception, along with key performance indicators (KPIs) and targets. Various types of indicators should be reflected in the results framework to suggest the different objectives of M&E activities—for example, tracking implementation progress, adaptive project management, and the evaluation of outcomes and impacts. There are three types of indicators that track different scales:

- **Output indicators:** which are linked directly with portfolio investment activities and are more easily tracked
- **Outcome indicators:** which are closely—but not exclusively—related to project activities

- **Impact indicators:** measuring change in the broader goals, these are broader in scope, and they provide insights toward the end of a five-year project lifespan.

140. **A consultation process informed the development of this M&E system.** Consultations (semi-structured interviews and focus groups) were conducted with staff at the MoFA to reflect the core development impacts of the CSAIP and multiple purposes of M&E. MoFA staff provided critical input and support in three main areas: (a) establishing the scope of the M&E plan; (b) determining investment-level elements to be monitored and evaluated; and (C) defining general guidelines for how M&E will be implemented, based on currently available M&E reporting system(s), M&E responsibilities, and key actions for implementing the M&E plan. Table 25 and Table 27 provide examples of output-level outcome and impact indicators relevant for the nine portfolio investments.

141. **Output indicators are directly tied with the project activities.** Different investments may have similar project activities, so the indicators and how they are measured would be similar. A complete list is prepared when the investments are made as part of the M&E system design. Data for output indicators is typically collected through the Project Management Information System (PMIS), which can be coordinated with existing information systems under the MoFA.

Table 25: Sample Output-Level Indicators Relevant for the CSAIP, by Project

Project	Output Indicator and Measurement
Cereal-legume integration Diversified tree crops Climate-smart cocoa production	<ul style="list-style-type: none"> • Improved varieties released (by crop type); number, types • Nurseries with improved planting material established (mainly for tree crops); number • Improved warehouses established; number • Solar driers established (mainly for cocoa); number • Processing units established; number • Farmers receiving technical assistance on the use of improved (CSA) production/postharvest practices; number
Roots and tubers-livestock integration Poultry feed improvement and genetic resource enhancement Climate-resilient ruminants and genetic resource conservation	<ul style="list-style-type: none"> • Fodder/legume seed banks established; wide variety of species and breeds included • Livestock dugouts established; number • Animal housing with improved ventilation conditions and maintained microclimate established; number • Animal housing establishments respecting biosecurity measures; number • Animal housing establishments using energy from renewable sources; number • Vets and extension staff benefiting from trainings on use of vaccines; number • Improved livestock markets established (physical infrastructure); number • Farmers receiving technical assistance on crop-livestock integration strategies (for example, composting using farmyard manure, silage preparation); number • Farmer-extension-researcher communication platform established (for information exchange and learning)
Sustainable fisheries and aquaculture	<ul style="list-style-type: none"> • Aqua-agriculture systems (farms) established and products integrated; number • Farmers benefiting from advisory on sustainable aquaculture production: number

Project	Output Indicator and Measurement
Knowledge systems and advisory services	<ul style="list-style-type: none"> Beneficiaries of the farmer-based organization (FBO) approach; number New and refurbished agro- and hydro-meteorological facilities and automated weather stations (by sub-type); number Agromet bulletins released including frequency of release; number Communication materials developed for farmers; number, type Farmer questions resolved by advisory agents; number National strategy to leverage ICT tools in the agriculture sector
Water harvesting and irrigation technologies	<ul style="list-style-type: none"> Farmers trained in the development and use of water harvesting and irrigation technologies; number Irrigation facilities established; number

142. **Outcome-level indicators require both established M&E systems and special studies as they are not reported on a routine basis** (Table 26). Special studies can include baseline studies with follow-up longitudinal studies, national surveys, case studies introduced to routine M&E activities, and participatory beneficiary assessments (it is particularly important to evaluate farmers' opinions, changes in knowledge, behavior, and so on).

Table 26: Sample Outcome-Level Indicators Relevant to the CSAIP, With Contribution to CSA

Investment	Indicator and Measurement
Outcome: Improved breeds/ planting material (R)	
Breeds: 5, 6,7,8 Planting material: 1,2,3,4,8	<ul style="list-style-type: none"> Improved breed stock/planting material (varieties); Percentage change/coverage (%/ha) Farmers using improved breeds/seeds; Number of/Percent (by type of breed/seed) (number/%) Public/public-private funding allocated to R&D for improved breeds/varieties (%) change.
Outcome: Improved production practices and technologies (P, R)	
1,2,3,4,5,6,7,9	<ul style="list-style-type: none"> Farmers using CSA practices for production (by practice/technology type) (number/%) Area under improved production practices (%/ha of agriculture area)
Outcome: Improved postharvest/value addition activities and facilities and enhanced marketing conditions (P, R)	
1,2,6,7	<ul style="list-style-type: none"> Farmers engaged in value addition activities (by activity type) (number/%) Unit cost for transportation of agriculture products (US\$) Distance to markets (km)
Outcome: Improved animal health and welfare (P, R)	
4,6,7	<ul style="list-style-type: none"> Animal health services coverage (qualified vets to farmer ratio; client contacts per vet) Animal disease and pest incidence; Decrease in % Public/public-private funding allocated to R&D for new vaccine development; total (US\$) Livestock farmers with access to animal vaccines to control pests and diseases (number/%)
Outcome: Improved access to water for agriculture (P, R)	
1,7,9	<ul style="list-style-type: none"> Farmers using water harvesting technologies; by each technology (number/%) Farmers using dugouts for livestock (number/%) Crop area under irrigation; Increase (%)

Investment	Indicator and Measurement
Outcome: Diversified, integrated farm systems (P, R, M)	
4,6,7	<ul style="list-style-type: none"> • Farmers using diversification practices on their farm (number/%) • Area under agricultural diversification; by diversification type; products included (%; ha) • Farmers using integrated farm systems (crop-livestock; crop-trees; crop-livestock-trees; fish-poultry, and so on) (number/%)
Outcome: Strengthened demand-driven service delivery capacity (P, R)	
1,2,3,4,5,7,8,9	<ul style="list-style-type: none"> • Number of qualified extension staff (number) • Ratio of extension agents to farmers'/farmer groups (by farmer type-crop, livestock- and value chain activity-production, postharvest, storage, and so on) • Client contacts per extension agent (number) • Beneficiaries of digital-based extension services (by beneficiary type and digital tool) (number) • Quality rating of service/technical capacity by beneficiary; qualitative assessment • Increase in funding for extension services (US\$)
Outcome: Strengthened technical capacity of farmers to manage climate risks (P, R)	
1,5	<ul style="list-style-type: none"> • Farmers' knowledge/skills/capacity for managing climate risks; Qualitative change assessment
Outcome: Improved soils and pastures (P, R, M)	
1,3,4,7	<ul style="list-style-type: none"> • Soil erosion rates decrease; (%) • Soil improvements; Changes in soil physical indicators (texture, aggregation, moisture, porosity), chemical (C, N, mineral nutrients, organic matter), and biological indicators (microbial biomass C and N, biodiversity, soil enzymes, soil respiration, and so on) (%) • Sustainable communal grazing system (number/ ha) • Farmers with access to sustainable communal grazing systems (number/%) • Farmers with access to improved fodder/legume seeds; (number/%) • Farmers using improved fodder and legumes as green manure; (number/%)

Note: Investments: 1 = Cereal-legume integration; 2 = Diversified tree crops; 3 = Climate-smart cocoa production; 4 = Roots and tubers-livestock integration; 5 = Poultry feed improvement; 6 = Climate-resilient ruminants; 7 = Sustainable fisheries and aquaculture; 8 = Knowledge systems and advisory; 9 = Water harvesting technologies and irrigation management.

Resilience - R, Productivity - P, and Mitigation - M noted.

143. **Ghana already collects much of the data needed for measuring and analyzing the impact of interventions.** Much of the needed data for the sample impact indicators can be found in agricultural censuses and surveys (particularly for income); Ghana Demographic and Health Survey (particularly for nutrition and food security indicators); or donor reports (for example, Nutrition Profiles of the USAID, FAO). Table 27 shows sample impact indicators.

Table 27: Sample Impact Indicators Relevant to the CSAIP

Impact Indicator	Suggested Measurement(s)
Impact: Improved productivity, food and nutrition security	
Productivity	<ul style="list-style-type: none"> • Kg/ha (per CSAIP agricultural commodity)
Nutrition status of the population	<ul style="list-style-type: none"> • Prevalence of stunting, wasting, anemia, and being underweight among children and women
Food security of the population (availability,	<ul style="list-style-type: none"> • Prevalence of food insecurity, by type • Dietary diversity and food frequency (Food Consumption Score [FCS]; Household Dietary Diversity Scale [HDDS]; Spending on food)

Impact Indicator	Suggested Measurement(s)
accessibility, utilization, stability)	<ul style="list-style-type: none"> Consumption behavior (Coping Strategy Index [CSI]; Household Food Insecurity and Access Scale [HFIAS])
Impact: Increased farmers' incomes and climate resilience	
Income	<ul style="list-style-type: none"> Average farm income
Farm resilience to food insecurity	<ul style="list-style-type: none"> Resilience capacity index (FAO-RIMA [Resilience Index Measurement and Analysis] II)

5.4 Key considerations for next steps

144. **Several additional steps are needed to develop a comprehensive, nationally integrated information system for measuring and reporting progress in implementing CSA.** Based on a recent multi-country analysis,¹⁷⁰ additional information is needed to outline the components of the M&E plan, which includes establishing the scope of the M&E activities, outlining roles and responsibilities of participating institutions, defining the tools for implementation, establishing data management protocols, and refining logistics. These actions, adapted to Ghana's context, are summarized in Box 4. These suggested actions inform assessments of resources required for M&E setup and implementation; define the space for the M&E system within the CSAIP; and ensure long-term sustainability.

145. **Refining indicators is a needed step.** To make it actionable, the CSAIP M&E system should strike a balance between what is ideal to measure and what is practical (with regard to costs and time). It should be informed by the implementation context of the plan. The total number of indicators included needs to be reasonable and reflect the project's theory of change and the resources available to track them periodically. Applying SMART criteria (Specific, Measurable, Attainable, Relevant and Timely) when selecting the indicators will help shorten the list, ensuring relevance and usability of the system. Ideally, the final list of prioritized impact, outcome, and output indicators should be developed by project component; should contain clear targets (defined in terms of time, quantity, quality); and should be gender-disaggregated where possible.

146. **Data from a variety of sources can be combined and used.** The CSAIP's M&E system will also need to draw on data from various sources, including the PMIS, national datasets, and other studies. PMIS are typically based on regular project implementation reports and provide data on inputs (for example, number of extension staff), outputs (for example, farmers trained) and initial outcomes (for example, adoption rates of CSA technologies). National statistics are typically used for assessing long-term outcomes (5–10 years or more), while special studies and participatory evaluations are good sources for qualitative information (changes in attitudes, knowledge, behavior, well-being levels, and so on). Rapid rural appraisals and case studies are designed to provide targeted information in a cost- and time-effective way and can be an additional source of M&E data for the CSAIP projects.

¹⁷⁰ Nowak et al., 2019.

Box 4: Key questions to address in the design of a comprehensive M&E plan for the CSAIP

WHY: Determine the scope of the M&E Plan. Describe how data will be used and by whom, how it will feed into policy making and decision-making in general (including international reporting processes). Setting the scope is an essential first step, as it helps define the breadth of indicators required and the information system that will need to be put in place or adapted to track them.

WHO: Clearly delineate roles and responsibilities? Define what institutions will be responsible for different M&E activities, how responsibilities will be divided, and what staff and qualifications are required to carry out M&E activities (from data collection to cleaning, analysis, reporting, dissemination, coordination, and so on). Establishing clear procedures for regular information flow between decentralized implementation units and a central M&E unit is essential for a smooth implementation of the M&E plan.

WHAT: Establish what information and data need to be collected. This section of the CSAIP provides guidance on the initial design of the M&E, showing a first appraisal of potential opportunities for Ghana based on current levels of elaboration in the project concept notes. The list of indicators needs to be refined and aligned to the needs of information users and the objectives outlined in each project. To define these, additional consultations with investment stakeholders and M&E staff from existing governmental departments are required to ensure participation, alignment, and coordination.

HOW: Establish procedures and methodologies for M&E. Determine what methods and sources will be used to gather, analyze, and report the data; how the PMIS will manage data; and provide clear information on how data will flow between local and national levels. Baseline data should ideally be available in the project appraisal phase; if not, arrangements for collection of baseline data in the first year of the project should be spelled out in the M&E plan. Tools for established procedures and guidelines may include annual work plan and budget for M&E; planning and tracking tools; M&E calendar; and standard progress reports and quarterly reports, among others.

WHEN: Establish the frequency of data collection and reporting. Spell out the recommended frequency with which different data will be collected and reports prepared.

147. **Leveraging existing information systems can help quickly start the process.** M&E systems within the MoFA¹⁷¹ already contain a wealth of information relevant to the CSA investments. Table 28 illustrates how the M&E of the CSAIP is relevant and aligned to key national policies and their results frameworks. Moreover, the M&E system embedded in the MoFA tracks implementation, outcomes, and impacts of agriculture sector interventions at national, regional, and district levels. Exploring synergies between the CSAIP and existing information systems is a key step not only for improved coordination, alignment, and effective resource allocation, but also for harmonizing national and international reporting processes.

148. **Leveraging existing institutional arrangements can dynamically support M&E system development.** Currently, the Policy Planning, Monitoring, and Evaluation (PPMED) Directorate within the MoFA leads the M&E of agricultural sector programs, projects, and financial expenditure. Data is collected by Department of Agriculture in the Municipal and District Assemblies on a monthly, quarterly, seasonal, or annual basis, depending on the type of data. The newly created Ministry of M&E under the Presidency aims to monitor the performance of the different ministries in fulfilling national-level priorities and goals. This illustrates the tremendous opportunity to base the CSAIP's M&E activities on established, legitimate structures, rather than creating new ones.

149. **Clearly defining roles and responsibilities is integral to CSAIP M&E.** Even when using already established institutional structures, roles and responsibilities need to be spelled out. Ideally, the M&E

¹⁷¹ These include M&E frameworks and systems related to the National Climate Change Policy Master Plan (NCCP-MP), FASDEP II, METASIP II, and the Ghana Agriculture Sector Investment Plan (GASIP).

system for the CSAIP would be embedded within MoFA-PPMED, with relevant directorates and field offices carrying out routine monitoring. An M&E coordinating team would operate through the decentralized framework of the CSAIP, supporting and coordinating M&E staff at the project and municipal/district levels and assisting with their training. The coordinating team would also provide the necessary technical support; be responsible for regular reporting to stakeholders; and track and document the implementation progress, performance, and outcome evaluation. Regular data collection would mostly fall under extension officers’ mandates, while municipal/district-level data cleaning, analysis, and reporting to the M&E coordination team would be undertaken by municipal/district-level M&E officers.

150. Developing and strengthening a permanent M&E capacity is needed. A robust, functioning M&E system will require adequate investment in staffing, both in human resources and their training (skills). The MoFA is in the process of digitizing its M&E system to better standardize data collection and analysis. Limited financial, human, and logistic resources impose constraints on carrying out and coordinating activities, thus affecting sampling criteria. The technical skills of staff to analyze and clean data will affect the quality and reliability of data collected. An initial capacity assessment will need to be carried out with CSAIP staff (including extension agents, local government agencies, and so on) to understand existing capacities. This should focus on the level of established staffing, its strengths and weaknesses, and should detail training, technical assistance, and other inputs needed to strengthen M&E capacity. This ensures a results-based reporting approach throughout the CSAIP implementation period. As shown in Table 28, many of the CSAIP plans and policies already have M&E systems in place aligned to the CAADP172 and the National Development Plan, indicating an opportunity for the CSAIP M&E to build on existing structures and data. Additional policies and plans would be appropriately mapped to the CSAIP M&E as it is designed.

Table 28: Key Policies and Plans Relevant to CSA in Ghana and Main Relevant Outcomes

Selected policy objectives (PO) based on relevance to the main CSAIP outcomes and investments	Existence of M&E Plan with indicators
National Climate Change Policy (NCCP) and National Climate Change Master Plan (2015–2020)	
<p>Focus Area 1: Develop Climate-Resilient Agriculture and Food Security Systems</p> <ul style="list-style-type: none"> 1.1: Institutional capacity development for R&D, dissemination 1.2: Development and promotion of climate-resilient cropping systems 1.3: Adaptation of livestock production systems 1.4: Support to adaptation in the fisheries subsector 1.5: Support to water conservation and irrigation systems 1.6: Risk transfer and alternative livelihood systems 1.7: Improved postharvest management 1.8: Improved marketing policies <p>Focus Area 2: Build Climate-Resilient Infrastructure</p> <ul style="list-style-type: none"> 2.1. Build capacity to design climate-resilient infrastructure 2.2. Knowledge management and coordination 2.3. Climate-resilient sectoral and local development planning 	<p>There is no specific M&E framework for the NCCP, as climate adaptation and mitigation indicators are integrated within the MoFA’s M&E system. The NCCP outlines clear expected outcomes, and output indicators, with timelines, roles and budget.</p>

¹⁷² The CAADP objective to improve agricultural productivity to attain an annual growth rate of 6 percent, with particular attention to small-scale farmers, especially focusing on women. This would be done through the following pillars: (a) Land and Water Management; (b) Rural Infrastructure and Trade-related Capacities for Improved Market Access; (c) Increasing Food Supply and Reducing Hunger; (d) Agricultural Research, Technology Dissemination and Adoption; (e) Sustainable Development of Livestock, Fisheries and Forestry Resources.

Selected policy objectives (PO) based on relevance to the main CSAIP outcomes and investments	Existence of M&E Plan with indicators
<p>Focus Area 3: Increase Resilience of Vulnerable Communities to Climate-Related Risks 3.1: Early Warning Mechanisms 3.2: Public education on adaptation skills</p> <p>Focus Area 4: Improve Carbon Sinks 4.1: Improving governance, capacity, regulatory structures 4.5: Conservation of trees through agroforestry and on-farm practices, and greening of urban areas</p> <p>Focus Area 8: Gender and Climate Change 8.1: Gender-responsive climate change research 8.2: Livelihood protection, alternative and sustainable livelihoods and poverty reduction 8.3: Gender responsiveness in natural resource management 8.4: Gender-sensitive education, training, and capacity building on gender and climate change</p>	
Food and Agriculture Sector Development Policy (FASDEP II) (2007)	
<ol style="list-style-type: none"> 1. Food security, emergency preparedness, and reduced income variability 2. Increased growth in incomes from agriculture 3. Sustainable management of land and environment 4. Increased competitiveness and enhanced integration into domestic and international markets 5. Application of science and technology in food and agriculture development 6. Effective institutional coordination 7. Supporting policies and strategies 8. Cross-cutting interventions and policies 	Yes. Appendix 2 of the policy provides a matrix with outcomes, outputs, and related indicators.
Medium-Term Agriculture Sector Investment Plan (METASIP II) (2014–2017)	
<ol style="list-style-type: none"> 1. Agricultural productivity 2. Accelerated creation of decent jobs 3. Agricultural competitiveness and integration into domestic and international markets 4. Production risks and bottlenecks in agricultural industry 5. Crops development for food security, export and industry 6. Livestock and poultry development 7. Cross-cutting issues - gender and climate change 	Yes. M&E of the agriculture sector is handled under MoFA.
Ghana Agriculture Sector Investment Plan (GASIP)	
<ol style="list-style-type: none"> 1. Value chain development 2. Rural value chain infrastructure 3. Knowledge management, policy support, and coordination. 	Yes. M&E outlines with clear targets on improved water management for smallholder (especially women and youth), maize yields, climate resilience knowledge.
National Climate-Smart Agricultural Plan	

Selected policy objectives (PO) based on relevance to the main CSAIP outcomes and investments	Existence of M&E Plan with indicators
<ol style="list-style-type: none"> 1. Develop climate-resilient agriculture and food systems for all agroecological zones 2. Develop human resource capacity for climate-resilient agriculture 3. Elaborate on the implementation framework and the specific CSA activities to be carried out at the respective levels of governance 	<p>No specific M&E metrics; generally, falls under national agriculture M&E, which tend to include tracking for budgetary expenditures and suggestions—but no metrics—for tracking.</p>

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

A-1. Cereal-legume integration

PROJECT SUMMARY

OBJECTIVE: Introduce and optimize current cereal-legume rotations by developing climate-resilient crop varieties and introducing soil fertility management best practices.

PROJECT HIGHLIGHTS: Poverty reduction potential for smallholders; enhanced food security; increased resilience for high-climate impacted crops; mitigation benefits; no-regrets investment that will improve production in a system that desperately needs it; strong justification from climate modeling and financial analysis

REGIONS: Transitional, Savannah

PROJECTED BENEFICIARIES: 200,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation, Mitigation

KEY CSA INVESTMENT ACTIVITIES:

This investment relies on three key technologies well known in CSA approaches:

- Heat- and drought-tolerant crop varieties
- Disease-resistant crop varieties
- Soil fertility management

JUSTIFICATION

Legume-grain rotations dominate the Ghanaian savannah. These systems provide vital household nutrition and income. For example, higher maize yields following legumes versus continuous maize cropping is well documented, and legumes can provide yield in the event of maize failure. Legumes are high in nutrition, and demand for them, particularly soybeans, is growing substantially.

Legume-cereal systems can improve soils and productivity in several ways. Current soil fertility levels strongly influence the benefits realized and soil fertility levels vary significantly both across the savannah zones and between farms. Legumes may also be better suited to certain savannah subregions. Most farmers are unaware of opportunities to tailor legume-cereal systems to their soils and farm management goals.

At the same time, agricultural systems have played a huge role in soil and water resource degradation in Ghana. About 25 percent of Ghana's forests were converted to cropland between 2000 and 2014. Much of this expansion is due to low productivity on existing agricultural lands and the high cost of inputs to improve productivity. Legume-cereal systems offer the opportunity to intensify production and maintain or improve soil quality.

PROBLEM STATEMENT

There is significant untapped opportunity to tailor existing legume-grain systems for improved soil quality and economic outcomes. For example, low soil fertility stimulates legumes to rely on atmospheric N-fixation, which increases the partial soil N balance available to grain crops. Growing legumes in low-fertility soils thus helps recover soil N. Intercropping is particularly beneficial in less fertile fields and

marginal environments, such as the northern savannah region. On the other hand, growing legumes in fertile fields helps maintain soil fertility, offers non-N soil benefits—including improved soil structure, microbial biomass, weed control, and mineralized N—and significantly improves yield.

Sole grain and legume crops yield more per unit area than intercropped systems, but economic returns are greater for within-row intercrops than either sole crop. Research also suggests that benefits may vary significantly based on the selected legume variety. For example, cowpea and groundnut perform better than soybean when intercropped with maize, but soybean yields result in the largest net benefits. Additionally, soybean-cereal systems may be optimal in the northern savannah, cowpea-cereal systems in the southern savannah, and groundnut-cereal systems are suited to both subregions. Early maturing groundnut varieties may be essential given the growing trend of delayed rainy season onset in northern Ghana.

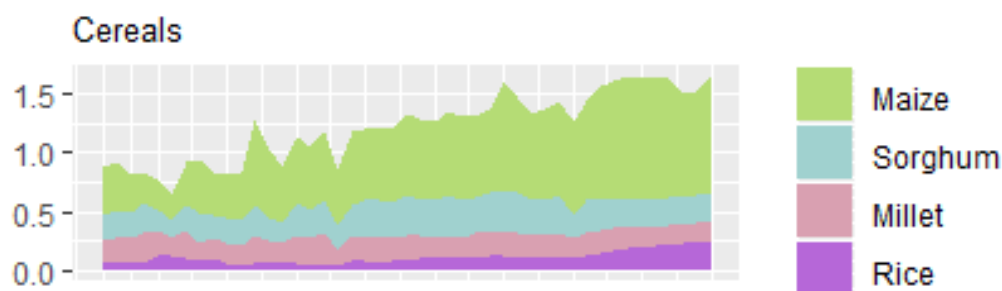
Improved legume and cereal varieties are needed to create resiliency in the face of climate impacts and to intensify production. For example, rhizobium-inoculated soybean seed has already increased yield for farmers in northern Ghana by an average of 1.2 tons/ha. This will mitigate agricultural expansion, improve household nutritional and economic outcomes, and foster national food supplies and economic stability.

CLIMATE MODELING

Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas or entire countries, as well as creating pockets of increased suitability. At a global scale, these shifts will be very significant in determining what countries can grow what crops, which in turn will affect international trade. At the same time, government GHG mitigation policies, together with demographic and economic growth trajectories, will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).¹⁷³ See Annex E for full information.

Climate change impacts on cereals are of relevance in Ghana, where they constitute a large share of daily caloric intake and cultivated area (Figure CL-1). The expansion of cereals, shown in Figure CL-1 and Table CL-1, is part of a trend in which Ghana’s agricultural frontier has roughly doubled since the 1980s. This has resulted in high levels of forest clearing to meet the demand for farmland, even if the agricultural suitability is low. This finding demonstrates that CSA practices that improve intensification—in turn limiting land conversion and forest clearing—directly contribute to mitigation.

Figure CL-1: Area Harvested in Cereals in Ghana 1973–2017 (million ha)



Most cereals, especially maize, exhibit high vulnerability to climate change no matter what scenario is picked, from losses of 8–11 percent in 2030 to 16–21 percent in 2050 compared to a no-climate change

¹⁷³ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

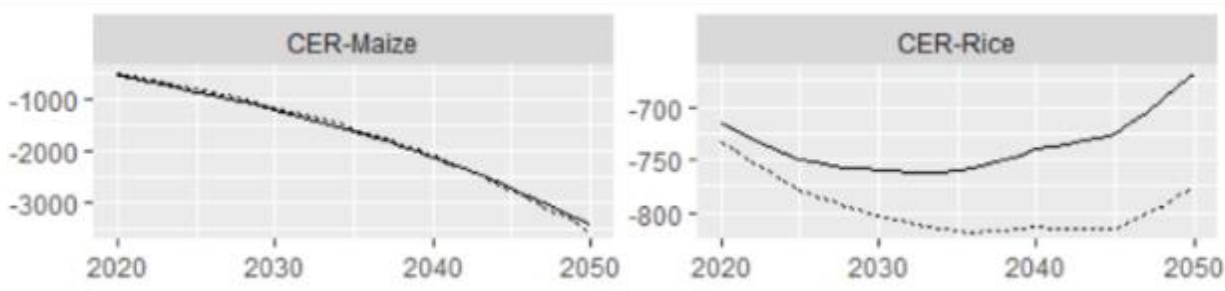
baseline. For other cereals, millet and sorghum show relatively smaller declines in the short term, but both have losses of around 4–6 percent by 2050.

Table CL-1: Percentage Difference in Rainfed Crop Yields Over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different GHG Concentration Scenarios (RCPs), With BAU Demographic and Economic Growth Trajectories (SSP2)

Percent difference from no climate change Scenario	Area harvested				Yield			
	Low GHG (RCP 4.5)		High GHG (RCP 8.5)		Low GHG (RCP 4.5)		High GHG (RCP 8.5)	
	2030	2050	2030	2050	2030	2050	2030	2050
Crop								
CER-Maize	0.12	-0.36	0.60	0.25	-7.99	-15.55	-10.82	-20.73
CER-Millet	0.60	0.93	1.29	2.30	-1.91	-3.87	-3.04	-6.04
CER-Rice	1.19	2.29	1.81	3.63	-1.25	-2.60	-0.80	-1.71
CER-Sorghum	0.82	1.53	0.66	1.23	-1.88	-3.78	-3.13	-6.19

Maize is especially predominant on farms. Despite this, Ghana is dependent upon imports to meet its internal cereal demand, especially for maize.

Figure CL-2: Net Trade Projections out to 2050 (SSP2 RCP 8.5)



Note: ___ Climate Change; No Climate Change.

POTENTIAL PROJECT IMPACTS

The CSAIPs are designed to build upon the strengths of commodities exhibiting resilience under climate change while offsetting potential damages to commodities exhibiting vulnerability. In separate analyses, the potential impacts of four CSAIPs on yield and trade were examined using IMPACT, under a BAU SSP 2 and pessimistic GHG concentration scenario (RCP 8.5).

The results suggest that the Cereal-Legume Integration CSAIP has considerable potential to improve maize, sorghum, and groundnut yields and trade trajectories (Figure CL-3).

Figure CL-3: Potential Impact of the Cereal-Legume Integration CSAIP on Maize, Sorghum, and Groundnut Yields and Balance of Trade. Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic GHG concentration scenario (RCP 8.5)



Model Assumptions: Maize, sorghum, and groundnut were analyzed. The assumptions on yield and farmer adoption rates for each crop were:

- Maize - current: 1.7–2 tons/ha; potential yield with project: 6 tons/ha; farmer adoption: 38 percent
- Sorghum - current: 1.3 tons/ha; potential yield with project: 1.5–2 tons/ha; farmer adoption: 34 percent
- Groundnut - current 1.3 tons/ha; potential yield with project: 3.5 tons/ha; farmer adoption: 33 percent
- Assumptions on technology were for a time horizon of 5 years, with 3 years as the time to reach half of adoption rate.

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

Both with and without climate risks, there is a huge boost of 40 percent increase in income to 200,000 households under CSA cereal-legume integration. Both with and without risks, the projects have a strong NPV and over 93 percent chance of a positive NPV. The differences in risk, which should be considered integral to the assessment of any agricultural sector project, are evident in the ROI and in the BCR. Overall, this project shows high gains for beneficiaries, a high chance for a positive NPV, and a strong BCR.

Table CL-2: Cereal-Legume CBA With and Without Climate Risks

Mean No. Beneficiaries	Change in Yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
With Climate and Pest Risks					
200,000	40	109.0	85	4.04	2.63 (3.17)

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

Mean No. Beneficiaries	Change in Yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
Without Climate and Pest Risks					
200,000	40	208.8	89	7.8	5.05 (5.32)

FINANCIAL ANALYSIS

Table CL-3: Financial Analysis

Technology	Change with Cereal-Legume Integration Project		
	Yield	Gross Returns	Costs
Cereal-Legume Integration			
Maize			
Improved Varieties	45.5 (9.2)	10.4 (10.7)	92.5 (1.3)
Organic Fertilizer	105 (5.5)	81.8 (14.2)	101.8 (21.3)
Inorganic Fertilizer	82.5 (2.9)	84.2 (14.3)	57.0 (9.5)
Intercropping w/ Legumes	7.8 (3.9)	12.2 (17.1)	24.1 (19.0)
Rotation w/ Legumes	48.3 (6.0)	162 (43)	35.5 (20.4)
Mulching	34.9 (3.8)	62.7 (16.6)	13.4 (10.2)
Reduced tillage	16.6 (3.3)	70.4 (24.4)	9.7 (11.9)
Sorghum			
Improved Varieties	32.2 (6.8)		
Organic Fertilizer	62.6 (5.7)		
Inorganic Fertilizer	67.0 (6.7)	66.2 (16.6)	31.0 (-)
Intercropping w/ Legumes	0.4 (6.8)		
Rotation w/ Legumes	38.1 (12.0)		43.3 (-)
Mulching	23.5 (6.4)	36.3 (13.9)	63.2 (19.7)
Reduced Tillage	-3.3 (11.9)	-73.0 (46.2)	
Mean of all technologies	40.0 (31)	51.3 (61.4)	47.2 (31.4)

Note: Values are the percentage change with and without project. Values derived from the ERA and other secondary sources.

Table CL-4: Values and Assumptions for Estimating the Number of Beneficiaries for Cereal-Legume Integration in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Cereal-legume	32,000	160

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary, following a typology of investment cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per

beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, cereal-legume integration has the following strong or supportive alignments:

- Strong alignment to one NDC goal: conservation agriculture
- Supportive to five NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; livestock and aquaculture productivity; governance reform

Relevant Policies

- Food and Agriculture Sector Development Policy (FASDEP II 2008)
- Ghana Poverty Reduction Strategy (GPRS II 2006–2009)
- Ghana Shared Growth and Development Agenda (GSGDA II 2014–2017)
- Agriculture Sector Plan (ASP 2009–2015)

Key Policy Gaps

- Inadequate technical and human capacity to effectively execute outlined policies
- Overreliance on donor funds for crucial activities
- Low institutional capacity for spearheading agricultural development initiatives

Key Policy Distortions

- Current land tenure regimes disincentivize investments in sustaining productivity or conservation and promote extensive practices; it is less expensive to expand production than invest in inputs and best practices on existing landscapes
- Current extension service models make implementation costs very high; consequently, most farmers do not have access to them

Key Contributors to Project Success¹⁷⁴

- Strong in-country and international expertise on CSA approaches and activities needed
- Good base of research throughout Ghana on tailoring these to specific agro-zones, soil conditions, and given farming context
- Broad grassroots support for cereal-legume integration practices

Key Risks / Barriers to Success¹⁷⁵

- Poor farmer access to advisory services and climate services
- Poor access to labor-saving technologies for soybean and groundnut harvesting

A further assessment of barriers to cereal-legume integration was provided by an in-country panel of experts. Expert opinion ranked, from highest to lowest intensity, the key barriers as irrigation/water supply followed by gender inclusivity, finance, labor resources, land tenure, technology cost, market access, farm mechanization, and access to information and inputs. Synergy with a government plan is the smallest barrier to implementing cereal-legume integration.

¹⁷⁴ Samuel T. Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana,” *Agroforestry Systems* 92, no. 2 (April 1, 2018): 375–87, <https://doi.org/10.1007/s10457-016-0035-8>.

¹⁷⁵ Wytze Marinus and Esther Ronner, “What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica,” n.d., 64.

Public Institutional Framework¹⁷⁶

- Ministry of Agriculture
- Ministry of Lands and Natural Resources
- Environmental Protection Agency
- Forestry Commission

Potential NGO Collaborators¹⁷⁷

- International Institute of Tropical Agriculture
- International Water Management Institute
- Council for Scientific and Industrial Research Ghana
- University for Development Studies Ghana
- Kwame Nkrumah University of Science and Technology
- PROIntensAfrica
- N2Africa

Most Promising Supporting Digital Agriculture Technologies

- Soil information services—enabled by big data, machine learning, and mobile technology—to support decision-making
- Mobile climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making¹⁷⁸
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to disseminate research and development outputs and support crop management decisions
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support input supply and product markets

DELIVERY - SYNTHESIS OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides implementation experience, a knowledge base, and lessons learned. Related projects underway include:

- USAID: Africa Rising Phase II: Creating Sustainable Systems for Agriculture
 - 2017–2022, US\$50 million (multiple countries)
 - Key achievements from phase 1: maize-cowpeas intercrop reduced weed infection by 40 percent, increased maize yield by 36 percent and reduced labor demand.
- Bill and Melinda Gates Foundation through Wageningen University: N2 Africa
 - 2009–ongoing, amount of funding not stated
 - Project aims to put nitrogen fixation to work for smallholder farmers in Africa. Achievements thus far include enhanced adoption of grain legume production across 600,000 farmers; improved access to information, markets, and agricultural inputs; local scientist capacity building; and enhanced demand for agro-products such as improved seeds and legume-specific fertilizer mixes.
- Drought-Tolerant Maize for Africa project

Other Relevant Completed Projects

- USAID: Agricultural Technology Transfer (ATT) Project
 - 2013–2018, US\$24 million

¹⁷⁶ Fred Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana,” n.d., 1.

¹⁷⁷ Kizito et al.

¹⁷⁸ The World Bank Group, “Agriculture Observatory.”

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Enhanced maize production; 165,250 farmers began using improved technologies and good agricultural practices (GAP) management practices.
- European Commission: Towards a long-term Africa-EU partnership to raise sustainable food and nutrition Security in Africa (PROIntensAfrica)
 - 2015–2017, £1.77 million
- AGRA: Scaling out of the integrated soil fertility management technology in the Volta Region, Ghana
 - 2011–2014, US\$540,000.

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- Blended finance opportunities via the Ministry of Agriculture and public research institutions

International Financing Opportunities

- Bilateral and multilateral donors supporting climate change resiliency, for example, USAID, FAO, World Bank

Private Financing Opportunities

- There are limited private financing opportunities for this investment; in-kind collaboration for provision of climate and advisory services is the most promising avenue for private sector engagement

Potential Private Sector Collaborators¹⁷⁹

- Esoko
- Farmerline

MAXIMIZING FINANCE FOR DEVELOPMENT

To ensure responsible CSA investment, it is important to

- strengthen private sector alignment with principles of responsible investment
- improve smallholder links through inclusive business support

Where private sector activity is limited, it becomes necessary to

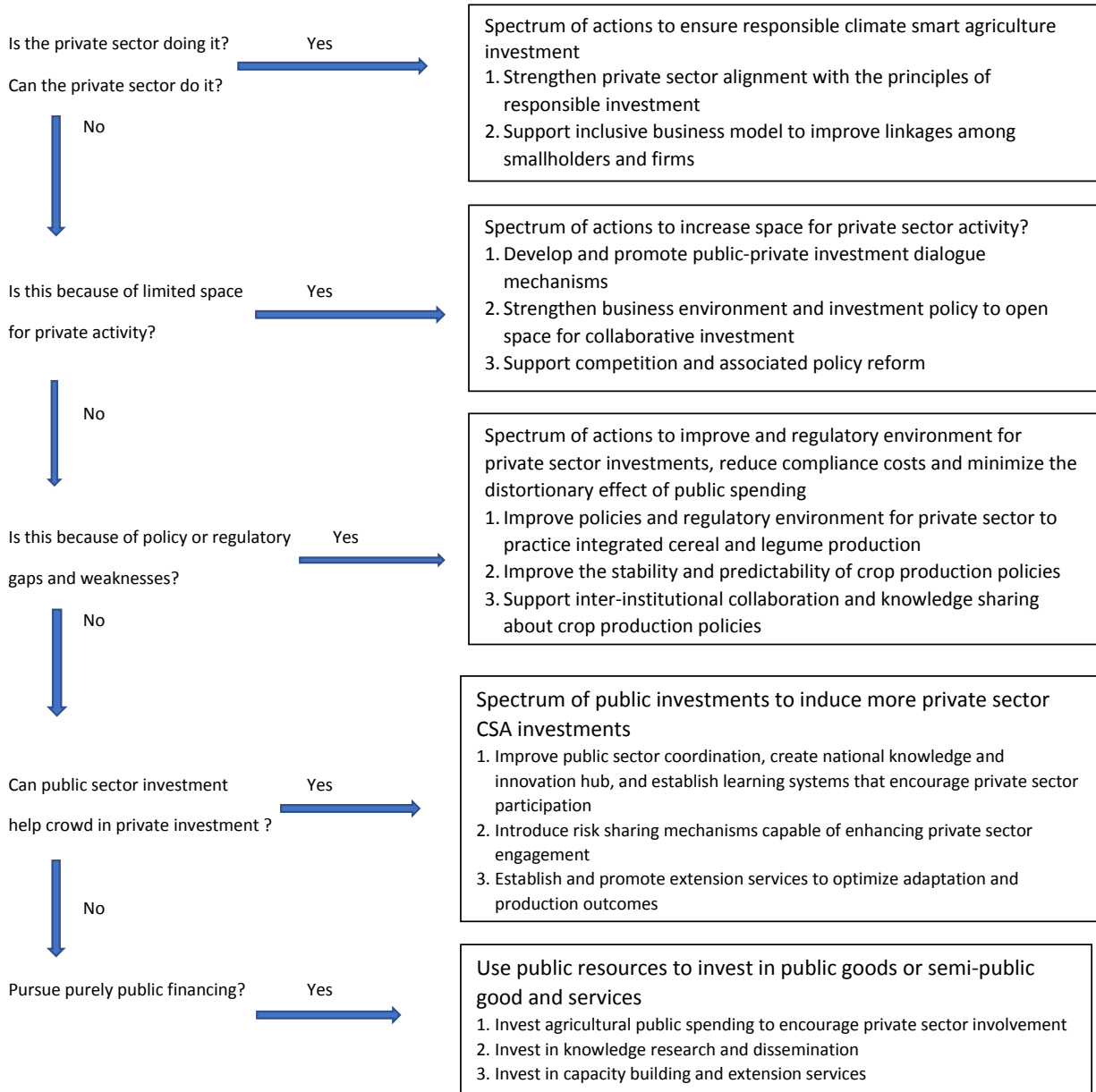
- develop and promote public-private mechanisms to aid investment
- promote improved business environment and investment policy to allow collaborative investment and associated policy reform
- reduce policy regulation weaknesses by improving policy regulations to ensure stability and predictability
- support inter-institutional collaboration and knowledge sharing

The public sector can facilitate private sector investment by

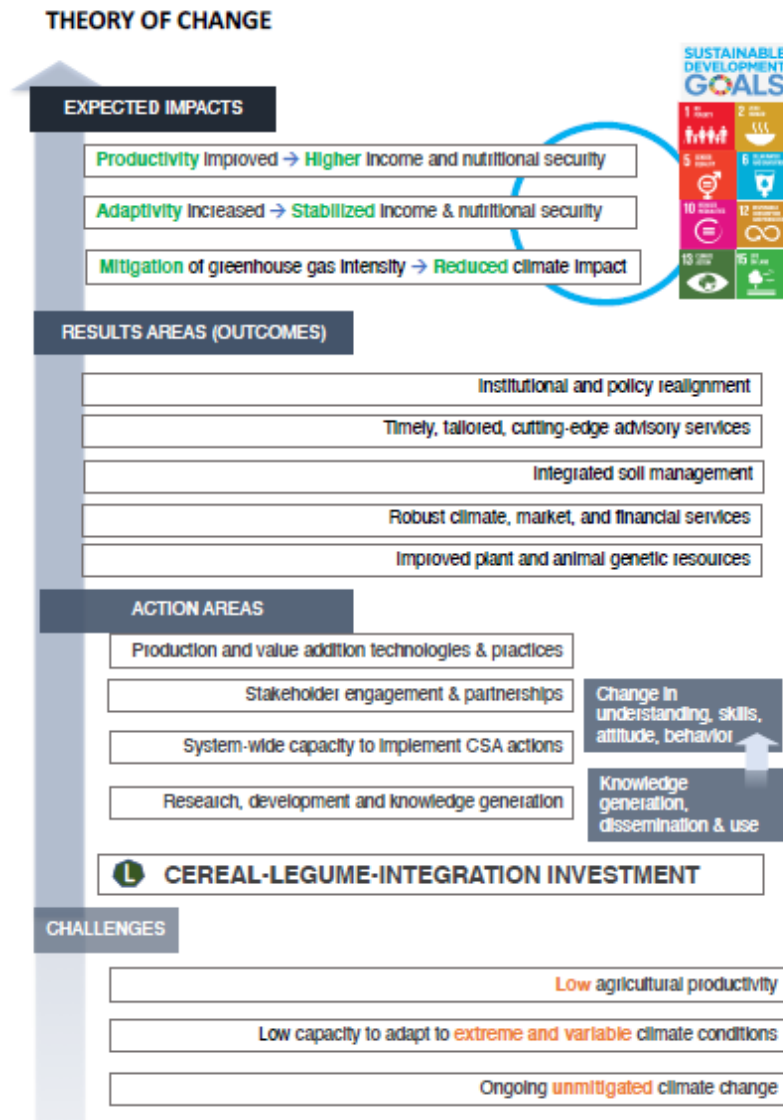
- enhancing public sector coordination that encourages private sector participation
- introducing risk-sharing mechanisms and developing extension programs to optimize adaptation and production outcomes
- supporting agricultural public spending, research, dissemination, and capacity building both on its own (for food security and national priorities) and for priorities as identified for private sector investment

¹⁷⁹ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES



THEORY OF CHANGE



A-2. Diversified tree crops

PROJECT SUMMARY

OBJECTIVE: Employ agroforestry techniques to make cashew and oil palm production climate smart.

PROJECT HIGHLIGHTS: Agroforestry, if done right, can sustainably support high-value crop mixes, while slowing the rate at which lands are converted to plantations or crop fields. This would help Ghana “get it right” by integrating cashew and oil palm into sustainable agroforestry approaches.

REGIONS: Forest, Transitional

PROJECTED BENEFICIARIES: 120,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation, Mitigation

KEY CSA INVESTMENT ACTIVITIES:

- Agroforestry: Diversification, Intensification
 - Heat- and drought-tolerant cashew and oil palm varieties
 - Disease-resistant cashew and oil palm varieties
 - Soil fertility; land and water management
- Advisory systems to promote agroforestry practices
- Realigning policy with national goals to support profitability and sectoral sustainability

JUSTIFICATION

Agroforestry offers a multitude of benefits that directly translate to improved productivity, household livelihoods, and food security; national economic growth; and domestic food supplies. These include

- Improved soil quality and fertility¹⁸⁰
 - reduced soil erosion
 - improved soil nutrients
 - improved moisture retention
 - soil microbial diversity, including nitrogen-capturing mycorrhizae fungi
 - organic carbon content
- reduced deforestation¹⁸¹
 - limited farmland expansion
 - enhanced pest control
 - enhanced microclimate regulation
- diversified farm livelihoods and resources¹⁸²
 - increased income
 - nutrition diversification and resiliency in case of crop failure
 - income diversification and resiliency in case of crop failure
 - biomass fertilizers when synthetic inputs are scarce
 - fodder for livestock

¹⁸⁰ Isaac Apuri, Kenneth Pephrah, and Godwin Thomas Wedam Achana, “Climate Change Adaptation through Agroforestry: The Case of Kassena Nankana West District, Ghana,” *Environmental Development* 28 (December 1, 2018): 32–41, <https://doi.org/10.1016/j.envdev.2018.09.002>; Ranjith P. Udawatta, Lalith Rankoth, and Shibu Jose, “Agroforestry and Biodiversity,” *Sustainability* 11, no. 10 (January 2019): 2879, <https://doi.org/10.3390/su11102879>.

¹⁸¹ Emmanuel Opoku Acheampong et al., “Deforestation Is Driven by Agricultural Expansion in Ghana’s Forest Reserves,” *Scientific African* 5 (September 1, 2019): e00146, <https://doi.org/10.1016/j.sciaf.2019.e00146>; P. Udawatta, Rankoth, and Jose, “Agroforestry and Biodiversity.”

¹⁸² Andi Nuddin et al., “Making the Case for Institutional Support on Designing Agroforestry Technology Models for Rehabilitating Critical Lands,” *Forest and Society* 3, no. 1 (April 23, 2019): 49–63, <https://doi.org/10.24259/fs.v3i1.5975>; Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana”; Nuddin et al., “Making the Case for Institutional Support on Designing Agroforestry Technology Models for Rehabilitating Critical Lands.”

- timber for fuel and furniture

Programmatic approaches to institutionally design agroforestry-promoting policies necessarily include¹⁸³

- treatment of agroforestry systems as holistic and structured units
- knowledge and skills for agroforestry on the part of farmers
- established roles and capacity of all relevant institutions
- strong coordination between sectors and ministries
- strong conservation agriculture systems
- robust control and supervision functions

Ghanaian farmers are also incentivized to practice agroforestry by the provision of grants, farming inputs, capacity training, public nurseries, and improved access to markets.¹⁸⁴ Production contracts wherein resources are provided also incentivize farmers to specialize, increase scale of production, and use inputs at appropriate levels without the threat of market constraints. These effects are particularly pronounced for small- and medium-sized producers.¹⁸⁵ At a higher level, redesigning product value chains for sustainability requires strong collaboration between multi-tier suppliers, strategic support from the private sector and NGOs, integrated management information and traceability systems, and a proven economic benefit to the climate-smart practices.¹⁸⁶

Agroforestry represents an important opportunity to more fully engage women and youth¹⁸⁷ **in the Ghanaian agricultural sector.** Over 85 percent of female Ghanaian farmers already practice agroforestry via alley cropping, scattered trees on farmland, taungya,¹⁸⁸ and home gardens. Furthermore, women farmers are highly engaged in all farm management activities (except the application of agrochemicals). Thus, training women in agroforestry and/or as agroforestry focal farmers could significantly enhance agroforestry practices and agroforestry-oriented extension services.¹⁸⁹ Cashew trees in particular can be extremely beneficial to livelihood and nutritional security; the cashew harvest occurs in the ‘lean months’ of nearly all major food crops, and can provide timely supplementary income.¹⁹⁰

PROBLEM STATEMENT

International demand for oil palm and cashew products is increasing. Ghanaian farmers have responded by increasingly devoting their time to commodity production for the export market, with a focus on cashews. This effort is supported by governmental programming. Nevertheless, the cashew and oil palm

¹⁸³ Nuddin et al., “Making the Case for Institutional Support on Designing Agroforestry Technology Models for Rehabilitating Critical Lands.”

¹⁸⁴ Kwame Antwi Oduro et al., “Farmers’ Motivations to Plant and Manage On-Farm Trees in Ghana,” *Small-Scale Forestry* 17, no. 3 (September 1, 2018): 393–410, <https://doi.org/10.1007/s11842-018-9394-5>; Richard Osei et al., “Socio-Economic Determinants of Smallholder Plantation Sizes in Ghana and Options to Encourage Reforestation,” *Southern Forests: A Journal of Forest Science* 81, no. 1 (January 2, 2019): 49–56, <https://doi.org/10.2989/20702620.2018.1490992>.

¹⁸⁵ Anette Ruml and Matin Qaim, “Effects of Marketing Contracts and Resource-Providing Contracts in the African Small Farm Sector: Insights from Oil Palm Production in Ghana,” *AgEcon Search*, 2019, <https://doi.org/10.22004/ag.econ.289547>.

¹⁸⁶ Martin Agyemang et al., “Evaluating Barriers to Green Supply Chain Redesign and Implementation of Related Practices in the West Africa Cashew Industry,” *Resources, Conservation and Recycling* 136 (September 1, 2018): 209–22, <https://doi.org/10.1016/j.resconrec.2018.04.011>.

¹⁸⁷ Osei et al., “Socio-Economic Determinants of Smallholder Plantation Sizes in Ghana and Options to Encourage Reforestation.”

¹⁸⁸ A system whereby individuals are given the right to cultivate crops during the early stages of forest plantation establishment; S. A. O. Chamshama et al., “Suitability of the Taungya System at North Kilimanjaro Forest Plantation, Tanzania,” *Agroforestry Systems* 17, no. 1 (January 1, 1992): 1–11, <https://doi.org/10.1007/BF00122924>.

¹⁸⁹ Francis Diawuo, Enoch Kwasi Kosoe, and Dzigbodi A. Doke, “Participation of Women Farmers in Agroforestry Practices in the Jaman South Municipality, Ghana,” *Ghana Journal of Development Studies* 16, no. 2 (January 1, 2019): 267–289–289, <https://doi.org/10.4314/gjds.v16i2.13>.

¹⁹⁰ GiZ et al., “A Value Chain Analysis of the Cashew Sector in Ghana,” African Cashew Initiative (Ghana, February 2010).

value chains are rife with environmental issues that threaten the sustainability and ongoing profitability of these industries.¹⁹¹

Low yields aggravate agricultural expansion, decrease nutritional stability, and exacerbate poverty. For example, Ghanaian oil palm farms yield an average 7 tons/ha/year, even though more than 20 tons/ha/year is achievable with existing management and extraction technologies. Costly fertilizers and pesticides are used past their point of effectiveness,¹⁹² while low-cost agroforestry practices such as forest residue fertilization¹⁹³ and efficient postharvest methods are largely untapped.¹⁹⁴ In an effort to compensate for these chronically low yields per hectare, oil palm areas have expanded approximately 12 percent since 1986.

Such technical inefficiency among producers correlates with lack of training, experience, and land security. Financial constraints and lack of knowledge for effective tree stock management are the primary barriers to farmers undertaking agroforestry practices; water shortages, unsupervised livestock, and bush fires are secondary barriers.¹⁹⁵ For women, who are already heavily engaged in agroforestry, lack of extension access and time poverty as a result of myriad domestic responsibilities are the primary constraints to expanding their production systems.¹⁹⁶ Catalyzing improved productivity through robust extension support would particularly benefit smallholders, who stand to gain yield increases of 1,400 percent and economic increases in excess of US\$1 billion.¹⁹⁷

Policy distortions prevent most oil palm and cashew farmers from accessing benefits that would reduce their constraints to investing in improved productivity. The current tree tenure regime in Ghana theoretically offers extension services and insurance protection against loss; however, in practice, tenure is inaccessible to most farmers. The majority are unaware of the tree titling process. The multiple layers of registering trees, along with the requisite social and financial capital, makes the process impossible for most farmers.¹⁹⁸

Cashew and oil palm expansion has been at the expense of food crops and forest lands. This has significant socioeconomic, land tenure, food security, ecosystem, and landscape implications that urgently need to be reexamined in the context of agricultural policy. Understanding the geographic distribution of commodity tree crops, integrated agroforestry practices, and their implications for food production and ecosystem services will be crucial in addressing these issues.¹⁹⁹

¹⁹¹ Agyemang et al., "Evaluating Barriers to Green Supply Chain Redesign and Implementation of Related Practices in the West Africa Cashew Industry."

¹⁹² E. K. Armah, "Productivity and Resource-Use-Efficiency of Cashew Production in Ghana" (Thesis, University Of Ghana, 2018), <http://ugspace.ug.edu.gh/handle/123456789/29747>.

¹⁹³ Partey et al., "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana."

¹⁹⁴ Tiemen Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana," *Agricultural Systems* 165 (September 1, 2018): 14–25, <https://doi.org/10.1016/j.agsy.2018.05.012>.

¹⁹⁵ Apuri, Peprah, and Achana, "Climate Change Adaptation through Agroforestry."

¹⁹⁶ Diawuo, Kosoe, and Doke, "Participation of Women Farmers in Agroforestry Practices in the Jaman South Municipality, Ghana."

¹⁹⁷ Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana."

¹⁹⁸ Cassandra Johnson Gaither, Rita Yembilah, and Sparkler Brefo Samar, "Tree Registration to Counter Elite Capture of Forestry Benefits in Ghana's Ashanti and Brong Ahafo Regions," *Land Use Policy* 85 (June 1, 2019): 340–49, <https://doi.org/10.1016/j.landusepol.2019.04.006>.

¹⁹⁹ Abubakari Ahmed, Eric Dompheh, and Alexandros Gasparatos, "Human Wellbeing Outcomes of Involvement in Industrial Crop Production: Evidence from Sugarcane, Oil Palm and Jatropha Sites in Ghana," *PLOS ONE* 14, no. 4 (April 25, 2019): e0215433, <https://doi.org/10.1371/journal.pone.0215433>; Kwabena Asubonteng et al., "Effects of Tree-Crop Farming on Land-Cover Transitions in a Mosaic Landscape in the Eastern Region of Ghana," *Environmental Management* 62, no. 3 (September 1, 2018): 529–47, <https://doi.org/10.1007/s00267-018-1060-3>.

CLIMATE MODELING

Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas—even entire countries—as well as creating pockets of increased suitability. At a global scale, these shifts will be significant in determining which countries can grow what crops, which in turn will affect international trade. At the same time, government GHG mitigation policies together with demographic and economic growth trajectories will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).²⁰⁰

Table TC-1: Percentage Difference in Rainfed Crop Yields over a No-Climate Change Reference Scenario for 2030 and 2050, under Different GHG Concentration Scenarios (RCPs), with BAU Demographic and Economic Growth Trajectories (SSP2)

Percent Difference from No-Climate Change Scenario	Area Harvested				Yield			
	Low Emissions (RCP 4.5)		High Emissions (RCP 8.5)		Low Emissions (RCP 4.5)		High Emissions (RCP 8.5)	
	2030	2050	2030	2050	2030	2050	2030	2050
Crop								
OLS-Palm Fruit	2.15	4.20	2.16	4.18	-3.66	-7.23	-3.17	-6.19
F&V-plantain	0.93	1.91	1.31	2.56	-2.73	-5.43	-2.00	-4.00

Ghanaian smallholders have tended to replace food crops with cash tree crops, pushing food crop production to expand into previous natural spaces to maintain nutritional security.²⁰¹ Environmental degradation reduces resiliency and exacerbates the effects of climate.

Long-lived tree crops also have major impacts on land tenure. The establishment of trees often represents claiming of the land and consolidates communal land rights into sole ownership—typically by male heads-of-household. This has been a source of community land conflict.²⁰² Furthermore, consolidating land ownership to adult males perpetuates exclusion of women from land access and tenure. It also creates a barrier to youth joining the agricultural sector, amplifying youth flight to urban areas and the aging of the agricultural work force.²⁰³

The suitable area for oil palm and cashew is projected to increase under climate change scenarios. This could facilitate further expansion of tree crops and exacerbate the food security and social equity issues. As such, CSA practices that focus on intensification rather than expansion of tree cropping are foundational to climate change mitigation, national nutritional security, and continued socioeconomic development.²⁰⁴

²⁰⁰ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015) for details.

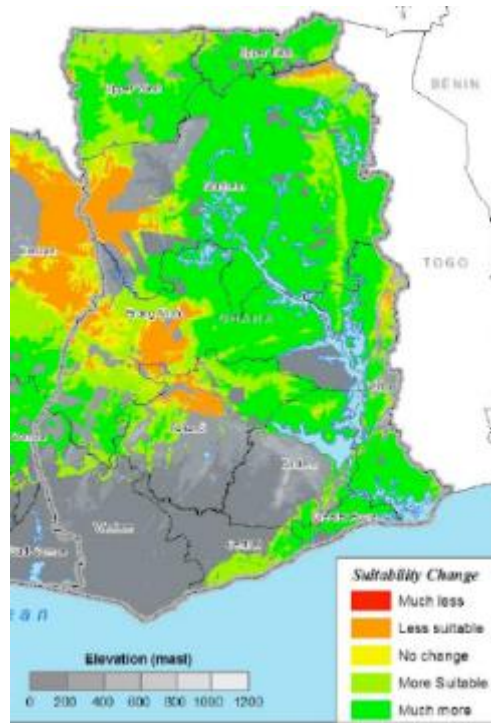
²⁰¹ Ruth Evans, Simon Mariwah, and K. Barima Antwi, "Growing Cashew Nuts in Ghana," Briefing for policy and practice, Land Access, Food Security, and Poverty Alleviation (University of Reading: Walk Institute for Climate System Research, n.d.).

²⁰² Evans, Mariwah, and Antwi.

²⁰³ Ruth Evans, "Cashew Cultivation, Access to Land and Food Security in Brong-Ahafo, Ghana: Preventing the Intergenerational Transmission of Poverty?," University of Reading, accessed October 29, 2019, <https://www.reading.ac.uk/geographyandenvironmentalscience/Research/HER/ges-RE-Ghana.aspx>.

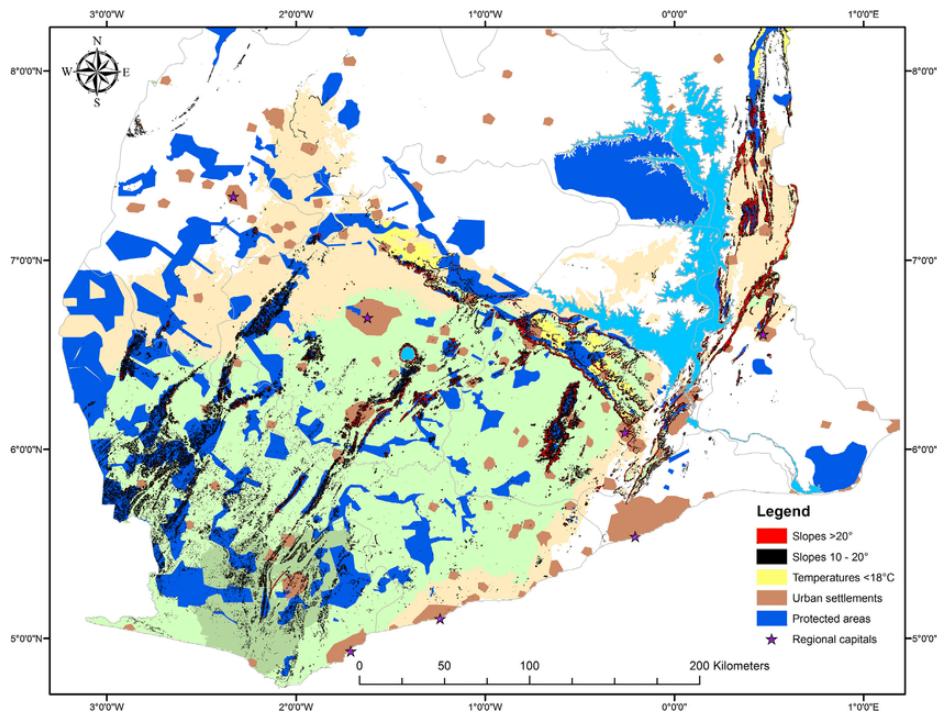
²⁰⁴ Tiemen Rhebergen et al., "Climate, Soil and Land-Use Based Land Suitability Evaluation for Oil Palm Production in Ghana," *European Journal of Agronomy* 81 (November 1, 2016): 1–14, <https://doi.org/10.1016/j.eja.2016.08.004>.

Figure TC-1: Suitability Change for Cashew-Growing Regions by 2050²⁰⁵



²⁰⁵ Peter Laderach et al., “Predicting the Impact of Climate Change on Cashew Growing Regions in Ghana and Cote d’Ivoire” (Managua, Nicaragua: International Center for Tropical Agriculture (CIAT), September 2011), https://www.africancashewalliance.com/sites/default/files/documents/ghana_ivory_coast_climate_change_and_cashew.pdf.

Figure TC-2: Map of Southern Ghana Showing Suitable and Available Areas (in green) with Potential for Oil Palm Expansion, after Excluding Urban Settlements and Protected Areas²⁰⁶



POTENTIAL PROJECT IMPACTS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

The CSA diversified tree crops project would raise the income of 120,000 farmers and their families by a projected 20 percent. It is worth highlighting that there is a high NPV relative to cost in both with- and without-risk scenarios. The chance of high and positive NPV in both scenarios is particularly good. Even though there will be a positive income change, the ROI and BCR are low; the strength of this project is its significant mitigation effect.

Table TC-2: Tree Crop CBA With and Without Climate Risks

Mean Beneficiaries	No. Beneficiaries	Change in yield (%) ^a	NPV (US\$, million) ^b	Chance Positive (%) ^b	NPV	ROI ^b	BCR (SD)
With Climate and Pest Risks							
120,000	20	204.2	92	8.24	1.1 (2.12)		
Without Climate & Pest Risks							
120,000	20	217.6	94	8.79	5.64 (8.00)		

Note: a. Average percentage change between beneficiaries with versus without project. b. Average of 100 model runs.

²⁰⁶ Rhebergen et al., "Climate, Soil and Land-Use Based Land Suitability Evaluation for Oil Palm Production in Ghana," November 1, 2016.

FINANCIAL ANALYSIS

Table TC-3: Financial Analysis

Technology	Change with Diversified Tree Crops		
	Yield	Gross Returns	Costs
Diverse Tree Crop Systems			
Cashew			
Improved Varieties	21		
Intercropping	-7.8		
Soil Fertility Management			
Oil Palm			
Improved Varieties			
Agroforestry			
Soil Fertility Management			
Improved management	73		
Mean of all Technologies	29		

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table TC-4. Values and Assumptions for Estimating the Number of Beneficiaries for Diversified Tree Crops in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Diversified Tree Crops	29,040	242

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, diversified tree crops have the following strong or supportive alignments:

- Strong alignment to seven NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; conservation agriculture; governance reform; actively manage natural spaces; livelihood diversity
- Supportive to one NDC goal: wildfire management

Relevant Policies²⁰⁷

- Ghana Forest Plantation Strategy (2016–2040)
- Ghana Forest and Wildlife policy (2012)
- Tree Crops Policy (TCP)
- Timber Resource Management Act (2002)

Key Policy Gaps²⁰⁸

- Lack of resources and capacity to support effective enforcement of forest exploitation laws
- Absence of land-use planning in rural areas
- Lack of common definition of sustainability
- Lack of acknowledgement of landscape and emissions issues by sector policies and certifying bodies
- Misalignment between prevailing policies

Key Policy Distortions

- Tree tenure regimes disincentivize retention of trees on-farm and create barriers to transparency and efficiency between producers and governing bodies
- Land tenure regimes disincentivize investments in sustained productivity or conservation and promote extensive practices; it is less expensive to expand production than invest in inputs and best practices on existing landscapes
- Current extension service models have high implementation costs; consequently, most farmers do not have access to them
- Policies are interpreted toward economic gain rather than sustainable future community use, creating unnecessary competition between farmers and entrepreneurs for land and forest resource access

Key Contributors to Project Success²⁰⁹

- High profitability of the industry
- Private sector and international investment in continued oil palm and cashew productivity in Ghana
- Proven improved productivity of agroforestry systems
- Strong engagement of female farmers in agroforestry
- Enabling policy environment

Key Risks/Barriers to Success²¹⁰

- Lack of (a) institutional resources to enforce forest conservation laws;²¹¹ (b) integrated management and traceability systems;²¹² (c) commitment and support from government, private sector, and non-profit stakeholders;²¹³ (d) research outputs on best agroforestry practices in Ghanaian oil palm and cashew production.²¹⁴

²⁰⁷ Rhebergen et al., “Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana.”

²⁰⁸ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund”; Christian Bunn, Climate Smart Cocoa in Ghana, September 30, 2019.

²⁰⁹ Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana.”

²¹⁰ Marinus and Ronner, “What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica.”

²¹¹ Acheampong et al., “Deforestation Is Driven by Agricultural Expansion in Ghana’s Forest Reserves.”

²¹² Agyemang et al., “Evaluating Barriers to Green Supply Chain Redesign and Implementation of Related Practices in the West Africa Cashew Industry.”

²¹³ Agyemang et al.

²¹⁴ Agyemang et al.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Institutional culture discourages collaboration between implementing governing bodies and sectors.²¹⁵
- Institutional inertia discourages increasing transparency and efficiency of current policy practices.²¹⁶
- Limited farmer access to knowledge and economic and agronomic resources to support innovation.²¹⁷
- Prioritization of cash crops can decrease nutritional security and cause land conflicts.²¹⁸

Farmer and forester decisions are driven by economic and policy constraints detailed under key policy gaps and distortions sections above. A further assessment of barriers to tree crop production, specifically cashews, was provided by an in-country panel of experts. The results showed that land tenure systems, availability of labor resources, and reliability of irrigation water supply are the main barriers to cashew production and value chains. These barriers were followed by finance, cost of technology, and market access. Synergy with government plans ranked as the least barrier to cashew production.

Public Institutional Framework²¹⁹

- Ministry of Food and Agriculture
- Ministry of Lands and Natural Resources
- Environmental Protection Agency
- Forestry Commission
- National REDD+ Programme
- Tree and Industrial Crop Development Authority²²⁰

Potential NGO Collaborators²²¹

- CGIAR
- Rainforest Alliance
- International Institute of Tropical Agriculture
- African Cashew Initiative²²²
- Walker Institute²²³

Most Promising Supporting Digital Agriculture Technologies

- Mobile finance services, along with digitized farm records to support credit line establishment
- Smart contracting for transparent and equitable land tenure processes
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best practices and disseminate research and development outputs
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support management decisions²²⁴
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

²¹⁵ Karbo et al., “Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture.”

²¹⁶ Bunn, *Climate Smart Cocoa in Ghana*.

²¹⁷ Armah, “Productivity and Resource-Use-Efficiency of Cashew Production in Ghana.”

²¹⁸ Evans, Mariwah, and Antwi, “Growing Cashew Nuts in Ghana.”

²¹⁹ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

²²⁰ FruitWorldMedia, “Production of Cashew in Ghana to Be Enhanced,” *The Clipper*, August 2, 2018, <https://theclippermag.com/index.php/nuts/cashews/production-of-cashew-in-ghana-to-be-enhanced/>.

²²¹ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

²²² GiZ et al., “A Value Chain Analysis of the Cashew Sector in Ghana.”

²²³ Evans, Mariwah, and Antwi, “Growing Cashew Nuts in Ghana.”

²²⁴ The World Bank Group, “Agriculture Observatory.”

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

An interconnected foundation of related projects provides a strong knowledge base and lessons learned. Related projects underway include:

- Government of Ghana: Cashew Development Plan²²⁵
 - 2017–2027, US\$123.8 million
 - Project aims to expand production from 70,000 tons to 200,000 tons while supporting research and development to improve access to inputs and technologies.
- GIZ and ComCashew (formerly known as ACI): The Competitive Cashew Initiative²²⁶
 - 2016–2020, US\$139 million
 - Key achievements include over 47,000 farmers trained and over 10,000 ha of new plantations cultivated; technical support to various actors along the value chain; yield surveys; production of improved planting material.
- Bill and Melinda Gates Foundation: African Cashew Initiative²²⁷

Other Relevant Completed Projects

- AfDB: Ghana Cashew Development Project²²⁸
 - 2000–2010, US\$11.54 million
 - Achieved the growth of 31,187 cashew trees and constructed 192 km of feeder roads benefiting 13,673 households.
- International Plant Nutrition Institute: Oil palm best management practices in Ghana²²⁹
 - 2012–2017, undisclosed budget
 - Demonstrated potential impact of enhanced extension services on water and fertilizer management practice to reduce the gap between actual and potential yield.
- USAID: Coastal Sustainable Landscape Project (CSLP)
 - 2013–2018, US\$6.8 million
 - Supported on-farm tree planting for commercial and agroforestry species.

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- REDD+
- The Government of Ghana is supporting oil palm and cashew production through a variety of enabling policies and programs

Private Financing Opportunities

- The profitability of the oil palm and cashew sectors imply the investment of many private sector actors in the continued productivity of these crops.

International Financing Opportunities

- Emissions Reductions Payment Agreement via Forest Carbon Partnerships Facility Carbon Fund
- Bill and Melinda Gates Foundation
- GIZ

²²⁵ AgricInGhana Media, “Ghana Launches a 10 Year Cashew Development Plan,” 2019, <http://agricinghana.com/>.

²²⁶ giz, “Competitive Cashew Initiative (ComCashew),” 2019, <https://www.giz.de/en/worldwide/19011.html>.

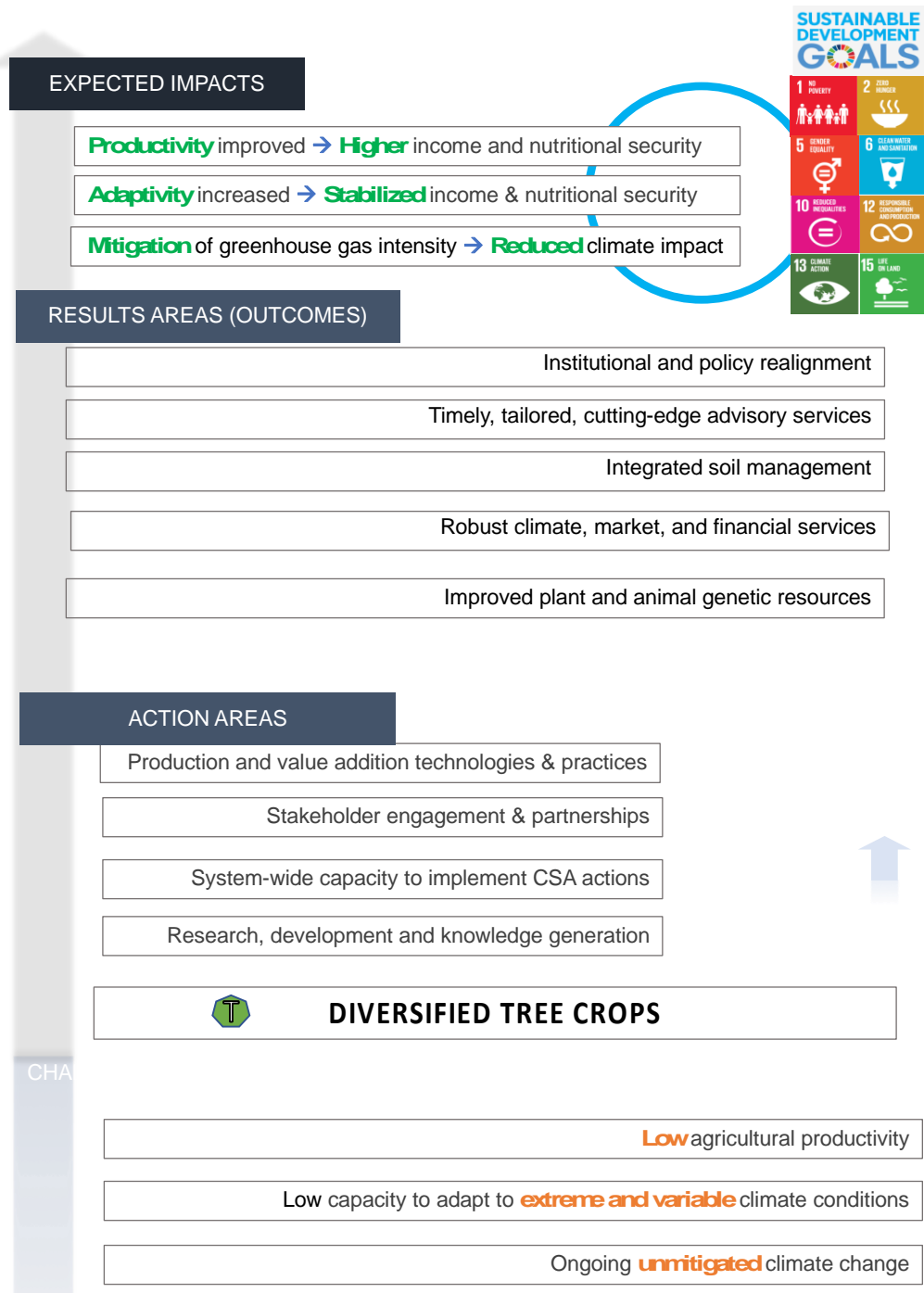
²²⁷ GIZ et al., “A Value Chain Analysis of the Cashew Sector in Ghana.”

²²⁸ Groupe de la Banque Africaine de Développement, “Ghana - Cashew Production Development Project,” October 9, 2019, <https://projectsportal.afdb.org/dataportal/VPProject/show/P-GH-AAA-001?lang=fr>.

²²⁹ International Plant Nutrition Institute, “Oil Palm Best Management Practices in Ghana,” 2018, <http://ssa.ipni.net/topic/oil-palm-best-management-practices>.

- Technoserve

THEORY OF CHANGE



A-3. Climate-smart cocoa production

PROJECT SUMMARY

OBJECTIVE: Sustain and expand Ghana’s agricultural economy in the face of climate change through climate-smart innovations in the production of the country’s top agricultural commodity.

PROJECT HIGHLIGHTS: Key project trying to transform Ghana’s cocoa sector; climate impacts will be high and negative on the sector, but CSA efforts show remarkable ability to reverse losses. Individual farmer benefits are high; although this ‘transformation project package’ is expensive, it is justified given demonstration and leverage potential.

REGIONS: Forest, Transitional

PROJECTED BENEFICIARIES: 150,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation

KEY CSA INVESTMENT ACTIVITIES:

Improve suitability of cocoa growing areas using agroforestry techniques

- Heat-, drought-tolerant, and disease-resistant planting materials
- Replacing old trees and improving soil fertility
- IPM and cocoa spraying

JUSTIFICATION

Cocoa is a primary driver of the Ghanaian agricultural economy. Over 12 million people rely on the cocoa producing regions of Ghana for their livelihoods.²³⁰ Cocoa accounts for 1.6 percent of the national GDP and 8.1 percent of the agricultural GDP.²³¹ Negative impacts on the cocoa economy would have major repercussions for that national economy, particularly rural livelihoods and development.²³² International demand for cocoa is very high and increasing; as a result, many stakeholders are invested in the long-term sustainability of the Ghanaian cocoa sector, including the Government of Ghana²³³ and domestic and international private sector actors.²³⁴ The sector also holds great sway over livelihoods and ecological sustainability in Ghana; hence domestic and international NGOs,²³⁵ as well as bilateral and multilateral international donors,²³⁶ are also heavily involved in cocoa production in Ghana.

Climate change poses significant threats to the Ghanaian cocoa industry. Current cocoa production practices in Ghana are exacerbating these threats and minimizing farmers’ ability to adapt to the impacts of climate change. Climate-smart agroforestry practices have proven to improve cocoa yields both in Ghana and other cocoa-producing regions of the world.²³⁷

²³⁰ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund.”

²³¹ Ghana Statistical Service, “Rebased 2013–2018 Annual Gross Domestic Product,” April 2019, 11.

²³² Christian Bunn et al., “Recommendation Domains to Scale out Climate Change Adaptation in Cocoa Production in Ghana,” *Climate Services*, September 2019, 100123, <https://doi.org/10.1016/j.cliser.2019.100123>.

²³³ Cocoa Board, “Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II),” UNDP in Ghana, 2019, https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/ESPII.html.

²³⁴ The Hershey Company, “Three-Year Study Concludes That CocoaLink ‘Significantly Improved the Livelihoods’ of Ghanaian Cocoa Farmers,” *Business Wire*, March 18, 2014, <https://www.businesswire.com/news/home/20140318005928/en/Three-Year-Study-Concludes-CocoaLink-%E2%80%9CSignificantly-Improved-Livelihoods%E2%80%9D>.

²³⁵ SNV, “Cocoa Eco-Project,” 2019, <http://www.snv.org/project/cocoa-eco-project>.

²³⁶ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund.”

²³⁷ Richard Asare et al., “On-Farm Cocoa Yields Increase with Canopy Cover of Shade Trees in Two Agro-Ecological Zones in Ghana,” *Climate and Development* 11, no. 5 (May 28, 2019): 435–45, <https://doi.org/10.1080/17565529.2018.1442805>; Issaka Abdulai et al., “Characterization of Cocoa Production, Income Diversification and Shade Tree Management along a Climate Gradient in Ghana,” *PLOS ONE* 13, no. 4 (April 16, 2018): e0195777, <https://doi.org/10.1371/journal.pone.0195777>.

The Ghanaian cocoa sector is highly internally regulated. All farmers must register with the Cocoa Board, which controls input supply, product purchase, prices,²³⁸ extension services, and most other aspects of the industry. In addition to the complexities of the Ghanaian land tenure system, cocoa farmers must register each tree as part of the tree tenure regime.²³⁹ This process is quite labor- and paperwork-intensive, and as such most farmers do not register their trees consistently. This results in the loss of many of the benefits associated with the memberships dues they pay to the Cocoa Board.²⁴⁰

Digital agricultural innovations show significant promise in the cocoa sector. Over 90 percent of Ghanaian cocoa farmers use mobile phones. CocoaLink has demonstrated that timely, practical push-SMS services to cocoa farmers significantly increase productivity across both large populations and multiple production years.²⁴¹ The SMS service was so successful that the organization responded to demands for a non-Android based service. Now internet users can access a CocoaLink bot through Facebook messenger to ask questions and access articles and quizzes.²⁴²

PROBLEM STATEMENT

Cocoa production is the impetus for one of the highest deforestation rates in Africa—3.2 percent annually. Cocoa landscapes cover approximately 6 million ha of Ghana’s forest zones. They account for nearly 139,000 ha of forest loss each year, or 83 percent of total annual deforestation, making it the single most important commodity driver of deforestation in Ghana. Deforestation and degradation due to cocoa production in Ghana emit over 45.1 MtCO₂e emissions annually.²⁴³ Deforestation and landscape degradation exacerbate climate change.

Cocoa trees are highly susceptible to climate change. Heat, drought, pests, and erosion all heavily impact cocoa production.²⁴⁴ The prevalence of each of these conditions will increase substantially in Ghana due to climate change. Given current practices, expected losses in the cocoa sector will reach US\$410 million annually (1 percent of Ghana’s GDP) by 2050.²⁴⁵

Within the cocoa-growing region of Ghana, each agroecological subregion (Figure CO-1) is threatened by climate change in distinct ways and to varying degrees. This implies a need for region-tailored responses and solutions.²⁴⁶ Climate change will bring marked shifts in these agroecological subregions (Figure CO-2). Significant swaths of the current cocoa-growing region will cease to be suitable for cocoa production by 2030.²⁴⁷ Production in most remaining cocoa-production areas will become more uncertain (Figure CO-3). Some small areas will increase in suitability for cocoa production.²⁴⁸

²³⁸ Reuters, “Chocolate Gold: Ivory Coast and Ghana Set a Fixed Price for Cocoa,” Aljazeera, August 9, 2019, <https://www.aljazeera.com/ajimpact/chocolate-gold-ivory-coast-ghana-set-fixed-price-cocoa-190806221440295.html>.

²³⁹ Johnson Gaither, Yembilah, and Samar, “Tree Registration to Counter Elite Capture of Forestry Benefits in Ghana’s Ashanti and Brong Ahafo Regions.”

²⁴⁰ Bunn, Climate Smart Cocoa in Ghana; Christian Bunn et al., “Climate Smart Cocoa in Ghana,” Info Note (CCAFS & CIAT, September 2019).

²⁴¹ The Hershey Company, “Three-Year Study Concludes That CocoaLink ‘Significantly Improved the Livelihoods’ of Ghanaian Cocoa Farmers.”

²⁴² Farmerline LTD, “Farmerline Launches New CocoaLink Service: A Free Mobile App That Puts the Power of Mobile Technology in Farmers’ Hands,” May 24, 2018, <https://farmerline.co/2018/05/24/farmerline-launches-new-cocoalink-service-a-free-mobile-app-that-puts-the-power-of-mobile-technology-in-farmers-hands/>.

²⁴³ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund”; ghananewsagency.org, “Ghana Signs Deal to Cut Carbon Emissions and Reduce Deforestation,” GhanaWeb, July 10, 2019, <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-signs-deal-to-cut-carbon-emissions-and-reduce-deforestation-762012>.

²⁴⁴ Yaro, “Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana.”

²⁴⁵ Bunn et al., “Climate Smart Cocoa in Ghana.”

²⁴⁶ Bunn et al.; Bunn et al., “Recommendation Domains to Scale out Climate Change Adaptation in Cocoa Production in Ghana.”

²⁴⁷ World Bank, “Ghana Dashboard,” 2017; USAID, “Ghana.”

²⁴⁸ Bunn et al., “Climate Smart Cocoa in Ghana”; Bunn et al., “Recommendation Domains to Scale out Climate Change Adaptation in Cocoa Production in Ghana.”

Figure CO-1: Current Cocoa Agroecological Subregions in Ghana²⁴⁹

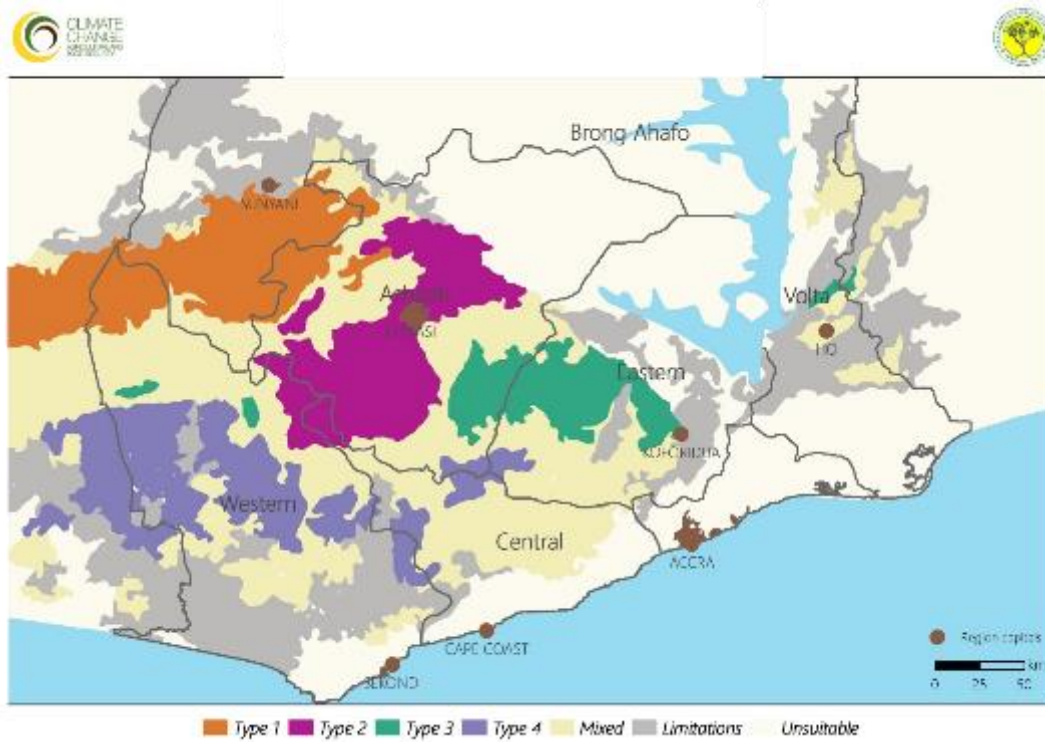
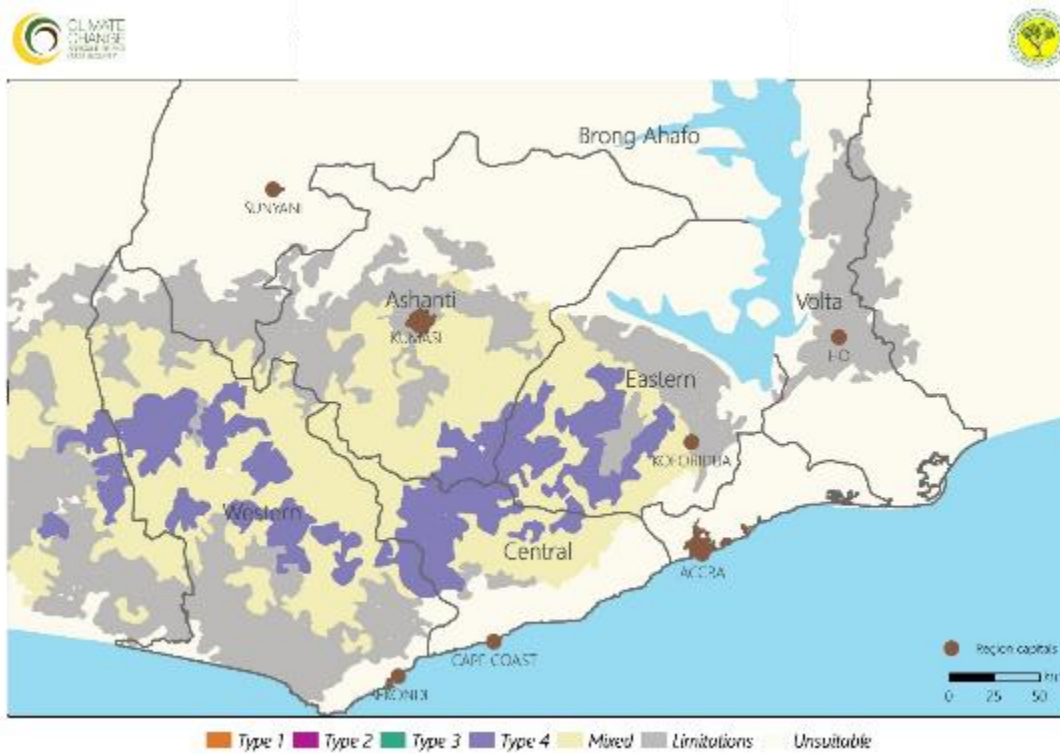


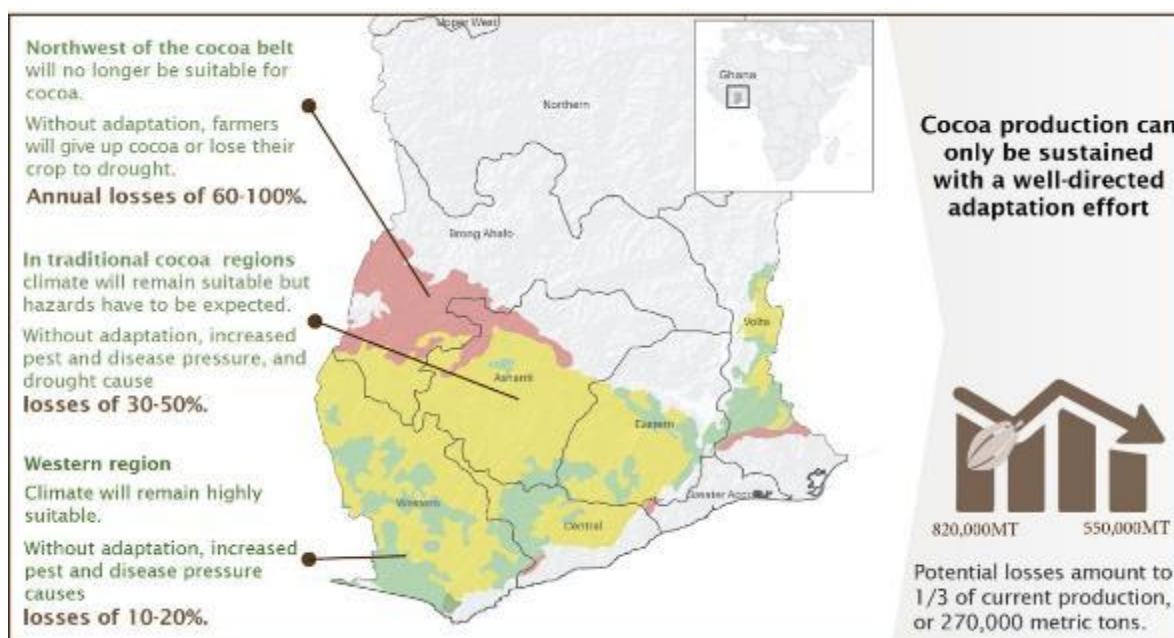
Figure CO-2: Cocoa Agroecological Subregions in Ghana by 2050²⁵⁰



²⁴⁹ Bunn et al., "Recommendation Domains to Scale out Climate Change Adaptation in Cocoa Production in Ghana."

²⁵⁰ Bunn et al.

Figure CO-3: Cost of Inaction Across Cocoa Subregions of Ghana²⁵¹



KEY CSA INVESTMENT ACTIVITIES

The current context of issues facing cocoa production, the CSA responses, cost benefits, and barriers are well understood (see Table CO-1). This CSA cocoa project will improve the suitability of cocoa growing areas using agroforestry techniques, including

- Heat-, drought-tolerant, and disease-resistant planting materials
- Replacing old trees and improving soil fertility
- IPM and cocoa spraying

The impact of these actions on yields is detailed in Table CO-4: Financial Analysis.

Table CO-1: CSA Interventions in Cocoa

Current state of cocoa farming	Climate-smart practice	Cost	IRR/NPV vs. BAU	Barriers to adoption
<i>Fertilizer application</i>				
<ul style="list-style-type: none"> • Insufficient quantity • Wrong timing • Wrong composition • Not adequate to soil 	<ul style="list-style-type: none"> • Correct fertilizer application increases land productivity, avoids soil depletion and offsets land-use changes. 130% higher yields 	<ul style="list-style-type: none"> • Higher fertilizer cost • Soils analysis • Training • More labor 	<ul style="list-style-type: none"> • +50% • +100% 	<ul style="list-style-type: none"> • Inadequate public fertilizer schemes • Lack of weather services to support the timing of application
<i>Planting material</i>				
<ul style="list-style-type: none"> • Inadequate varieties 	<ul style="list-style-type: none"> • Hybrid varieties from verified sources in 	<ul style="list-style-type: none"> • Cost of obtaining 	<ul style="list-style-type: none"> • +2% • +25% 	<ul style="list-style-type: none"> • Lack of access to verified seeds

²⁵¹ Bunn et al., "Climate Smart Cocoa in Ghana."

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

Current state of cocoa farming	Climate-smart practice	Cost	IRR/NPV vs. BAU	Barriers to adoption
<ul style="list-style-type: none"> • Old material • Random planting 	ordered plantation offer higher yields and better resilience.	seedlings doubled		<ul style="list-style-type: none"> • Lack of varieties that are ready for the future climate
<i>Shade cover</i>				
<ul style="list-style-type: none"> • Low shade cover • Natural shade trees • Low density 	<ul style="list-style-type: none"> • Long-term sustainability of the system increases by adding more trees with a functional structure. 	<ul style="list-style-type: none"> • Lower yields in the first years • More labor 	<ul style="list-style-type: none"> • -10% • -10% 	<ul style="list-style-type: none"> • Fear of higher disease incidence • Uncertain land and tree tenure results in a preference for short term benefits
<i>Irrigation</i>				
<ul style="list-style-type: none"> • No irrigation • No drainage 	<ul style="list-style-type: none"> • Better water management by drip irrigation can increase yields substantially (+75%) and trenches reduce soil erosion and flooding during intensive rainfall. 	<ul style="list-style-type: none"> • US\$2,500 for irrigation equipment and installation 	<ul style="list-style-type: none"> • -30% • -25% 	<ul style="list-style-type: none"> • High upfront investment for irrigation • Trenches and low-tech irrigation with plastic bottles require substantial labor but are more profitable • Such systems require training
<i>Pest and disease management</i>				
<ul style="list-style-type: none"> • Pest control is insufficient, and fungicides are not applied 	<ul style="list-style-type: none"> • Changes in climate increase pest pressure. IPM raises yields by 25% 	<ul style="list-style-type: none"> • 15 labor days per ha, • Pesticides, and fungicides 	<ul style="list-style-type: none"> • +3% • +30% 	<ul style="list-style-type: none"> • Misuse and mishandling of pesticides threaten health, environment, and effectiveness of agents • Very high training deficit in the region

CLIMATE MODELING

Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas (for example, entire countries) but also creating pockets of increased suitability. At a global scale, these shifts will be significant in determining what countries can grow what crops, which in turn will affect international trade. At the same time, government GHG mitigation policies, together with demographic and economic growth trajectories, will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).²⁵² See Annex E for full information.

Under a variety of socioeconomic and GHG concentration scenarios, climate change is projected to negatively affect cocoa in both the medium and long term

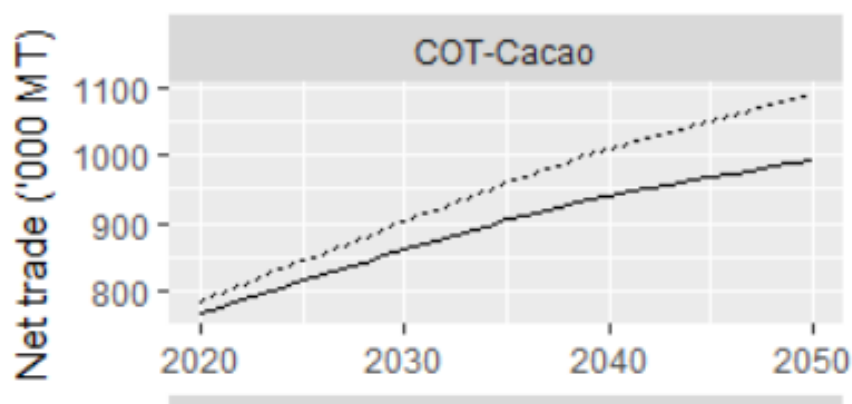
²⁵² IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

Table CO-2: Percentage Difference in Rainfed Crop Yields Over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different GHG Concentration Scenarios (RCPs), with BAU Demographic and Economic Growth Trajectories (SSP2)

Percent Difference from No-Climate Change Scenario	Area harvested				Yield			
	Low emissions (RCP 4.5)		High emissions (RCP 8.5)		Low emissions (RCP 4.5)		High emissions (RCP 8.5)	
	2030	2050	2030	2050	2030	2050	2030	2050
Cocoa	-0.05	-0.06	-0.03	-0.03	-3.33	-6.59	-2.80	-5.49

Cocoa, vital to Ghana’s economy, exhibits considerable vulnerability. Modelling shows losses around 3 percent in the short term (2030) but as high as 5–7 percent by 2050. The IMPACT model also shows a decline in the overall cocoa area, in all scenarios and all time periods.

Figure CO-4: Net Trade Projections out to 2050 (SSP2 RCP 8.5)

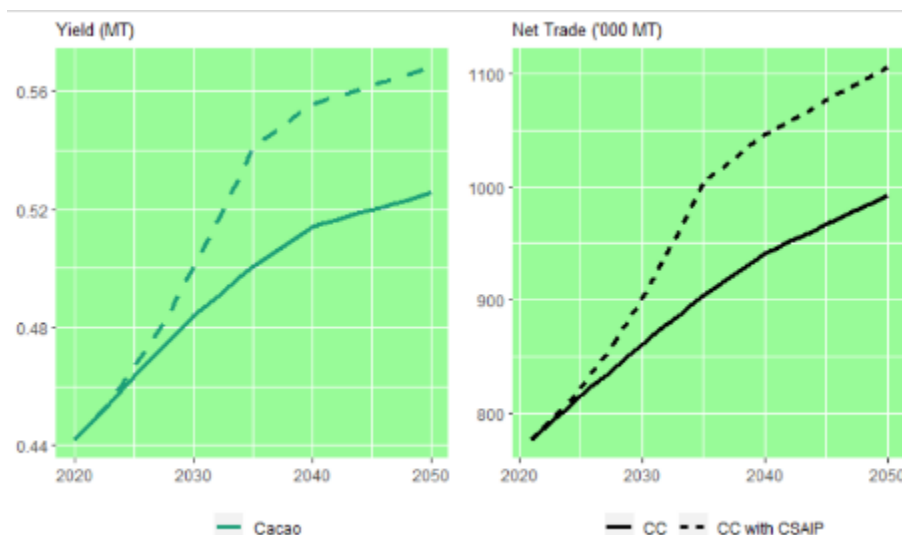


Note: Scenario: __CC;NoCC.

POTENTIAL IMPACTS OF CSA INVESTMENTS

Modelling suggests that the Cocoa Production CSAIP could offset potential damages to Ghana’s cocoa production and sustain Ghana’s competitive edge in cocoa exports. These exports are critically important to Ghana (Figure CO-5). The CSA actions improve overall yields and the net trade. Thus, the CSA package essentially erases the considerable vulnerability cocoa exhibits to climate change (Table CO-2).

Figure CO-5: Potential Impact of the Cocoa Production CSAIP on Rainfed Cocoa Yields and Balance of Trade. Trajectories modeled using IMPACT under a BAU SSP 2 and a pessimistic representative carbon concentration scenario (RCP 8.5)



Model Assumptions: The assumptions on yield and farmer adoption rates for cocoa were:

- Cocoa - current: 0.5 tons/ha; potential yield with project: 1 ton/ha; farmer adoption: 25 percent
- Assumptions on technology were for a time horizon of 5 years, and 3 years as the time to reach half of adoption rate.

ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

Cocoa is a dominant force in Ghana’s economy, driving much of its agricultural export sector. The CSA cocoa project would raise the income of 100,000 cocoa farmers and their families by a projected 20 percent. Yet the project is not without risks in that sector, as reflected by the difference in the mean NPV with and without risks. It is worth highlighting that the without-risk estimate is more than double the mean NPV when risk is included. The ROI are low, because many of these investments (for example, planting new and resilient trees) have a low return within the project time frame. But, as shown in Table CO-6, they represent the beginning elements of transforming the CSA sector. Given the results of the climate modeling, which shows that these CSA interventions can reverse project cocoa yield declines, this project should also be considered foundational to the sector’s transformation. It entails high project costs and low BCR in the short term but represents an attempt to transform the cocoa sector.

Table CO-3: Cocoa CBA With and Without Climate Risks

Mean No. Beneficiaries	Change in yield (%)	Mean NPV (US\$, millions)	Chance Positive NPV (%)	ROI	BCR (SD)
With Climate and Pest Risks					
150,000	32	188.8	89	4.15	2.72 (3.96)
Without Climate and Pest Risks					
150,000	32	231.1	93	5.10	3.33 (4.33)

Table CO-4: Financial Analysis

Technology	Change with Investments for CSA Cocoa ²⁵³		
	Yield	Gross Returns	Costs
Cocoa			
Inorganic fertilizer	50		
Agroforestry - Alley cropping	-25		
Improved varieties	14		
Drip irrigation	75		
IPM	25		
Mean of all Technologies	28		

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table CO-5: Values and Assumptions for Estimating the Number of Beneficiaries for CSA Cocoa in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Cocoa	54,000	360

ESTIMATED PROJECT COSTS:

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS**Alignment to NDC**

Of the 12 identified goals of the NDC that are potentially related to CSA, cocoa has the following strong or supportive alignments:

- Strong alignment to six NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; cocoa emission reduction; governance reform; actively manage natural spaces
- Supportive to two NDC goals: wildfire management; conservation agriculture

Relevant Policies²⁵⁴

- Environmental Sustainability and Policy for Cocoa Production in Ghana (ESP 2013–2016)
- Cocoa Action Strategy (2014)
- Ghana Cocoa Sector Development Strategy (CSDS I 1999)
- Ghana cocoa and forests initiative national implementation plan (2018–2020)

Key Policy Gaps²⁵⁵

²⁵³ Based on statistics from literature.

²⁵⁴ Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana."

²⁵⁵ Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund"; Bunn, Climate Smart Cocoa in Ghana.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Lack of resources and capacity to support effective enforcement of forest exploitation laws
- Absence of land-use planning in rural areas
- Lack of common definition of sustainability
- Lack of acknowledgement of landscape and emissions issues by sector policies and certifying bodies

Key Policy Distortions

- Tree tenure regimes disincentivize retention of trees on-farm and create barriers to transparency and efficiency between producers and governing bodies
- Land tenure regimes disincentivize investments in sustained productivity or conservation and promote extensive practices; it is less expensive to expand production than invest in inputs and best practices on existing cocoa landscapes
- Current extension service models make implementation costs very high; consequently, most farmers do not have access to them
- Farmers do not consistently receive the inputs, financing, capacity building, and certifications associated with required fee-based membership in the Cocoa Board²⁵⁶
- Fixed-price funds²⁵⁷ may not consistently reach farmers

Key Contributors to Project Success²⁵⁸

- Strong grassroots support from community leaders and cocoa farmers
- Strong support from the federal government of Ghana, including a willingness to shift institutional culture and paradigms
- Proven high productivity of climate-smart agroforestry cocoa practices
- High profitability of the industry
- Private sector and international investment in continued cocoa productivity in Ghana

Key Risks/Barriers to Success²⁵⁹

- Institutional culture discourages
 - collaboration between implementing governing bodies and sectors
 - increasing transparency and efficiency of current policy practices
- Limited farmer and forester access to knowledge and the economic and agronomic resources necessary to support innovation
- Farmer and forester decisions are driven by economic and policy constraints detailed under the 'Key Policy Gaps' and 'Key Policy Distortions' sections below

A further assessment of barriers to CSA cocoa production was provided by an in-country panel of experts. Expert opinion ranked, from highest to lowest intensity, the key barriers as finance, land tenure systems, cost of technology, availability of labor resources, and access to information and inputs. Synergy with government plans is ranked as the least barrier to implementing CSA cocoa.

Public Institutional Framework²⁶⁰

- Ghana Cocoa Board
- Ministry of Lands and Natural Resources
- Environmental Protection Agency

²⁵⁶ Convergence, "Conducting a Feasibility Study for a Financing Facility for Cocoa Smallholders in Ghana," Design Grant Summary (Rainforest Alliance & RaboBank, May 2018).

²⁵⁷ Reuters, "Chocolate Gold: Ivory Coast and Ghana Set a Fixed Price for Cocoa."

²⁵⁸ Partey et al., "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana."

²⁵⁹ Marinus and Ronner, "What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica."

²⁶⁰ Kizito et al., "Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana."

- Forestry Commission
- HIA Consortium and Governance Board
- National REDD+ Programme

Potential NGO Collaborators²⁶¹

- World Cocoa Foundation
- Rainforest Alliance
- International Institute of Tropical Agriculture
- Nature Conservation Research Centre
- IUCN-Ghana
- Arocha-Ghana
- Cocoa Research Institute of Ghana

Most Promising Supporting Digital Agriculture Technologies

- Mobile climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making²⁶²
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to disseminate research and development outputs and support crop management decisions
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support input supply and product markets
- Smart contracting for transparent, streamlined, and equitable land tenure processes

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides a strong knowledge base and lessons learned. Relevant projects underway include:

- Ghana: Cocoa Forest REDD+ Programme
 - 2017–2021, US\$121 million private sector investments and US\$53 million from the Government of Ghana
 - This project has an estimated 50 percent yield increase and over 294 MtCO₂e (44 percent) emission reductions. IRR > 438 percent and NPV = 20 percent (US\$339 million)²⁶³
- World Bank: Emission Reductions Payment Agreement via Forest Carbon Partnership Facility Carbon Fund
 - Up to US\$50 million based on performance
 - Project aims for carbon emissions reductions through climate-smart cocoa production
- World Bank: Enhancing Natural Forest and Agroforest Landscapes Project²⁶⁴
 - 2019–2023, US\$19.39 million
 - Project aims to reduce degradation and deforestation and enhance private investment in forest plantation around cocoa landscapes.
- GIZ: Sustainable Smallholder Agribusiness in Western and Central Africa²⁶⁵
 - 2014–2019, undisclosed amount

²⁶¹ Kizito et al.

²⁶² The World Bank Group, “Agriculture Observatory.”

²⁶³ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund.”

²⁶⁴ Ghana FIP, “Enhancing Natural Forest and Agroforest Landscapes Project,” Text/HTML, World Bank, February 27, 2015, <https://projects.worldbank.org/en/projects-operations/project-detail/P148183>.

²⁶⁵ giz, “Sustainable Smallholder Agribusiness in Western and Central Africa,” 2014, <https://www.giz.de/en/worldwide/16002.html>.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Led by the Ghana Cocoa Board, project aims to enhance cocoa production and general food production through good management practices for cocoa. It supplies technical advice, inputs, market information, insurance, and loan services.
- UNDP: Environmental Sustainability and Policy for Cocoa Production in Ghana (ESP II)²⁶⁶
 - 2016–2020, US\$1.85 million
 - Project aims at enhancing adoption of environmentally sustainable and climate change resilient cocoa production practices.
 - 34,914 farmers trained; 336,170 economic trees planted; 1,668 extension agents and lead farmers trained
- DANIDA: Climate-Smart Cocoa Systems for Ghana (CLIMCOCOA)²⁶⁷
 - 2016–2020, US\$1.4 million university research grant
 - Project aims to estimate the effect of climate change and variability of cocoa yield under different scenarios and analyze the potential of agroforestry to ameliorate cocoa yield losses under high temperature and drought conditions.

Other Relevant Completed Projects

- CocoaLink²⁶⁸
 - Sponsored by Hershey’s
 - Reached 45,000 Ghanaian cocoa farmers in 1,800 communities; generated 1.2 million free local language SMS; increased yields by 45.6 percent in three years
- SNV: Cocoa Eco-Project²⁶⁹
 - 2013–2015, undisclosed amount
 - Implemented with IITA and Kaupa Kokoo Farmers Union (KKFU)
 - Project aimed at increasing productivity of smallholder farmers through identification and promotion of sustainable intensification and diversification strategies.
 - Enhanced production from 400 kg/ha to 800–1,200 kg/ha
- UNDP: Environmental Sustainability and Policy for Cocoa Production in Ghana (ESP I)²⁷⁰
 - 2013–2016, US\$1.7 million
 - Project aimed to create institutional systems, tools, and policies to rehabilitate cocoa landscapes; to conserve and expand forests, buffer zones, and corridors; and to incentivize cocoa farmers to adopt best management practices.
 - Project trained 10,000 farmers on benefits of environmental cocoa production practices, community tree tenure rights, and forest laws and regulations.

Table CO-6: Potential Interventions for Ghanaian Cocoa Production Based on Degree of Threat²⁷¹

Intervention	Incremental Adaptation	Systemic Adaptation	Transformation
Plant	<ul style="list-style-type: none"> ● Improved planting material and propagation ● Spacing ● Pruning 	<ul style="list-style-type: none"> ● Improved planting material and propagation ● Spacing 	<ul style="list-style-type: none"> ● Improved planting material and propagation ● Spacing ● Pruning

²⁶⁶ Cocoa Board, “Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II).”

²⁶⁷ Danida Research Portal, “Climate Smart Cocoa Systems for Ghana (CLIMCOCOA),” June 2016, <http://drp.dfccentre.com/project/climate-smart-cocoa-systems-ghana-climcocoa>.

²⁶⁸ The Hershey Company, “Three-Year Study Concludes That CocoaLink ‘Significantly Improved the Livelihoods’ of Ghanaian Cocoa Farmers.”

²⁶⁹ SNV, “Cocoa Eco-Project.”

²⁷⁰ Cocoa Board, “Environmental Sustainability and Policy for Cocoa Production in Ghana (ESP I),” UNDP in Ghana, 2016, https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/environmental-sustainability-and-policy-for-cocoa-production-in-.html.

²⁷¹ Bunn et al., “Climate Smart Cocoa in Ghana.”

		• Pruning	
Plot	<ul style="list-style-type: none"> • Diverse shade • Flood-tolerant shade species 	<ul style="list-style-type: none"> • Diverse shade • Buffer strips 	<ul style="list-style-type: none"> • Diverse shade • High percentage of shade cover
Diversification	<ul style="list-style-type: none"> • Mushroom cultivation • Snail production • Optimize shade 	<ul style="list-style-type: none"> • Food crop diversification 	<ul style="list-style-type: none"> • Intercropping with cola nut/African plum/cashew/timber
Soil	<ul style="list-style-type: none"> • Mulch • Cover crops • Manual weeding 	<ul style="list-style-type: none"> • Biochar • Irrigation • Zero burn and tillage 	<ul style="list-style-type: none"> • Soil organic carbon enhancement • Irrigation • Zero burn and tillage
Pest and Disease	<ul style="list-style-type: none"> • IPM • Phytosanitary measures • Resistant varieties 	<ul style="list-style-type: none"> • IPM • Phytosanitary measures • Resistant varieties 	<ul style="list-style-type: none"> • IPM • Phytosanitary measures • Resistant varieties

For the interventions above, the required landscape and enabling environment begins with:²⁷²

- Watershed protection
- Riparian buffers
- Forest and wildlife protection
- Farmer groups for reforestation
- Protection of off-reserve forests
- Resourcing the Forestry Commission, the Minerals Commission, the Water Resources Commission and other relevant agencies to enable completion of their mandates
- Farmer field school and mass media campaigns to raise awareness about the threat of climate change and preventive measures against forest fires
- Roads, bridges, and other construction activities planned away from riparian areas, wetlands, and aquifers

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- REDD+
- The Ghana Cocoa Board controls profit margins, input supplies, purchasing, terms, financing, capacity building, and most other aspects of cocoa production. As such, financing solutions must necessarily be integrated with the Cocoa Board. Blended financing solutions appear to be the most promising.²⁷³
- Fixed pricing for exports with premiums for producers²⁷⁴

Potential Private Sector Collaborators

- Touton
- Olam
- Mondelez

²⁷² Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund”; Bunn, Climate Smart Cocoa in Ghana.

²⁷³ Convergence, “Conducting a Feasibility Study for a Financing Facility for Cocoa Smallholders in Ghana.”

²⁷⁴ Reuters, “Chocolate Gold: Ivory Coast and Ghana Set a Fixed Price for Cocoa.”

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Armajaro
- Hershey's²⁷⁵
- ECOM

Private Financing Opportunities

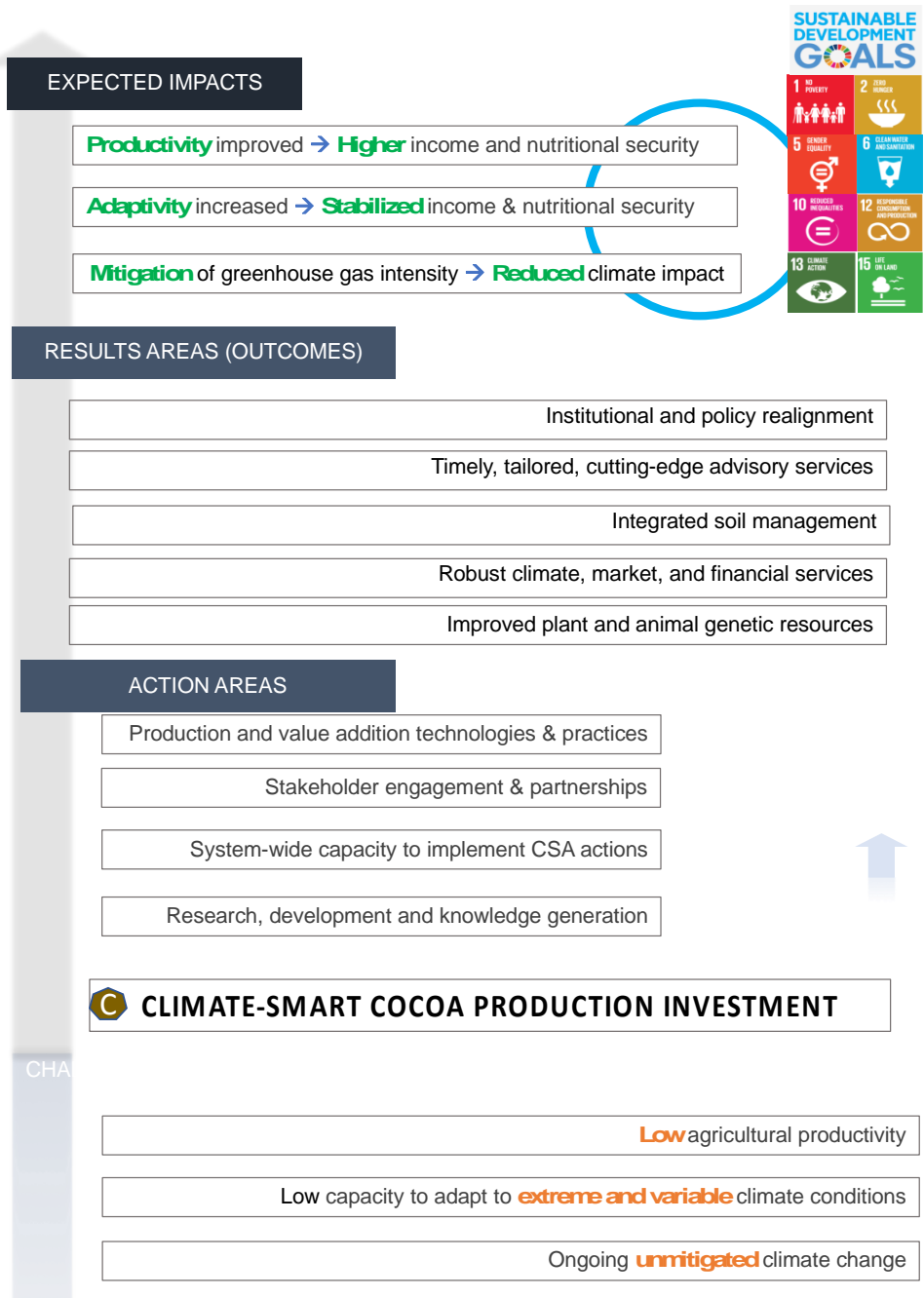
- Cocoa is a very profitable international market, so there is significant private sector investment in its continued productivity and quality. Many private sector actors are thus ready to engage in ensuring the sustainability of the cocoa economy in Ghana. Please see the list of private sector collaborators above.

International Financing Opportunities

- Emissions Reductions Payment Agreement via Forest Carbon Partnerships Facility Carbon Fund

²⁷⁵ The Hershey Company, "Three-Year Study Concludes That CocoaLink 'Significantly Improved the Livelihoods' of Ghanaian Cocoa Farmers."

THEORY OF CHANGE



A-4. Roots and tubers-livestock integration

PROJECT SUMMARY

OBJECTIVE: Decrease production costs and increase climate resiliency using integrated root-tuber-livestock systems.

PROJECT HIGHLIGHTS: improving food security and building resilient systems; increasing income and savings of poor farmers; increasing on-farm efficiencies; supporting improvement of smallholder sector; potential to boost exports for yams; adding new value chains.

REGIONS: Transitional, Savannah, Coastal

PROJECTED BENEFICIARIES: 200,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation, Mitigation (partial)

KEY CSA INVESTMENT ACTIVITIES:

- Reduce cost and improved accessibility of high-quality livestock feeds
- Improve resource-use efficiency and economic resiliency by using crop residues as livestock feed
- Optimize crop productivity through integrated soil fertility management using manures
- Heat-tolerant, drought-tolerant, fast-growing, and disease-resistant cassava and yam varieties

JUSTIFICATION

The diversity of integrated crop-livestock production systems makes them synergistically more productive and resilient than either system alone.²⁷⁶ The vast majority of Ghanaian smallholders already own livestock. Most livestock are free-range, and about 90 percent of farmers also feed crop residues to their livestock; agro-industrial by-products (such as bran) are another common feed supplement.²⁷⁷

Cassava and yam are widely grown staple food crops in Ghana. Cassava is the main staple food crop of Ghana; it is grown by over 90 percent of farmers and contributes over 20 percent of the agricultural GDP.²⁷⁸ It is very tolerant of poor growing conditions; even with poor soil, droughts, and frequent disease, it can yield about 13 tons of tubers per hectare.²⁷⁹ Yams contribute more than 15 percent of the agricultural GDP and account for about 11 percent of total annual calories consumed. Unlike cassava, however, yams require good rainfall and fertile soils.²⁸⁰ There is significant untapped opportunity for improved heat-tolerant, drought-tolerant, and disease-resistant varieties of both crops. Additionally, cassava breeding could offer short-duration and fast-growing varieties.

Livestock feed is a high-potential use for yam and cassava crop residues. Both crops produce root and peel residues, as well as foliage and shoots that can be harvested several times through the year. These can be used as feed for cattle, sheep, goats, pigs, poultry, rabbits, pigs, broiler and layer poultry, and fish without adverse effects on growth or productivity.²⁸¹ Animals raised on cassava leaves have lower

²⁷⁶ Renato Villano, Bright Owusu Asante, and Boris Bravo-Ureta, "Farming Systems and Productivity Gaps: Opportunities for Improving Smallholder Performance in the Forest-Savannah Transition Zone of Ghana," *Land Use Policy* 82 (March 1, 2019): 220–27, <https://doi.org/10.1016/j.landusepol.2018.12.010>; Bright O. Asante et al., "Determinants of Farm Diversification in Integrated Crop–Livestock Farming Systems in Ghana," *Renewable Agriculture and Food Systems* 33, no. 2 (April 2018): 131–49, <https://doi.org/10.1017/S1742170516000545>.

²⁷⁷ Solomon Konlan et al., "Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana," *International Journal of Livestock Research* 6, no. 6 (2016): 39, <https://doi.org/10.5455/ijlr.20160613094759>.

²⁷⁸ Kwame Oppong-Apane, "Cassava as Animal Feed in Ghana: Past, Present and Future" (Accra, Ghana: FAO, 2013).

²⁷⁹ Ioannis Mavromichalis, "Using Cassava as a Global Livestock Feed Ingredient," *Feed Strategy*, April 18, 2017, <https://www.feedstrategy.com/animal-feed-manufacturing/using-cassava-as-a-global-livestock-feed-ingredient/>.

²⁸⁰ P. Anaadumba, "Analysis of Incentives and Disincentives for Yam in Ghana," Technical Note, MAFAP (Rome: FAO, 2013).

²⁸¹ Janet Pandi, "Promoting Sweet Potato as Animal Feed," *The National* (blog), August 3, 2015, <https://www.thenational.com.pg/promoting-sweet-potato-as-animal-feed-2/>; Asit Chakrabarti, "Sweet Potato: An Excellent Source of Livestock Feed," ResearchGate, March 4, 2014,

incidences of parasites, general good health and disease resistance, low mortality, and require few or no antibiotics.²⁸² Yam leaves are high in protein (similar to alfalfa) and amino acid content; they also have a good mineral profile and vitamins A, B2, C, and E.²⁸³

Processing yam and cassava residues offers several important advantages. For monogastric animals, drying, heating, or grinding inactivates protease inhibitors.²⁸⁴ Conserving residues as silages also mitigates seasonal feed shortages and reduces the impact of seasonal price fluctuations,²⁸⁵ thus fostering economic, productive, and climate resiliency. Importantly, yam and cassava residues are sources of animal feed that do not compete with human food security, are abundant, and are free or low cost.

Livestock manure is an important alternative source of fertilizer. Small ruminant manure has similar chemical characteristics to synthetic fertilizer.²⁸⁶ Integrated use of manure and NPK fertilizer has proven to be particularly profitable across various crops, including cassava and yam. In many cases, crops fertilized with a combination of manure and synthetic fertilizers are more productive and resource-use efficient than crops fertilized with either manure or synthetic fertilizer alone.²⁸⁷

PROBLEM STATEMENT

Maize is widely grown in Ghana but significant demand both for human and livestock consumption has resulted in maize deficits. Because of the high cost of maize, many farmers have shifted toward agro-industrial by-products for animal feed.²⁸⁸ Nevertheless, feed costs continue to constitute 40–70 percent of the production costs of all types of livestock, including pigs, ruminants, poultry, and fish.²⁸⁹

Some have proposed using yam root and cassava tuber as a relatively low-cost, accessible component of animal feed.²⁹⁰ This approach has various complexities: cassava must be properly preserved to avoid spoilage and toxic hydrocyanic acid accumulation.²⁹¹ Cassava also completely lacks protein and essential vitamins, and thus must be carefully supplemented.²⁹² Yams can cause choking if they are not chopped, and they are associated with tooth decay in animals. Feeding of yams that are sprouted, frozen, rotten,

https://www.researchgate.net/publication/303856559_Sweet_Potato_-_An_Excellent_Source_of_Livestock_Feed/link/575853c208ae414b8e3f58da/download.

²⁸² Maggie Hennessy, "IITA Looks to Make Cassava a Major Source of Animal Feed," News, *FeedNavigator* (blog), February 10, 2014, <https://www.feednavigator.com/Article/2014/02/10/IITA-looks-to-make-cassava-a-major-source-of-animal-feed>; Research Program on Roots, Tubers, and Bananas, "Cassava as Animal Feed in Africa: Taking Advantage of Expanding Cultivation," CGIAR, October 24, 2013, <http://www.rtb.cgiar.org/blog/2013/10/24/cassava-as-animal-feed-in-africa-taking-advantage-of-expanding-cultivation/>; Ho Bunyeth and T R Preston, "Growth Performance and Parasite Infestation of Goats given Cassava Leaves as a Supplement to Grazing in Lowland and Upland Regions of Cambodia," *Livestock Research for Rural Development* 18, no. 2 (2006): 8.

²⁸³ Pandi, "Promoting Sweet Potato as Animal Feed."

²⁸⁴ Bunyeth and Preston, "Growth Performance and Parasite Infestation of Goats given Cassava Leaves as a Supplement to Grazing in Lowland and Upland Regions of Cambodia."

²⁸⁵ NewVision, "Converting Sweet Potato Garbage into High Quality Livestock Feed," October 26, 2017, http://www.newvision.co.ug/new_vision/news/1464515/converting-sweet-potato-garbage-quality-livestock-feed.

²⁸⁶ K. O. Ansah et al., "Manure Characteristics of Small Ruminants Fed Agro By-Products in the Guinea Savannah Agro-Ecological Zone of Ghana," *Ghana Journal of Agricultural Science* 54, no. 1 (January 1, 2019): 67-76-76.

²⁸⁷ Gizachew Kebede Biratu et al., "Cassava Response to the Integrated Use of Manure and NPK Fertilizer in Zambia," *Heliyon* 4, no. 8 (August 1, 2018): e00759, <https://doi.org/10.1016/j.heliyon.2018.e00759>; FAO, "Fertilizer Use by Crop in Ghana," 2003, <http://www.fao.org/3/a0013e/a0013e09.htm>.

²⁸⁸ Oppong-Apene, "Cassava as Animal Feed in Ghana: Past, Present and Future."

²⁸⁹ Oppong-Apene; Lawrence Yaw Kusi et al., "The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature," *International Journal of Management Sciences* 5, no. 6 (2015): 14; Eric Amenyogbe et al., "A Review of Ghanas Aquaculture Industry," *Journal of Aquaculture Research & Development* 09, no. 08 (2018), <https://doi.org/10.4172/2155-9546.1000545>; NewVision, "Converting Sweet Potato Garbage into High Quality Livestock Feed."

²⁹⁰ G.J. Scott, "Roots, Tubers, Plantains and Bananas in Animal Feeding" (FAO, 1989), <http://www.fao.org/3/T0554E/T0554E13.htm>; Pandi, "Promoting Sweet Potato as Animal Feed"; Oppong-Apene, "Cassava as Animal Feed in Ghana: Past, Present and Future."

²⁹¹ Oppong-Apene, "Cassava as Animal Feed in Ghana: Past, Present and Future."

²⁹² Integrated Cassava Project, "Cassava in the Livestock Feed Industry," IITA & CGIAR, CassavaBiz, 2005, <http://www.cassavabiz.org/postharvest/lvstock.htm>.

or in combination with raw soybeans can cause serious health complications.²⁹³ Finally, using staple food crops to produce livestock feed may exacerbate the existing competition between human and livestock needs.

A lack of access to fertilizer and other inputs is one of the major constraints on agricultural productivity in Ghana, and one of the primary causes of agricultural encroachment on natural spaces.²⁹⁴ Ghanaian farmers applied an average of 21 kg/ha to arable land in 2016, versus the world average of 140.5 kg/ha.²⁹⁵ A dearth of credit and other financial services, highly variable markets, low irrigation rates, and fertilizer-use inefficiency further aggravate the underlying causes of this issue.²⁹⁶ Repeated under-fertilization results in degraded soils and exacerbates agricultural expansion. Some crops remove more nutrients from the soil than others. For example, cassava and yam account for less than 20 percent of total cropped areas, but 37 percent of nitrogen-deficient cropped areas. The harvesting process for cassava and yams also negatively affects soil structure and makes it particularly prone to erosion. The most depleted soils (soils whose fertility has declined thus affecting productivity) in the national landscape are in the southeast and west-central zones, which correspond to the areas of intense cassava production.²⁹⁷

Significantly greater fertilizer access and use is needed to support national goals of improved productivity and resilience in the Ghanaian agricultural sector. To support robust production increases throughout the sector, total fertilizer inputs will need to increase approximately 333 percent from 120,000 tons (2016) to roughly 400,000 tons annually. Integrated soil fertility management and the application of the 4R technique (right source, right placement, right quantity and right time) for synthetic fertilizer are needed. Using livestock manures to supplement synthetic fertilizers will also play a crucial role in achieving this goal.²⁹⁸

Previous integrated soil fertility management programs for roots and tubers have had limited success. Land insecurity is a major barrier to investing in soil fertility.²⁹⁹ The current Ghanaian land tenure system makes it easier to expand to new lands than invest money and labor in the continued productivity of existing lands. Farmers also lack reasonable access to financial services, timely extension information, and risk-mitigating mechanisms (such as insurance) to support such innovations in their current practices.³⁰⁰

CLIMATE MODELING

Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas and even entire countries, as well as creating pockets of increased suitability. At a global scale, these shifts will be very significant in determining what countries can grow what crops, which in turn will affect international trade. At the same time, government GHG mitigation policies, together with

²⁹³ Jane A Parish, "Feeding Sweet Potatoes to Beef Cattle" (Mississippi State University, n.d.).

²⁹⁴ M. Kermah et al., "N₂-Fixation and N Contribution by Grain Legumes under Different Soil Fertility Status and Cropping Systems in the Guinea Savanna of Northern Ghana," *Agriculture, Ecosystems & Environment* 261 (July 2018): 201–10, <https://doi.org/10.1016/j.agee.2017.08.028>; Michael Kermah et al., "Maize-Grain Legume Intercropping for Enhanced Resource Use Efficiency and Crop Productivity in the Guinea Savanna of Northern Ghana," *Field Crops Research* 213 (November 2017): 38–50, <https://doi.org/10.1016/j.fcr.2017.07.008>.

²⁹⁵ World Bank, "Fertilizer Consumption (Kilograms per Hectare of Arable Land)," Data, 2016, https://data.worldbank.org/indicator/AG.CON.FERT.ZS?locations=ZG&most_recent_value_desc=true&view=chart.

²⁹⁶ Land and Plant Nutrition Management Service, "Fertilizer Use by Crop in Ghana," Land and Water Development (Rome: FEO, 2005).

²⁹⁷ FAO, "Fertilizer Use by Crop in Ghana."

²⁹⁸ Heffernan Ariga, "Ghana Fertilizer Assessment," African Fertilizer and Agribusiness Partnership (Alabama: IFDC, June 2012).

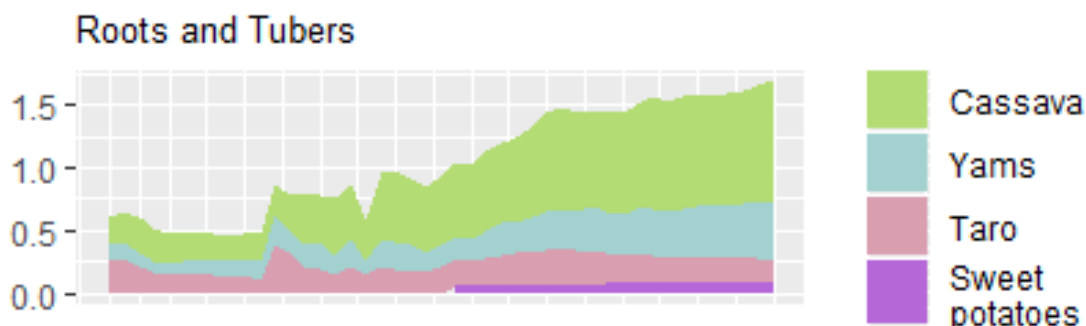
²⁹⁹ Emmanuel Frossard et al., "The Challenge of Improving Soil Fertility in Yam Cropping Systems of West Africa," *Frontiers in Plant Science* 8 (November 21, 2017), <https://doi.org/10.3389/fpls.2017.01953>.

³⁰⁰ Johnson Gaither, Yembilah, and Samar, "Tree Registration to Counter Elite Capture of Forestry Benefits in Ghana's Ashanti and Brong Ahafo Regions"; Christian Andres et al., "Social Network to Inform and Prevent the Spread of Cocoa Swollen Shoot Virus Disease in Ghana," *Agronomy for Sustainable Development* 38, no. 5 (October 2, 2018): 53, <https://doi.org/10.1007/s13593-018-0538-y>; James Boafo, "Expanding Cashew Nut Exporting from Ghana's Breadbasket: A Political Ecology of Changing Land Access and Use, and Impacts for Local Food Systems," *The International Journal of Sociology of Agriculture and Food* 25, no. 2 (August 27, 2019): 152–72.

demographic and economic growth trajectories, will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).³⁰¹

Most predictions of climate change impacts on biophysical suitability hold management and technology constant at current levels. For example, some studies indicate that by 2050, cassava yields are expected to decline by 13.5 percent and yam by 30 percent. Yet the IMPACT study discovers more optimistic findings, as shown below.

Figure RT- 1: Area Harvested in Roots and Tubers in Ghana 1973–2017 (million ha)



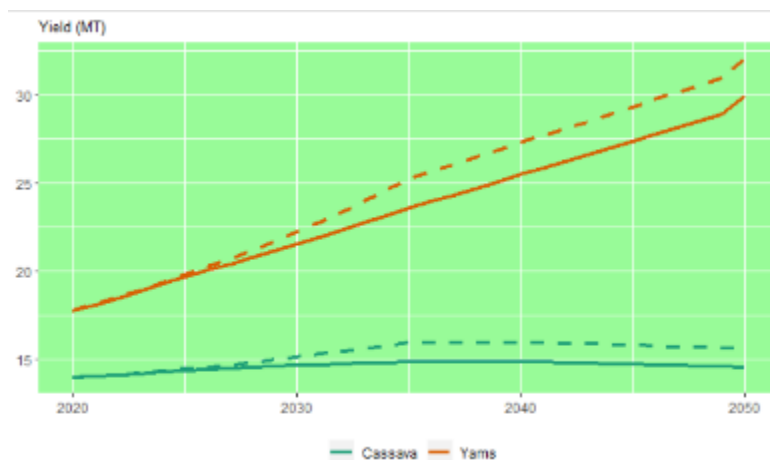
The expansion of roots and tubers, especially cassava, shown in Figure RT-1 and Table RT-1, is part of a trend where Ghana’s agricultural frontier has roughly doubled since the 1980s. This has resulted in high levels of forest clearing to meet the demand for farmland, even in if the agricultural suitability is low. This finding demonstrates that CSA practices that improve intensification, which in turn limit land conversion and forest clearing, directly contribute to mitigation.

Table RT-1: Percentage Difference in Rainfed Crop Yields over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different GHG Concentration Scenarios (RCPs), with BAU Demographic and Economic Growth Trajectories (SSP2)

Percent Difference from No-Climate Change Scenario	Area Harvested				Yield			
	Low emissions (RCP 4.5)		High emissions (RCP 8.5)		Low emissions (RCP 4.5)		High emissions (RCP 8.5)	
	2030	2050	2030	2050	2030	2050	2030	2050
Crop								
R&T-Cassava	0.35	0.79	0.27	0.72	-1.25	-2.42	-0.70	-0.99
R&T-Other Roots	0.20	0.50	0.35	0.80	-1.63	-3.25	-1.05	-2.07
R&T-Yams	0.38	0.90	0.38	0.92	-1.06	-2.07	-0.50	-0.93

³⁰¹ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

Figure RT- 2: Projected Yield for Roots and Tubers in Ghana over a No-Climate Change Reference Scenario for 2030 and 2050



On a positive note, roots and tubers, such as cassava and yams, exhibit relative resilience under climate change modeling. The CSAIPs are built upon the strengths of commodities exhibiting such resilience, while simultaneously offsetting potential damages to commodities exhibiting vulnerability.

Table RT-2: Net Trade Findings, Positive and Negative, for Roots, Tubers and Livestock over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different GHG Concentration Scenarios (RCPs), with BAU Demographic and Economic Growth Trajectories (SSP2)

NET TRADE NEGATIVE						
	RCP4.5_SSP2		RCP6.0_SSP2		RCP8.5_SSP2	
	2030	2050	2030	2050	2030	2050
AMT-Beef	0.03	-0.04	0.10	0.07	-0.14	-0.36
AMT-Lamb	-0.87	-0.78	-0.62	-0.53	-1.59	-1.55
AMT-Pork	-0.51	-0.74	-0.35	-0.49	-0.95	-1.48
R&T-Cassava	-2.74	-3.94	-7.06	-8.73	-5.40	-8.03
R&T-Other Roots	0.90	0.16	0.80	0.15	-2.84	-4.03
NET TRADE POSITIVE						
	RCP4.5_SSP2		RCP6.0_SSP2		RCP8.5_SSP2	
	2030	2050	2030	2050	2030	2050
R&T-Yams	2.479	1.903	1.810	1.245	6.537	6.114

Yams, which are more challenging to grow than cassava, show the highest resilience and a possibility of expanding as an exportable commodity for Ghana in the future. Given the potential for CSA practices to overcome yield gaps and build resilience, the CSA Roots, Tubers, and Livestock Integration investment is poised to build on the projected resilience of yams and cassava while offsetting potential damages to livestock production, which is generally considered more vulnerable to climate change.

Model Assumptions: Roots and tubers were analyzed. The assumptions on yield and farmer adoption rates for were:

- Roots and Tubers - current: 4 tons/ha; potential yield with project: 6 tons/ha

- Assumptions on technology were for a time horizon of 5 years, with 3 years needed to reach 50 percent adoption.

ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

The CSA roots, tubers, and livestock integration project boosts the incomes of 200,000 smallholder farmers and their families by 27 percent, boosts their resilience against climate shocks, and increases their food security. The NPV of the project is strong, especially if risks are discounted, and it has a strong chance of success. Higher potential impacts from risks are reflected in the lower ROI and BCR, which are both better without including risks. This project does not provide strong returns on the investments at a project level; none of the individual CSA interventions provide a particularly high return except for irrigation. Yet all are fundamental actions to build resilience into this smallholder sector, to begin to have healthier soils, and to increase crop diversity with higher and more resilient yields—translating into greater food security for families and better livestock, representing savings.

Table RT-3: CSA Roots, Tubers, and Livestock Integration CBA With and Without Climate Risks

Mean No. Beneficiaries	Change in yield (%) ^a	NPV (US\$, millions) ^b	Chance Positive NPV (%) ^b	ROI ^b	BCR (SD)
With Climate and Pest Risks					
200,000	27	24.0	54	0.52	0.36 (2.39)
Without Climate and Pest Risks					
200,000	27	75.9	77	1.74	1.15 (2.76)

Note: a. Average percentage change between beneficiaries with vs without project. b. Average of 100 model runs.

Table RT-4: Financial Analysis

Technology	Change with Integrated Root-Tuber-Livestock Systems		
	Yield	Gross Returns	Costs
Yam			
Inorganic Fertilizer	32.6 (8.4)		
Organic fertilizer	4.1 (18.5)		
Water Harvesting	28.4 (31.0)		
Cassava			
Improved Varieties	4.0 (11.2)		
Inorganic Fertilizer	36.5 (4.2)		
Organic Fertilizer	45.4 (13.0)		
Water Harvesting	28.7 (5.5)		
Cattle			
Improved Breeds	33.6 (6.4)		

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

Feed Supplementation	32.8 (9.1)		
Goats			
Improved Breeds	16.4 (6.0)		
Feed Supplementation	37.2 (5.8)		
Mean of all Technologies	27.2 (13.5)		

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table RT-5: Values and Assumptions for Estimating the Number of Beneficiaries for Tuber-Livestock in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Tuber-livestock	50,000	250

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200-600 per beneficiary (see Annex E. Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, root-tuber, and livestock integration has the following strong or supportive alignments:

- Strong alignment to four NDC goals: conservation agriculture; postharvest storage & processing; livestock and aquaculture productivity; livelihood diversity
- Supportive to five NDC goals: reforestation/ afforestation; enforcing felling standards; enrichment planting; wildfire management; governance reform

Relevant Policies³⁰²

- Food and Agriculture Sector Development Policy (FASDEP II 2010–2015)

Key Policy Gaps³⁰³

- Lack of financial and risk mitigation services deters farmers from innovations
- Inadequate production volume data necessary for investment decisions and policy formulations
- Lack of institutional support for promising technologies that could encourage mixed production systems

Key Policy Distortions

- Current land tenure regime incentivizes expansion over investments in current land
- Current markets make fertilizer inputs scarce, expensive, and of unreliable quality
- Institutional priority for supporting innovations in cash cropping rather than food cropping

³⁰² Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana."

³⁰³ Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund"; Bunn, Climate Smart Cocoa in Ghana.

Key Contributors to Project Success³⁰⁴

- Most smallholders already own livestock in partial integration with crop systems
- Some local crop varieties already demonstrate heat, drought, and disease resistance
- Well-established national research facilities and programs
- Multiple university programs training agricultural professionals, including researchers

Key Risks/Barriers to Success³⁰⁵

- Historic availability of fodder resources has made improved fodder systems a low priority for farmers despite significant advantages under climate change scenarios³⁰⁶
- High land insecurity combined with low finance and risk mitigation services deter farmers from investing in soil quality
- High labor intensity of using manure as a fertilizer alternative under extensive grazing system

Public Institutional Framework³⁰⁷

- Ministry of Food and Agriculture
- Environmental Protection Agency
- Universities conducting research and training personnel at BS, MS, and PhD levels:
 - University of Ghana
 - University of Cape Coast
 - University of Natural Resources and Energy
 - Kwame Nkrumah University of Science and Technology
 - University of Development Studies
 - Agriculture Colleges

Potential NGO Collaborators³⁰⁸

- International Institute of Tropical Agriculture
- Technical Centre for Agricultural and Rural Cooperation (CTA)
- International Fertilizer Development Center
- CGIAR Institutes and Programs
 - Research Program on Roots Tubers and Bananas
 - International Livestock Research Institute
 - HumidTropics CGIAR Program
 - Livestock and Fish CGIAR Program

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides a strong knowledge base and lessons learned. Related projects underway include:

- IFAD: Ghana Agricultural Sector Investment Programme³⁰⁹
 - 2014–2021, US\$77.99 million
 - Linking farmers to agribusiness enterprises and scaling up value chains of roots and tubers

³⁰⁴ Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana.”

³⁰⁵ Marinus and Ronner, “What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica.”

³⁰⁶ Michael Blummel et al., “Feed the Future Innovation Lab on Small Scale Irrigation (ILSSI): Ethiopia, Ghana, and Tanzania” (International Livestock Research Institute, 2018), https://cgspace.cgiar.org/bitstream/handle/10568/100485/smallscale_irrigated_fodder.pdf?sequence=1.

³⁰⁷ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

³⁰⁸ Kizito et al.

³⁰⁹ Sarah Ntoah Ashu, “Ghana Agricultural Sector Investment Programme (GASIP),” Draft Supervision Report (Republic of Ghana: IFAD, November 23, 2016).

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Promising entry point to introduce the tuber-livestock integration concept
- FAO: Strengthening links between small actors and buyers in the roots and tubers sector in Africa³¹⁰
 - 2015–2019, US\$472,764
 - Aligning national and regional strategies to support improvement of root and tuber markets; enhancing smallholder access to climatic risk management instruments, information services, and finance services
- Nigeria: “Commercially Converting Cassava Peel into Livestock Feed, Creating Livelihoods for Women,” CGIAR International Livestock Research Institute and CGIAR Research Program on Roots, Tubers, and Bananas with funding from USAID³¹¹

Other Relevant Completed Projects:

- IFAD: Root and Tuber Improvement and Marketing Programme
 - 2005–2014, US\$32.05 million
 - Targeted root and tuber improvement; no consideration of integration with livestock
- DANIDA, Strengthening root and tuber value chain in Ghana
 - 2013–2017, US\$1 million
 - Aimed at mapping out crops value chains, constraints, and institutional settings

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

International Financing Opportunities

- African Development Bank (AfDB)
- Agricultural Market Development Trust (AGMARK)
- New Partnership for Africa’s Development (NEPAD)
- African Union Commission
- United States Agency for International Development
- Alliance for a Green Revolution in Africa

Potential Private Sector Collaborators

- Commercial feed producers
- Commercial producers of by-products commonly used as supplemental feed
- Processors of livestock products
- Processors of cassava and yam products (for example, breweries)

Private Financing Opportunities

- African Fertilizer and Agribusiness Partnership
- Fertilizer Canada
- International Plant Nutrition Institute

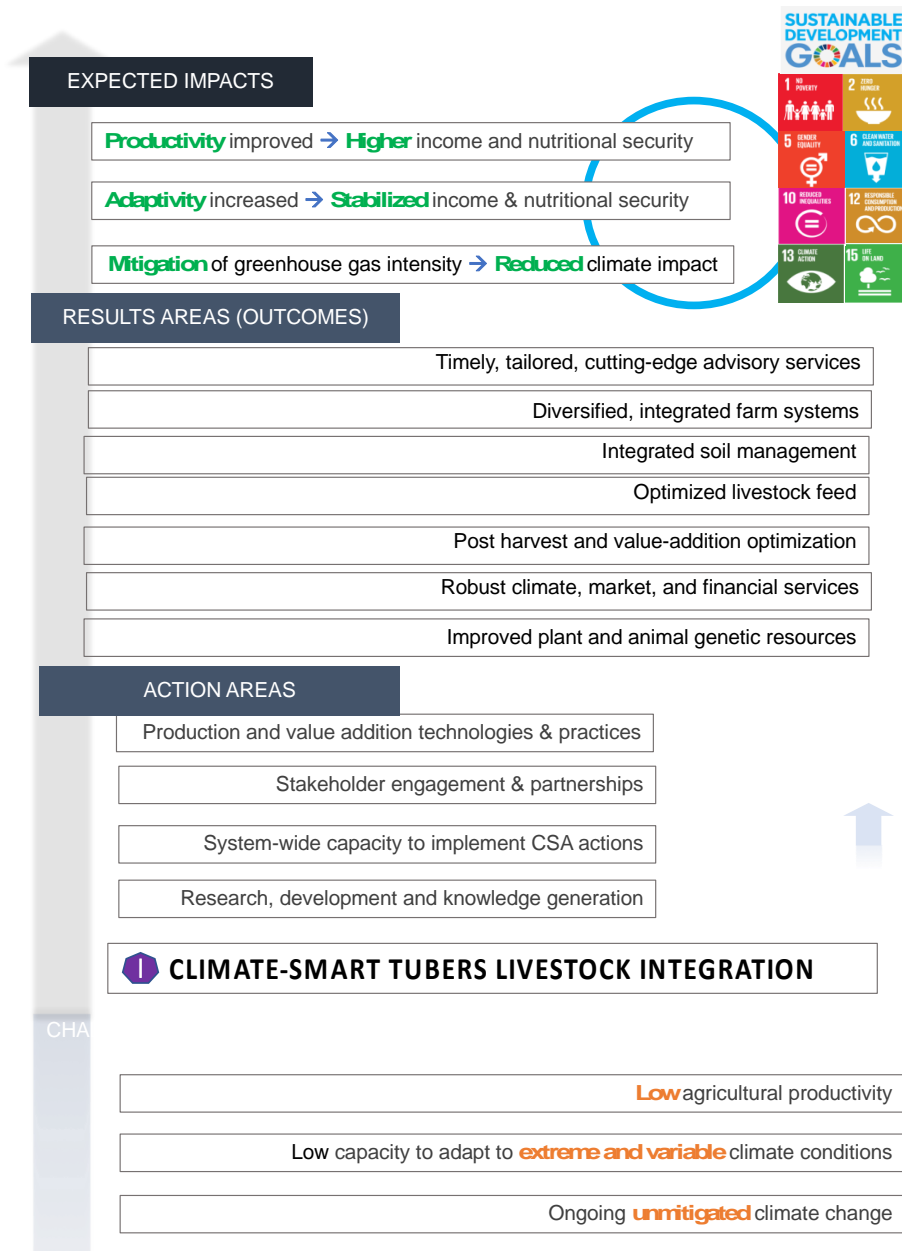
³¹⁰ FAO, “Strengthening Linkages between Small Actors and Buyers in the Roots and Tubers Sector in Africa,” Work Plan, Ghana, 2015, <http://www.fao.org/3/a-az554e.pdf>.

³¹¹ Ewen Le Borgne, “New Factories in Nigeria Transform Cassava Peels into Livestock Feed, Creating Jobs and Incomes for Women,” *ILRI News* (blog), August 23, 2017, <https://news.ilri.org/2017/08/23/ifad-cassava-processing-site-visit/>; Susan MacMillan, “USAID Supports the Commercial Potential of Cassava Peel for Livestock Feed in Nigeria,” *ILRI Clippings* (blog), February 1, 2017, <https://clippings.ilri.org/2017/02/01/usa-id-supports-the-commercial-potential-of-cassava-peel-for-livestock-feed-in-nigeria/>; Research Program on Roots, Tubers, and Bananas, “Roots, Tubers, and Bananas,” Proposal (CGIAR, July 2016), <http://www.rtb.cgiar.org/publication/view/rtb-proposal-2017-2022-volume-iii/>.

Most Promising Supporting Digital Agriculture Technologies

- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best practices and disseminate research and development outputs
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support management decisions
- Mobile peer-to-peer platforms—enabled by big data, machine learning, and mobile technology—to support knowledge exchange, middleman reduction, economies of scale, input supply, and product sales at fair market rates

THEORY OF CHANGE



A-5. Climate-smart poultry

PROJECT SUMMARY

OBJECTIVE: Revitalize the Ghanaian poultry sector with climate-smart approaches to feed and genetic resource enhancement.

PROJECT HIGHLIGHTS: Poultry is a vital sector for protein with high and rising demand; climate risks are high for maize and for poultry; CSA builds resilience for both maize and poultry sectors; increases production to reduce imports; high value chain and private sector potential

REGIONS: Transitional, Savannah, Forest

PROJECTED BENEFICIARIES: 160,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation

KEY CSA INVESTMENT ACTIVITIES:

- Improved poultry genetic resources for climactic resiliency and disease resistance³¹²
- Information and advisory services on poultry production³¹³
- Optimized poultry feed,³¹⁴ including termite collection innovation and increased national productivity of yellow maize

The impact of these actions on yields is detailed in Table PO-3: Financial Analysis.

JUSTIFICATION

Ghana is capable of self-sufficiency in of poultry supplies. The Government of Ghana began promoting commercial poultry production in the 1960s; as a result, by the 1970s, 95 percent of poultry meat and egg demand were supplied domestically. Poultry is in particularly high demand during festive occasions.³¹⁵ Ghanaian consumers prefer domestic to imported poultry products and are willing to pay a premium for the same. Antibiotic- and hormone-free, fresh, and cut meats are also preferred, with antibiotic/hormone-free having a particularly important impact.³¹⁶

Feed represents approximately 82 percent of the cost of poultry production. Maize constitutes 50–60 percent of the total feed formulation. About 85 percent of the country’s maize is grown on farms of less than 2 ha. Although maize is by far the most important cereal crop in Ghana, yields remain far below potential. The average Ghanaian farm yields 1.6 tons/ha, while demonstration plots have produced 4–5 tons/ha using improved varieties, appropriate fertilizer application, appropriate planting density, and adequate weed control. Medium- and small-scale poultry producers rely on mills for feed supply, while large-scale producers generally operate their own feed mills. Commercial mills are currently operating at only 40–50 percent of capacity due to low demand of their product.³¹⁷

The Ghanaian poultry sector relies on small and medium producers of local breeds and is highly gender segregated. Chickens and guinea fowl are the most commonly produced poultry. Medium- and small-scale poultry producers (less than 10,000 birds) comprise 80 percent of national production. Producers—who have the highest ROI and value addition—are predominantly men, while traders and processors are

³¹² Potsdam Institute for Climate Impact Research, “Climate Risk Analysis and Adaptation in Ghana’s Agriculture Sector,” Guidance note for policy makers (Deutsche Gesellschaft für Internationale Zusammenarbeit, April 2019); CIAT, “CSAIP Inception Report,” Climate Smart Agriculture Investment Plan, Ghana (World Bank Group & CGIAR, September 19, 2019).

³¹³ Partey et al., “Developing Climate-Smart Agriculture to Face Climate Variability in West Africa.”

³¹⁴ CIAT, “CSAIP Inception Report.”

³¹⁵ Kusi et al., “The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature.”

³¹⁶ Collins Asante-Addo and Daniela Weible, “Is There Hope for Domestically Produced Poultry Meat? A Choice Experiment of Consumers in Ghana,” *Agribusiness*, August 30, 2019, <https://doi.org/10.1002/agr.21626>.

³¹⁷ Kusi et al., “The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature.”

primarily women.³¹⁸ There is a high penetration of mobile phone usage among producers, but network failure presents a significant barrier to mobile phones as an information and advisory resource.³¹⁹ Nearly all (98 percent) birds are local breeds.³²⁰ There is considerable genetic diversity in local chicken breeds but genetic diversity of guinea fowl is low.³²¹

PROBLEM STATEMENT

The Ghanaian poultry sector has been in steep decline. For example, 80 percent of broilers were domestically sourced in 2000, but by 2010 this had fallen to just 10 percent. The primary reasons for this near-collapse of the industry are major increases in the cost of poultry feed and the ready availability of strong international competitors. Major increases in the cost of corn have stunned the industry; white corn prices climbed from US\$13/50 kg in July 2010 to US\$32/50 kg in July 2013. Yellow corn is more desirable than white corn for poultry feed because it gives the egg yolk a bright yellow color. However, yellow corn is often unavailable entirely, and farmers have resorted to adding pigment to poultry feed to achieve the same effect. Termites are a readily available protein source for poultry producers, but a lack of innovation in collection methods has resulted in limited use of this free resource.³²²

Domestically produced broilers sell for approximately US\$5 per kg versus US\$2.67 per kg for imported products, including added 40 percent import duties. The average cost of producing broilers in Ghana (live weight 2 –2.5 kg) is now US\$6 for the most efficient large-scale producers. For medium- and small-scale producers, it is higher. The Ghana National Poultry Farmers' Association successfully pressured the government to increase tariffs from 20 percent to 40 percent, but the decision was overturned within months following action by the International Monetary Fund.³²³

In addition to the high cost of crucial inputs and overwhelming international competition, Ghanaian farmers are grappling with myriad other challenges. Extreme climactic conditions affect bird health, increase mortality, and decrease productivity.³²⁴ There is inadequate access to veterinary services, including vaccinations.³²⁵ Local breeds have low productivity.³²⁶ Poor infrastructure, market access, and postharvest processes further aggravate these challenging circumstances. About 70 percent of farmers report animal mortality as their primary challenge, and 82 percent are seeking training in poultry health.³²⁷ Farmers struggle with information access capacity, inadequate information resources, and inappropriate availability of information³²⁸ (for example, airing time of agricultural radio programs) on common topics

³¹⁸ Akwasi Mensah-Bonsu, Nancy N. Lartey, and John K. M. Kuwornu, "Gender-Segregated Analysis of the Poultry Value Chain in Ghana," *Gender, Technology and Development* 0, no. 0 (September 26, 2019): 1–35, <https://doi.org/10.1080/09718524.2019.1661611>.

³¹⁹ Benjamin Yao Folitse et al., "The Determinants of Mobile-Phone Usage among Small-Scale Poultry Farmers in Ghana," *Information Development* 35, no. 4 (September 1, 2019): 564–74, <https://doi.org/10.1177/0266666918772005>.

³²⁰ F. K. Avornyo et al., "Characteristics of Guinea Fowl Production Systems in Northern Ghana. A Baseline Study of 20 Districts in Northern Ghana," accessed October 2, 2019, <https://www.lrrd.cipav.org.co/lrrd28/8/avor28134.html>.

³²¹ Michael Mensah Brown et al., "Phenotypic Diversity, Major Genes and Production Potential of Local Chickens and Guinea Fowl in Tamale, Northern Ghana," *Asian-Australasian Journal of Animal Sciences* 30, no. 10 (October 2017): 1372–81, <https://doi.org/10.5713/ajas.17.0145>.

³²² Hettie Arwoh Boafo et al., "Use of Termites by Farmers as Poultry Feed in Ghana," *Insects* 10, no. 3 (March 2019): 69, <https://doi.org/10.3390/insects10030069>.

³²³ This may be a politically charged point, particularly in the international arena and/or with multilateral donors. Kusi et al., "The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature"; James Sumberg, Martha Awo, and George T.-M. Kwadzo, "Poultry and Policy in Ghana: Lessons from the Periphery of an Agricultural Policy System," *Development Policy Review* 35, no. 3 (2017): 419–38, <https://doi.org/10.1111/dpr.12223>.

³²⁴ S. F. Gbedemah, F. O. Torgbor, and S. K. Kufogbe, "Adaptation Strategies of Poultry Farmers to Rising Temperature in the Greater Accra Region of Ghana," *West African Journal of Applied Ecology* 26, no. 0 (January 1, 2018): 41–55–55.

³²⁵ R. K. Agbehadzhi et al., "Economic Contribution of Local Hatchery Performance in the Poultry Value Chain in Ghana," *Poultry Science* 98, no. 6 (June 1, 2019): 2399–2404, <https://doi.org/10.3382/ps/pez020>.

³²⁶ Yakubu Issaka Balma and Nartey Yeboah Richard, "Socio-Economic Attributes of Guinea Fowl Production in Two Districts in Northern Ghana," *African Journal of Agricultural Research* 11, no. 14 (April 30, 2016): 1209–17, <https://doi.org/10.5897/AJAR2015.10258>.

³²⁷ Avornyo et al., "Characteristics of Guinea Fowl Production Systems in Northern Ghana. A Baseline Study of 20 Districts in Northern Ghana."

³²⁸ Partey et al., "Developing Climate-Smart Agriculture to Face Climate Variability in West Africa."

such as egg storage, nutrition, shelter, marketing, and debeaking.³²⁹ A producer's degree of access to financial services has also proven to be a particularly important factor; the survival rate of poultry producers is positively affected by access to universal banks and cooperative credit unions to a significant degree.³³⁰

CLIMATE MODELING

Climate change will drastically alter what production is suitable for a given place, reducing suitability across large areas (for example, entire countries) but also creating pockets of increased suitability. At a global scale, these shifts will be very significant in determining what countries can produce what commodities, which in turn will affect international trade. At the same time, government GHG mitigation policies, together with demographic and economic growth trajectories, will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).³³¹ See Annex E for full information.

Table PO-1: Percentage Difference in Poultry Yields over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different Emissions Concentration Scenarios (RCPs)

	2018 Baseline Value(TM)	RCP4.5_SSP2		RCP6.0_SSP2		RCP8.5_SSP2	
		2030	2050	2030	2050	2030	2050
AMT-Poultry	56.90	-0.21	-0.30	-0.19	-0.29	-0.35	-0.50

While climate change reduces poultry production at all time periods across all scenarios, the loss levels are relatively minor. The IMPACT model considers the reductions that occur with the price and availability of poultry feed (for example, soy, corn). Looking at Table PO-2, the net trade balance for poultry worsens, although the different scenarios have different levels of decline. Ghana's projected trade deficits reflect the greater comparative advantage that other countries will have at poultry production.

Table PO-2: Overall Net Trade Balance for Poultry over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different Emissions Concentration Scenarios (RCPs)

	Net Trade Negative					
	RCP4.5_SSP2		RCP6.0_SSP2		RCP8.5_SSP2	
	2030	2050	2030	2050	2030	2050
AMT-Poultry	-1.22	-1.17	-0.84	-0.80	-2.25	-2.24

Table PO-3: Net Import of Poultry over a No-Climate Change Reference Scenario for 2030 and 2050, Under Different Emissions Concentration Scenarios (RCPs)

Percentage Change with Climate Change	Net Import Commodities			
	RCP4.5_SSP2		RCP8.5_SSP2	
	2030	2050	2030	2050
AMT-Poultry	-0.22	-0.44	-0.43	-0.88

³²⁹ Benjamin Yao Foltite et al., "Poultry Farmers' Information Needs and Sources in Selected Rural Communities in the Greater Accra Region, Ghana," *International Information & Library Review* 50, no. 1 (October 9, 2017): 1–12, <https://doi.org/10.1080/10572317.2017.1351020>; Potsdam Institute for Climate Impact Research, "Climate Risk Analysis and Adaptation in Ghana's Agriculture Sector."

³³⁰ George Acheampong, "Financial Institution Ties and Survival of Small Commercial Poultry Farms (SCPFs) in Ghana," *Journal of Entrepreneurship in Emerging Economies*, June 4, 2018, <https://doi.org/10.1108/JEEE-08-2017-0061>.

³³¹ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

Table PO-3 shows that there will be an increase of net poultry imports in the future, accounting for increases in future demand. However, the technologies introduced as part of climate-smart poultry can offset some of the challenges climate change poses and increase overall resilience in the poultry sector, potentially reducing overall imports.

ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

Small poultry farmers (160,000) would expect to see their incomes rise by 27 percent with the CSA poultry project. The project has a strong mean NPV, and a good chance for a positive NPV, both with and without risks. The relatively high ROI, 4.3 with risks and 5.7 without, means that it may be possible to bring in the private sector, or to combine public and private sector financing. This project shows a strong BCR.

Table PO-4: Climate-Smart Poultry CBA With and Without Climate Risks

Mean No. Beneficiaries	Change in yield (%) ^a	Mean NPV (US\$, millions)	Chance Positive NPV (%) ^b	ROI	BCR (SD)
With Climate and Pest Risks					
160,000	27	81.6	71	3.19	1.97 (4.90)
Without Climate and Pest Risks					
160,000	27	119.3	77	4.63	2.88 (5.7)

Note: a. Average percentage change between beneficiaries with versus without project. b. Average of 100 model runs.

Table PO-5: Financial Analysis

Technology	Change with Poultry Improvement		
	Yield	Gross Returns	Costs
Chickens - Meat			
Improved Breeds	11.4 (2.5)		
Feed Supplementation	6.1 (2.5)	13.9 (9.4)	0.7 (0.6)
Feed Substitutions	1.2 (2.9)	0.9 (2.5)	-10.5 (3.3)
Chicken – Eggs			
Feed Supplementation	119 (119)		
Feed Substitutions	-2.4 (3.6)		
Mean of all Technologies	27.1 (51.7)		

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table PO-6. Values and Assumptions for Estimating the Number of Beneficiaries for CSA Poultry in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Poultry	32,000	200

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, poultry has the following strong or supportive alignments:

- Strong alignment to three NDC goals: postharvest storage and processing; livestock and aquaculture productivity; livelihood diversity
- Supportive to two NDC goals: conservation agriculture; governance reform

Key Policy Gaps³³²

- There is currently a nationwide competition between human food supplies and poultry feed production; this may be best alleviated through policy changes.
- Lack of proper animal health facilities and welfare for poultry

Key Policy Distortions

- Review of existing tariffs and/or embargos on maize and poultry products to ensure alignment with national interests and objectives
- Weak implementation of policies that favor the poultry subsector
- Unregulated breeding of day-old chicks has resulted in low-quality production and financial losses for poultry farmers
- Ineffective and weak advocacy from poultry farmers' association

Key Contributors to Project Success³³³

- Consumer preference for domestic poultry products and willingness to pay a premium for the same
- Potential for 250–300 percent increase in maize productivity with existing technologies
- Availability of termites as a low-cost and nutritious source of feed

Key Risks/Barriers to Success³³⁴

- Price and availability of poultry feed
- Competition between human food supplies and poultry feed production for maize supplies³³⁵
- Collapse or near-collapse of major players, for example, Acme Hatchery, Pomadze Farms, Darko Farms
- Poor maize and poultry farmer access to information and inputs

Public Institutional Framework³³⁶

- Ministry of Food and Agriculture
- Research organizations and universities

³³² Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund"; Bunn, Climate Smart Cocoa in Ghana.

³³³ Partey et al., "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana."

³³⁴ Marinus and Ronner, "What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica."

³³⁵ Kusi et al., "The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature."

³³⁶ Kizito et al., "Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana."

Potential NGO Collaborators³³⁷

- ACDI/VOCA
- National Association of Poultry Farmers

Most Promising Supporting Digital Agriculture Technologies

- Pest and disease early warning systems, enabled by weather stations, big data, machine learning, and mobile technology
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best livestock practices and disseminate research and development innovations
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides implementation experience, a strong knowledge base, and lessons learned. Related projects underway include:

- USDA Projects: Ghana Poultry Project (GPP) and Assisting Management in the Poultry and Layer Industry by Feed Improvement and Efficiency strategies project (AMPLIFIES Ghana)³³⁸
 - 2015 –2020, US\$56 million
 - No information of the project progress from the donors
- Ministry of Food and Agriculture and the Ghana National Association of Poultry Farmers:³³⁹ Ghana Broiler Revitalization Project (GHABROP)
 - 2014 –2024, US\$5.115 million

Other Relevant Completed Projects: None found

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- This investment aligns well with any program invested in maize productivity and national food security.

International Financing Opportunities

- This investment aligns well with any program invested in poultry and maize productivity and national food security.

Potential Private Sector Collaborators

- It is of keen private sector interest to revitalize the domestic poultry market; various large-scale producers are prepared to invest.³⁴⁰

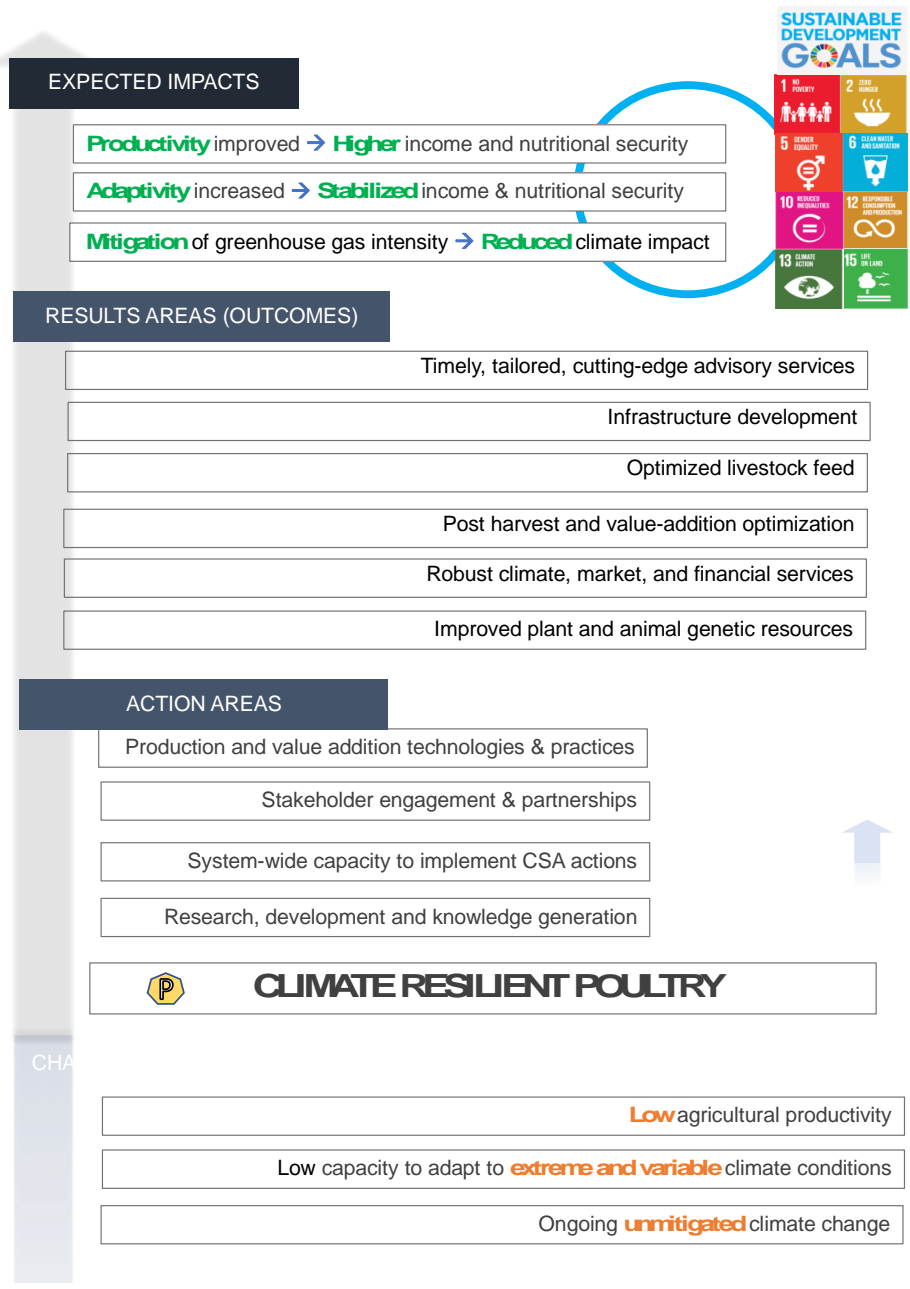
³³⁷ Kizito et al.

³³⁸ ACDI-VOCA and USDA, “Ghana Poultry Project,” ESRI ArcGIS, 2019, <https://www.arcgis.com/apps/Cascade/index.html?appid=2fc0e02e10d4477e969a5a5a5a751599>; ACDI/VOCA, “Ghana Poultry Project (GPP),” 2019, <https://www.acdivoca.org/projects/ghana-poultry-project-gpp/>.

³³⁹ Michael Priestly, “Ghana’s Broiler Sector to Get Leg-up from Revitalization Project,” The Poultry Site, July 16, 2014, <https://thepoultrysite.com/news/2014/07/ghanas-broiler-sector-to-get-legup-from-revitalization-project>.

³⁴⁰ Gbedemah, Torgbor, and Kufogbe, “Adaptation Strategies of Poultry Farmers to Rising Temperature in the Greater Accra Region of Ghana.”

THEORY OF CHANGE



A-6. Climate-resilient ruminants and genetic resource conservation

PROJECT SUMMARY

OBJECTIVE: Use climate-smart techniques to increase the resource-use efficiency and climate resiliency of ruminant production.

PROJECT HIGHLIGHTS: Most Ghanaian farmers have ruminants; this suite of actions increases resilience to climate change, boosts smallholder income, and nutritional security; diminishes risk.

REGIONS: Forest, Transitional, Savannah

PROJECTED BENEFICIARIES: 150,000 smallholder farmers and their families

CSA PILLARS: Production,

KEY CSA INVESTMENT ACTIVITIES:

- Irrigation for growing feed
- Establish grazing and watering corridors for livestock
- Establish browsing stands as fodder banks
- Heat-stress and disease-resistant ruminant varieties
- Manure as an alternative fertilizer

The impact of these actions on yields is detailed in Table RR-2: Financial Analysis.

JUSTIFICATION

The diversity of integrated crop-livestock production systems makes them synergistically more productive and resilient than either system alone.³⁴¹ An overwhelming majority of smallholders raise ruminants as a source of income in addition to the production of crops. Access to inputs, credit, and market information are major drivers of both diversification and technical efficiency in Ghanaian livestock owners.³⁴²

Ruminants in Ghana are primarily fed via free-range grazing and crop residues. Ruminants are typically free-range in the dry season; they are kept tethered, sometimes with feed supplementation, in the wet season. About 90 percent of farmers feed crop residues to their livestock. Agro-industrial by-products such as corn milling waste, brewers' spent grain, maize bran, and rice bran are also used. Very few households have stands of browse plants like *Leucaena leucocephala*, *Cajanus cajan*, or *Gliricidia sepium*.³⁴³ Ghanaian farmers have low motivation to irrigate forage crops; land holdings are large enough that forage scarcity does not often become an urgent issue.³⁴⁴ Nevertheless, as the impacts of climate change progress, seasons of insufficient feed will reduce productivity and mortality will increase due to disease and extreme weather, particularly heat.³⁴⁵

Small ruminants in particular offer significant benefits to Ghanaian smallholders. Small ruminants have short gestation periods, high prolificacy, rapid growth rate, high feed conversion efficiency, high disease

³⁴¹ Villano, Asante, and Bravo-Ureta, "Farming Systems and Productivity Gaps"; Asante et al., "Determinants of Farm Diversification in Integrated Crop-Livestock Farming Systems in Ghana."

³⁴² Asante et al., "Determinants of Farm Diversification in Integrated Crop-Livestock Farming Systems in Ghana"; Bright Owusu Asante et al., "Performance of Integrated Crop-Small Ruminant Production Systems in West Africa," *Agroforestry Systems* 93, no. 3 (June 1, 2019): 989–99, <https://doi.org/10.1007/s10457-018-0196-8>.

³⁴³ Konlan et al., "Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana."

³⁴⁴ Blummel et al., "Feed the Future Innovation Lab on Small Scale Irrigation (ILSSI): Ethiopia, Ghana, and Tanzania."

³⁴⁵ F.K. Avornyo et al., "Candidate Fodder Trees and Shrubs for Sustainable Ruminant Production in Northern Ghana," *Livestock Research for Rural Development* 30, no. 9 (2018); Konlan et al., "Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana."

resistance capacity, and easy marketability.³⁴⁶ Small ruminant manure is also an important alternative source of fertilizer, with similar chemical characteristics to synthetic fertilizer.³⁴⁷

A majority of Ghanaian smallholders already own small ruminants. In northern Ghana, 86–97 percent of smallholders own goats, 50–88 percent own sheep, and 17–43 percent own cattle.³⁴⁸ Ghanaian small ruminant-crop integrated systems have relatively high technical efficiency (65 percent, compared with 68 percent in The Gambia and 46 percent in Benin).³⁴⁹ Assuming 86 percent goat ownership, 88 percent sheep ownership, and 43 percent cattle ownership rates, crop residues and agricultural by-products can supply about 10 percent of the dry matter needed for livestock feed. Without cattle, this percentage increases substantially to 53 percent.³⁵⁰

Improved varieties of ruminants offer significant potential in terms of resource-use efficiency and climate resiliency. Existing technologies in livestock management, breeding, and health could sustainably develop the livestock industry to close the animal protein gap.³⁵¹ Heat stress is the most detrimental factor for the economy of small ruminant production. HSF1, HSP70, HSP90, THR, NOS can act as biomarkers to identify indigenous breeds of sheep and goats with high heat resilience for gene therapy.³⁵²

Livestock corridors can help build resiliency for pastoralists in search of pasture and water resources. Cross-border mobility may be particularly important as pastoralists avoid areas affected by livestock disease or engage in trade. Conflicts between farmers and pastoralists have become recurrent as natural resources become increasingly scarce. The Economic Community of the West African States member countries have formulated and passed legislations for international livestock corridors, but these have yet to be put into operation.³⁵³

Establishing corridors can help protect the interests of both pastoralists and farmers. When establishing corridors, it is crucial to weigh benefits and costs, consider the effect of corridor establishment on competing land uses (particularly farming), understand the need for and means of protecting the corridors, and identify the appropriate authority to establish and protect the corridor. There is a major distinction between groups who view the primary function of the corridor as protecting local farms, and those that view it as protecting pastoralist movement.³⁵⁴

PROBLEM STATEMENT

The primary constraints on livestock productivity in Ghana include feed scarcity, limited grazing land, theft, high incidence of disease and mortality, poor housing, and high veterinary costs.³⁵⁵ Methods for

³⁴⁶ V. Sejian et al., “Genes for Resilience to Heat Stress in Small Ruminants: A Review,” *Small Ruminant Research* 173 (April 1, 2019): 42–53, <https://doi.org/10.1016/j.smallrumres.2019.02.009>.

³⁴⁷ Ansah et al., “Manure Characteristics of Small Ruminants Fed Agro By-Products in the Guinea Savannah Agro-Ecological Zone of Ghana.”

³⁴⁸ T. Ansah and A. C. Issaka, “Ruminant Livestock Feed Resources in the Kumbungu District of Ghana,” 2018, <http://udsspace.uds.edu.gh:80/handle/123456789/1912>; Avornyo et al., “Candidate Fodder Trees and Shrubs for Sustainable Ruminant Production in Northern Ghana.”

³⁴⁹ Asante et al., “Performance of Integrated Crop-Small Ruminant Production Systems in West Africa.”

³⁵⁰ Ansah and Issaka, “Ruminant Livestock Feed Resources in the Kumbungu District of Ghana.”

³⁵¹ Eveline M. Ibeagha-Awemu et al., “Leveraging Available Resources and Stakeholder Involvement for Improved Productivity of African Livestock in the Era of Genomic Breeding,” *Frontiers in Genetics* 10 (April 24, 2019), <https://doi.org/10.3389/fgene.2019.00357>.

³⁵² Sejian et al., “Genes for Resilience to Heat Stress in Small Ruminants.”

³⁵³ Salihou Mamadou Alidou, “Cross-Border Transhumance Corridors in West Africa” (CapEx, February 2016).

³⁵⁴ Erin Kitchell, Matthew D. Turner, and John G. McPeak, “Mapping of Pastoral Corridors: Practices and Politics in Eastern Senegal,” *Pastoralism* 4, no. 1 (October 8, 2014): 17, <https://doi.org/10.1186/s13570-014-0017-2>.

³⁵⁵ Konlan et al., “Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana”; Avornyo et al., “Candidate Fodder Trees and Shrubs for Sustainable Ruminant Production in Northern Ghana.”

increasing feed availability, including shrub browsing stands,³⁵⁶ are necessary to support animal health and productivity.

Climate extremes are becoming more prevalent and increase livestock mortality. Heat- and disease-resistant breeds are of growing importance for maintaining household nutritional and economic security.

There is significant opportunity to align policy with national goals in climate resiliency, productivity, and economic growth. Policies designed to encourage integrated crop-livestock systems and provide the necessary inputs to support adoption of the same will help spread risk and promote farm efficiency and resiliency.³⁵⁷ Policies on domestic and international corridors may also be considered a way to increase land security, control disease, increase revenue, and promote trade.³⁵⁸

ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

The CSA-resilient ruminant project raises the income of 150,000 poor smallholder families by 27 percent. It has a proposed investment of US\$37 million compared to a mean NPV of US\$58.6 million if climate risks are included and US\$108.9 million if they are excluded. Both with and without risks, there is a strong chance of a positive NPV. With risks included, the ROI is 1.93 and the BCR is 1.18; without risks the ROI is 3.56 and BCR is 2.19.

Table RR-1: Climate-Resilient Ruminant Cost-Benefit Analysis With and Without Climate Risks

Mean No. Beneficiaries	Change in Yield (%) ^a	Mean NPV (US\$, millions) ^b	Chance Positive NPV (%) ^b	ROI ^b	BCR (SD)
With Climate and Pest Risks					
150,000	27	38.1	51	1.43	0.77 (7.26)
Without Climate and Pest Risks					
150,000	27	88.5	65	3.07	1.78 (7.74)

Note: a. Average percentage change between beneficiaries with versus without project. b. Average of 100 model runs.

Table RR-2: Financial Analysis

Technology	Change with Investments for Climate-Resilient Ruminants		
	Yield	Gross Returns	Costs
Climate-Resilient Ruminants			
Cattle (Meat)			
Improved Breeds	33.6 (6.4)		
Feed Supplementation	37.2 (5.8)	21.2 (1.1)	27.4 (12.6)
Feed Substitutions	6.0 (8.9)	12.4 (14.4)	-14.4 (8.4)

³⁵⁶ Konlan et al., "Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana"; Richard E. Estell et al., "The Changing Role of Shrubs in Rangeland-Based Livestock Production Systems: Can Shrubs Increase Our Forage Supply?," *Rangelands* 36, no. 2 (April 2014): 25–31, <https://doi.org/10.2111/RANGELANDS-D-13-00066.1>.

³⁵⁷ Villano, Asante, and Bravo-Ureta, "Farming Systems and Productivity Gaps."

³⁵⁸ Ghana Business News, "Provide Livestock Corridors to Check Influx of Foreign Animals – Veterinary Officer," July 11, 2019, <https://www.ghanabusinessnews.com/2019/07/11/provide-livestock-corridors-to-check-influx-of-foreign-animals-veterinary-officer/>.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

Improved Pasture	31.3 (2.6)		
Goats (Meat)			
Improved Breeds	16.4 (6.0)		
Feed Supplementation	32.8 (9.1)	68.2 (5.1)	16.1 (48.6)
Feed Substitutions	9.6 (7.6)		1.0 (8.0)
Improved Pasture			
Sheep (Meat)			
Improved Breeds	49.5 (3.8)		
Feed Supplementation	61.3 (19.1)	42.8 (12.5)	130 (46.1)
Feed Substitutions	7.1 (5.3)		-9.1 (1.4)
Improved Pasture	9.7 (11.4)		
Mean of all Technologies	26.8 (18.5)	36.1 (24.9)	

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table RR-3. Values and Assumptions for Estimating the Number of Beneficiaries for CSA ruminants in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
CS Ruminants	37,500	250

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E. Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, ruminants have the following strong or supportive alignments:

- Strong alignment to seven NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; conservation agriculture; postharvest storage and processing; livestock and aquaculture productivity; actively manage natural spaces; livelihood diversity
- Supportive to two NDC goals: governance reform; water distribution and access

Relevant Policies³⁵⁹

- Ghana Livestock Development Policy and Strategy (2016)
- Ghana Poverty Reduction Strategy (2003–2005)

³⁵⁹ Rhebergen et al., “Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana.”

Key Policy Gaps³⁶⁰

- Lack of financial and risk mitigation services deters farmers from innovations
- Minimal animal production and health services support systems available
- Lack of coordination between communities and district/national-level organizations
- Minimal government investments and policy frameworks in the livestock sector

Key Policy Distortions

- Current land tenure regime incentivizes expansion over investments in current land
- Current markets make livestock feed inputs scarce, expensive, and of unreliable quality
- Institutional prioritization of resources for crop production has limited innovations in animal husbandry

Key Contributors to Project Success³⁶¹

- The majority of smallholders already own small ruminants in partial integration with crop systems
- Some local breeds of small ruminants demonstrate heat resistance
- Well-established national research facilities and programs
- Multiple university programs training agricultural professionals, including researchers

Key Risks/Barriers to Success³⁶²

- Competing interests of pastoralists and farmers
- Historic availability of fodder resources has resulted in low farmer interest in irrigation fodder systems and browsing stands under new climate scenarios
- Labor intensity of using manure as a fertilizer alternative under extensive grazing system

A further assessment of barriers to cereal-legume integration was provided by an in-country panel of experts. Expert opinion ranked, from highest to lowest, the key barriers as finance, the reliability of irrigation water supply, availability of support from government and other organizations, land tenure, cost of technology, access to information and inputs, farm mechanization and labor resources. Gender inclusivity and synergy with government plans were among the least-ranked barriers to implementing resilient ruminant production.

Public Institutional Framework³⁶³

- Ministry of Food and Agriculture
- Environmental Protection Agency
- Universities conducting research and training personnel at BS, MS, and PhD levels:
 - University of Ghana
 - University of Cape Coast
 - University of Natural Resources and Energy
 - Kwame Nkrumah University of Science and Technology
 - University of Development Studies
 - Agriculture Colleges

Potential NGO Collaborators³⁶⁴

- International Livestock Research Institute
- International Institute of Tropical Agriculture

³⁶⁰ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund”; Bunn, Climate Smart Cocoa in Ghana.

³⁶¹ Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana.”

³⁶² Marinus and Ronner, “What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica.”

³⁶³ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

³⁶⁴ Kizito et al.

- Technical Centre for Agricultural and Rural Cooperation (CTA)
- HumidTropics CGIAR Program
- Livestock and Fish CGIAR Program
- McGill University of Canada³⁶⁵
- Innovations for Poverty Action
- International Development Research Center

Most Promising Supporting Digital Agriculture Technologies

- Pest and disease early warning systems, enabled by weather stations, big data, machine learning, and mobile technology
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best livestock practices and disseminate research and development innovations
- Remote sensing, drones, GPS, and GIS for informing the establishment and management of corridors and water reservoirs
- IoT and remote sensing for monitoring water resources
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology to support decision-making in the face of extreme weather events³⁶⁶

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides implementation experience, a knowledge base, and lessons learned. Related projects underway include:

- World Vision: Livestock for Income and Nutrition Enhancement (LINE) Project³⁶⁷
 - Undisclosed duration and budget
 - Aims at improving goat and sheep breeds and building animal husbandry and marketing capacity
- Heifer International Ghana: Connecting Farmers to Markets and Increasing Incomes³⁶⁸
 - 1999–ongoing
 - Teaches goat, sheep, and dairy farmers how to rear livestock and diversify their income (for example, with shea butter processing)

Other Relevant Completed Projects

- AfDB: Ghana Livestock Development Project³⁶⁹
 - 2001–2011, US\$13.98 million
 - Aimed at improving livestock genetic resources, milk production, and availability of high-quality feed; reducing disease burden via control or eradication of prevalent ailments
 - 6 breeding stations established, 1,400 breeders trained, 307 ha of folder production established, 143,142 cattle vaccinated annually against CBPP (Contagious Bovine Pleuropneumonia), and 332,282 sheep and goats annually against PPR

³⁶⁵ Heifer International, “Ghana,” 2019, <https://www.heifer.org/about-us/where-we-work/ghana.html>.

³⁶⁶ The World Bank Group, “Agriculture Observatory.”

³⁶⁷ World Vision, “Food Security & Livelihoods,” Fact Sheet, Agriculture and Food Security, March 21, 2016, <https://www.wvi.org/sudan/publication/food-security-livelihoods-fact-sheet>.

³⁶⁸ Heifer International, “Ghana.”

³⁶⁹ AfDB, “Ghana - Livestock Development Project,” accessed October 19, 2019, <https://projectsportal.afdb.org/dataportal/VProject/show/P-GH-AA0-025>.

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities - None identified

International Financing Opportunities

- African Development Bank (AfDB)
- Agricultural Market Development Trust (AGMARK)
- New Partnership for Africa's Development (NEPAD)
- African Union Commission
- United States Agency for International Development

Potential Private Sector Collaborators

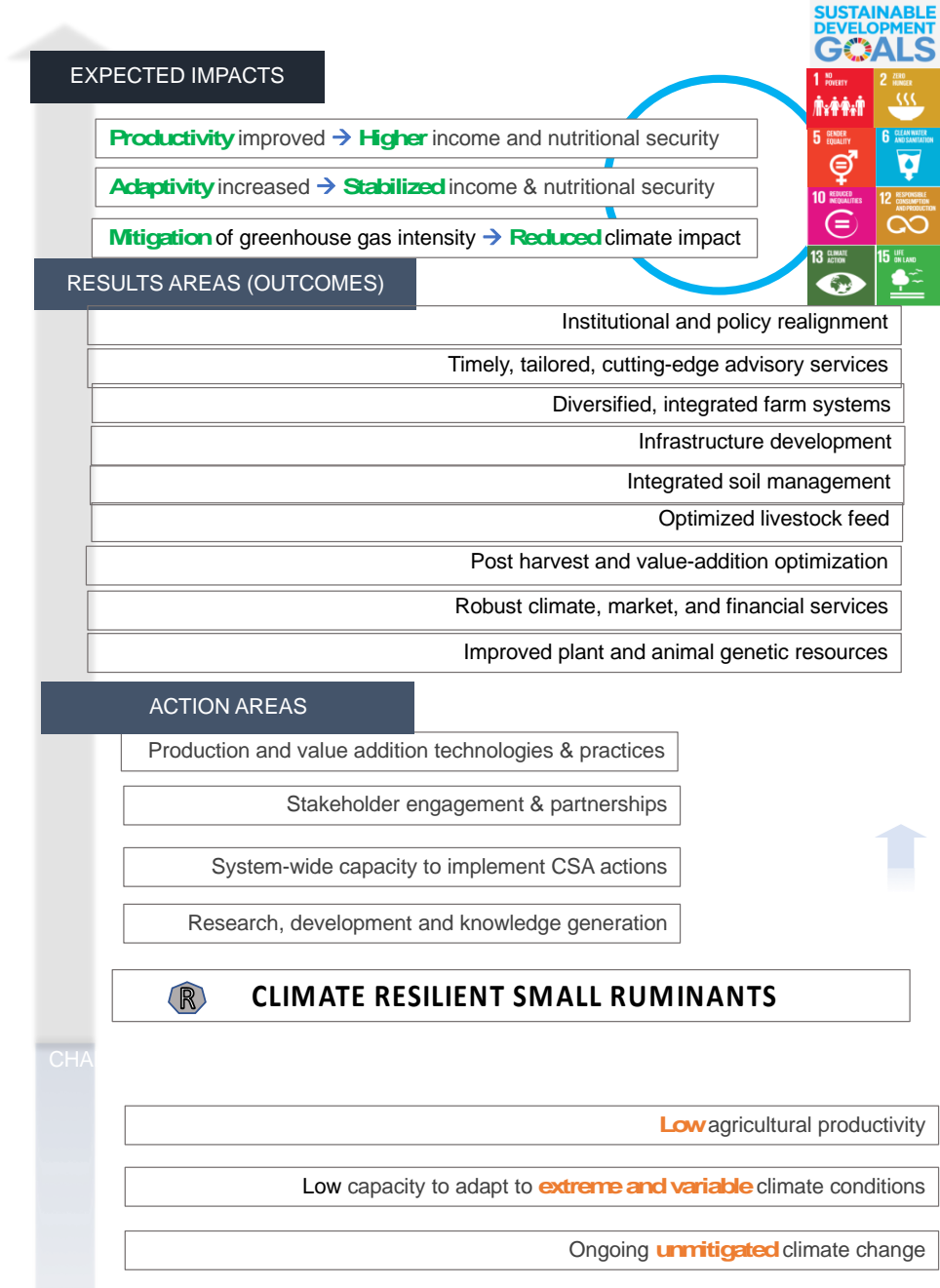
- Barry Callebaut³⁷⁰
- Commercial feed producers
- Commercial producers of by-products commonly used as supplemental feed
- Processors of livestock products

Private Financing Opportunities

- African Fertilizer and Agribusiness Partnership

³⁷⁰ Heifer International, "Ghana."

THEORY OF CHANGE



A-7. Sustainable fisheries and aquaculture

PROJECT SUMMARY

OBJECTIVE: Ensure the continued growth of Ghanaian aquaculture industry by using climate-smart practices to establish sustainable production of tilapia, catfish, shrimps, mussels, and clams.

PROJECT HIGHLIGHTS: Important possibility of reshaping aquaculture sector to be resilient and meet growing demand; meet growing protein requirements in country; provide jobs and value-added supply chain; high beneficiary benefit; high start-up cost for project but one that could leverage the whole sector

REGIONS: Transitional, Coastal Savannah, Forest

PROJECTED BENEFICIARIES: 70,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation

KEY CSA INVESTMENT ACTIVITIES:

- Improved fish fingerling (heat- and disease-resistant breed)³⁷¹
- Improved feed³⁷²
 - Enforcement of commercial standards³⁷³
 - Cost reduction
- Environmental planning to increase climate resiliency of culture-based fisheries³⁷⁴
- Needs-based research and dissemination of innovation through capacity building³⁷⁵
- Postharvest processing development with a focus on gender integration³⁷⁶

JUSTIFICATION

Ghana is one of the most suitable fishery regions in the world; its fisheries industry potential is immense. About 10 percent of the country's land surface is covered with water,³⁷⁷ including rivers, seas, dams, and dugouts. This makes aquaculture practically nationwide. Furthermore, there is already significant institutional and policy support for the industry.³⁷⁸ The Ghanaian government and World Bank have prioritized technological innovation in the aquaculture industry in recent years, and as a result the sector has seen substantial growth, from 10,200 tons in 2010 to over 57,400 tons in 2016. Nevertheless, the industry produces far below its capacity, and consumer demand is extremely high. Consequently, the country also wild harvested approximately 390,000 tons and imported US\$135 million worth of fish in 2016.³⁷⁹ Ghana presently has about 5,000 fish farmers operating approximately 19,000 fishponds and cages.

The aquaculture sector plays a significant role in the national economy and national food security. Aquaculture accounts for about 3–5 percent of the national GDP and employs about 10 percent of the labor force. It is also a nutritional security mainstay; fish provides about 60 percent of the nation's

³⁷¹ CIAT, "CSAIP Inception Report."

³⁷² CIAT.

³⁷³ Amenogbe et al., "A Review of Ghanas Aquaculture Industry."

³⁷⁴ Sandra Akugpoka Atindana, Patrick Kwabena Ofori-Danson, and Sandra Brucet, "Modelling the Effects of Climate Change on Shellfish Production in Marine Artisanal Fisheries of Ghana," *AAS Open Research* 2 (May 22, 2019): 16, <https://doi.org/10.12688/aasopenres.12956.1>.

³⁷⁵ Denis Worlanyo Aheto, Esther Acheampong, and Justice Odoiquaye Odoi, "Are Small-Scale Freshwater Aquaculture Farms in Coastal Areas of Ghana Economically Profitable?," *Aquaculture International* 27, no. 3 (June 1, 2019): 785–805, <https://doi.org/10.1007/s10499-019-00363-9>; Amenogbe et al., "A Review of Ghanas Aquaculture Industry."

³⁷⁶ Aindre Evans, "Caught in The Net: An Investigation into NGO Development Interventions Targeting Coastal Fish-Smokers in Ghana" (Leiden University, 2019), <https://openaccess.leidenuniv.nl/handle/1887/77129>.

³⁷⁷ Bortey Nketia Alabi Doku et al., "Fisheries Resources of Ghana: Present Status and Future Direction," n.d., 8.

³⁷⁸ Amenogbe et al., "A Review of Ghanas Aquaculture Industry."

³⁷⁹ Doku et al., "Fisheries Resources of Ghana: Present Status and Future Direction."

protein.³⁸⁰ The sector is relatively segregated: men generally conduct production activities, while women tend to be engaged in postharvest processing and trading. There is a growing interest in aquaculture among youth.³⁸¹ Age, experience, pond area, gender, pond type, and training in fish farming are strong predictors of the technical efficiency of farmers.³⁸²

Intensive cage culture of tilapia dominates Ghana’s aquaculture industry.³⁸³ About 90 percent of fish production in Ghana is based on cage culture; the remainder is conducted in earthen ponds and concrete tanks. Cage farming systems are found predominantly in reservoirs and Lake Volta. They have exploded in popularity, with an annual growth rate of 73 percent from 2010 to 2016. Small- and medium-scale farmers generally purchase fingerlings from large-scale farmers or the Water Research Institute, Aquaculture Research, and Development Centre at Akosombo (WRI-ARDEC). The WRI-ARDEC is also a primary source of technical advisories. Tilapia (*Oreochromis niloticus*) is preferred by both farmers and consumers, and accounts for over 80 percent of the annual harvest. Catfish (*Clarias gariepinus* and *Heterobranchus*) constitute the remaining 20 percent.³⁸⁴ Fish feed accounts for 40–70 percent of the total variable production costs of an aquaculture operation and represents the primary limiting factor for the growth of the industry.³⁸⁵

There are outstanding untapped opportunities in Ghana’s aquaculture sector. About 74 percent of potential productivity has been met given the present state of technology and input levels; this implies that 26 percent of technical potential has yet to be realized, even in the absence of innovation (Figure 1).³⁸⁶ Prominent among potential innovations are the production of live feed, marine fish culture, shellfish culture, integrated fish farming, production of indigenous species, and feed innovation.³⁸⁷ There are also several local species that are not yet commercially produced despite being in high consumer demand and doing very well under cultivation, including mullet, milkfish, prawns, mussels, oysters, and abalone.³⁸⁸ The government has attempted to foster shrimp production, but so far it has had little success.³⁸⁹

³⁸⁰ Amenogbe et al., “A Review of Ghanas Aquaculture Industry.”

³⁸¹ Amenogbe et al.

³⁸² Edward Ebo Onumah, Justina Adwoa Onumah, and Gideon Edu Onumah, “Production Risk and Technical Efficiency of Fish Farms in Ghana,” *Aquaculture* 495 (October 1, 2018): 55–61, <https://doi.org/10.1016/j.aquaculture.2018.05.033>.

³⁸³ Benson Obwanga et al., “A Comparative Study of Aquaculture Sector Development in Egypt, Ghana and Nigeria;,” n.d., 36.

³⁸⁴ Amenogbe et al., “A Review of Ghanas Aquaculture Industry.”

³⁸⁵ Amenogbe et al.

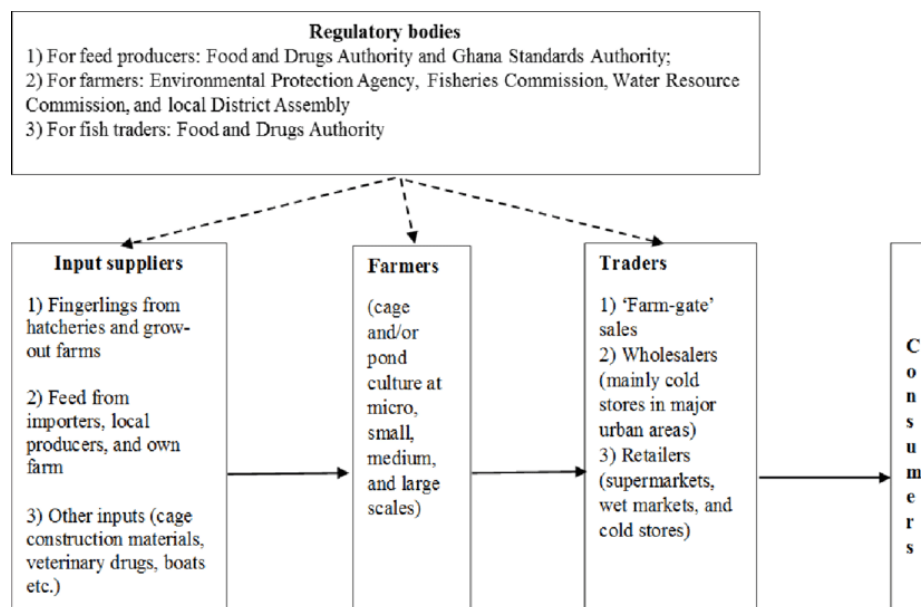
³⁸⁶ Onumah, Onumah, and Onumah, “Production Risk and Technical Efficiency of Fish Farms in Ghana.”

³⁸⁷ Amenogbe et al., “A Review of Ghanas Aquaculture Industry.”

³⁸⁸ Amenogbe et al.

³⁸⁹ Amenogbe et al.

Figure 1: Ghanaian aquaculture value chain map³⁹⁰



PROBLEM STATEMENT

Ghanaian aquaculture’s current profitability is threatened by serious sustainability challenges.³⁹¹ Overfishing, unsustainable fishing methods, and climate change have caused serious declines in marine fish supplies.³⁹² Extreme weather events, including erratic rainfall, extreme temperatures, floods, and drought have been shown to decrease small-scale operators’ fish supplies by 25 percent and revenue by 53 percent. This creates a direct relationship between climate change and poverty. Shellfish are particularly vulnerable to temperature changes.³⁹³ There is thus an urgent need to build environmental adaptive resilience via mapping of flood zones, tree planting, dyke systems, and water storage facilities (Figure 2).³⁹⁴ Climate-smart policies and sustainable resource-use strategies will also play a key role in upholding the aquaculture sector.³⁹⁵

³⁹⁰ Sena Amewu, “Figure 3.1. Aquaculture Value Chain Map for Ghana,” ResearchGate, accessed October 30, 2019, https://www.researchgate.net/figure/Aquaculture-value-chain-map-for-Ghana_fig3_326069939.

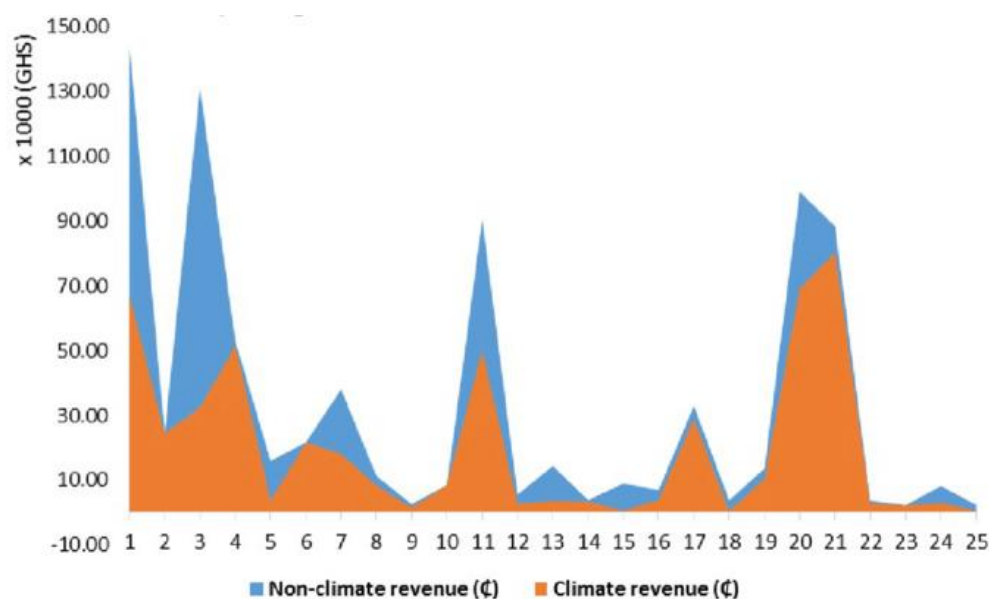
³⁹¹ Berchie Asiedu, Dickson Malcolm, and Seidu Iddrisu, “Assessing the Economic Impact of Climate Change in the Small-Scale Aquaculture Industry of Ghana, West Africa,” *AAS Open Research* 1 (November 1, 2018): 26, <https://doi.org/10.12688/aasopenres.12911.1>.

³⁹² Aheto, Acheampong, and Odoi, “Are Small-Scale Freshwater Aquaculture Farms in Coastal Areas of Ghana Economically Profitable?”

³⁹³ Atindana, Ofori-Danson, and Brucet, “Modelling the Effects of Climate Change on Shellfish Production in Marine Artisanal Fisheries of Ghana.”

³⁹⁴ Asiedu, Malcolm, and Iddrisu, “Assessing the Economic Impact of Climate Change in the Small-Scale Aquaculture Industry of Ghana, West Africa.”

³⁹⁵ Atindana, Ofori-Danson, and Brucet, “Modelling the Effects of Climate Change on Shellfish Production in Marine Artisanal Fisheries of Ghana.”

Figure 2: Climate change impacts on Ghanaian aquaculture revenues³⁹⁶

Limited producer capacity in modern aquaculture techniques and inadequate funding for research and development threaten to stagnate innovation in the sector. Policy limitations, poor extension services, a dearth of robust needs-based research and funding for the same, limited private sector investments, and a lack of coordination across relevant institutions leaves farmers without access to the technology innovations and capacity building that would enable continued growth of the sector.³⁹⁷

The high cost of efficient fish feed is a primary limiting factor for sustainability and continued growth of the industry. Feed constitutes 40–70 percent of the total production costs. Ghana has only one recognized fish feed production company; 80–90 percent of commercial fish feed purchased is imported. Most domestically produced feed is below standard because formulation largely depends on the cost of ingredients rather than nutritional requirements. Therefore, it may be composed of rice bran, brewer’s yeast, groundnut, maize, or anchovy meal. Imported commercial feeds typically contain 24–28 percent crude protein but cost at least 30 percent more than domestically produced feeds. Significantly, fish fed with maize or wheat bran grow significantly faster than those fed with rice bran due to the higher fiber content of rice.³⁹⁸

Inadequate availability and quality of fish seed also encumbers the industry. The FAO and technical experts have encouraged using sex reversal and hybridization techniques to achieve high-quality seed. However, these techniques are unpopular outside research centers given a lack of necessary technical capacity among producers. Farmers incur huge losses due to low quality seed; there is a significant need for stronger stakeholder commitment to capacity building and access to improved fish seed.³⁹⁹

The aquaculture postharvest value chain also remains relatively underdeveloped. There are significant opportunities for value additions to reduce postharvest losses, minimize handling costs, produce higher value products, and improve livelihoods.⁴⁰⁰ Low-cost postharvest processes, including smoking, salting,

³⁹⁶ Asiedu, Malcolm, and Iddrisu, “Assessing the Economic Impact of Climate Change in the Small-Scale Aquaculture Industry of Ghana, West Africa.”

³⁹⁷ Amenogbe et al., “A Review of Ghanas Aquaculture Industry.”

³⁹⁸ Amenogbe et al.

³⁹⁹ Aheto, Acheampong, and Odoi, “Are Small-Scale Freshwater Aquaculture Farms in Coastal Areas of Ghana Economically Profitable?”

⁴⁰⁰ Simon R. Bush et al., “Emerging Trends in Aquaculture Value Chain Research,” *Aquaculture* 498 (January 1, 2019): 428–34, <https://doi.org/10.1016/j.aquaculture.2018.08.077>; Amenogbe et al., “A Review of Ghanas Aquaculture Industry.”

and drying, are readily accessible in remote areas and represent an important opportunity for increasing the ROI of women in the value chain.⁴⁰¹

CLIMATE MODELING

Not applicable.

POTENTIAL PROJECT IMPACTS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

Both with and without climate risks, there is a 59 percent increase in income for 30,000 households under sustainable aquaculture. The project has good chances of success as shown by the positive NPV, both with climate and other risks, but especially without risks (74 percent). The ROI and the BCRs of this project are relatively low given the high cost per beneficiary of setting up the project. This project cost is lower relative to many of the others, and should be perhaps thought of as a ‘starter’ project—the start-up costs are high, but the gains per beneficiary are also very high. If additional beneficiaries join, and demand for higher-quality, healthier, and resilient products increases, then the framework is in place to expand the project more broadly, at a greatly reduced cost per beneficiary. This would improve the overall ROI and BCR.

Table AQ-1: Sustainable Fisheries and Aquaculture Cost-Benefit Analysis With and Without Climate Risks

Mean No. Beneficiaries	Change in Yield (%) ^a	NPV (US\$, millions) ^b	Chance Positive NPV (%) ^b	ROI ^b	BCR (SD)
With Climate and Pest Risks					
70,000	59	9.6	50	0.29	0.21 (0.92)
Without Climate and Pest Risks					
70,000	59	28.5	63	0.93	0.62 (1.24)

Note: a. Average percentage change between beneficiaries with vs without project. b. Average of 100 model runs.

Table AQ-2: Financial Analysis

Technology	Change with Sustainable Aquaculture		
	Yield	Gross Returns	Costs
Fish			
Improved Breeds	11.6 (17.4)		
Feed Supplementation	49.5 (30.5)		-10.4 (9.4)
Feed Substitutions	-2.3 (4.1)	-22.1 (35.0)	-15.1 (4.9)
Addition of Fish Ponds		80 (20)	
Mean of all Technologies	19.6 (26.8)		-12.8 (3.3)

Note: Values are the percentage change with and without project. Values derived from the ERA and other secondary sources.

⁴⁰¹ Evans, “Caught in The Net.”

Table AQ-3. Values and Assumptions for Estimating the Number of Beneficiaries for Sustainable Aquaculture in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Aquaculture	35,000	500

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

ENABLING ENVIRONMENT: SITUATION ANALYSIS**Alignment to NDC**

Of the 12 identified goals of the NDC that are potentially related to CSA, fisheries and aquaculture have the following strong or supportive alignments:

- Strong alignment to five NDC goals: conservation agriculture; postharvest storage and processing; livestock and aquaculture productivity; actively manage natural spaces; livelihood diversity
- Supportive to three NDC goals: wildfire management; governance reform; water distribution and access

Relevant Policies⁴⁰²

- Densu Estuary Community Co-Management Plan (in collaboration with USAID)
- Ghana National Aquaculture Development Plan (GNADP) (2013) (US\$85 million in collaboration with FAO)
- The Ministry of Fisheries and Aquaculture Development has forbidden the imports of farmed fish, specifically flash-frozen tilapia
- The National Aquaculture Strategic Framework (2006) and the Ghana National Aquaculture Development

Key Policy Gaps⁴⁰³

- Lack of funding for research and development of technology innovation
- Lack of implementation of policies curbing illegal fishing and overfishing
- Lack of community inclusion in national aquaculture planning process

Key Policy Distortions

- Tariffs on imported fish feed that make it inaccessible to domestic farmers
- Lack of enforcement of quality standards for domestically produced feed
- High cost/low rate of capacity building and innovation dissemination

Key Contributors to Project Success⁴⁰⁴

- Enabling policy environment
- Broad international support
- High consumer demand

⁴⁰² Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana."

⁴⁰³ Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund"; Bunn, Climate Smart Cocoa in Ghana.

⁴⁰⁴ Partey et al., "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana."

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Significant growth opportunities
- Sector profitability
- Established research centers, associations, councils, and other key organizations that integrate the value chain

Key Risks/Barriers to Success⁴⁰⁵

- High cost of imported feed
- Low quality of domestically produced feed
- Insufficient domestic supply of feed
- Poor capacity building and innovation dissemination networks
- Vulnerability of sector to climate change impacts

A further assessment of barriers to aquaculture was provided by an in-country panel of experts. Expert opinion ranked, from highest to lowest intensity, key barriers as finance and the reliability of water supply. Other equally important barriers in order of importance are cost of technology, support from government and other organizations, the land tenure system, market access, availability of resources, and mechanization. The least-ranked barrier associated with sustainable fisheries and aquaculture implementation is gender inclusivity. To ensure a more sustainable fisheries and aquaculture implementation, development practitioners must focus on investing in facilities that ensure reliability of water supply with funding opportunities.

Public Institutional Framework⁴⁰⁶

- Food and Drug Authority
- Ghana Standards Authority
- Water Resources Commission
- Ministry of Fisheries and Aquaculture Development
- Fisheries Commission
- Environmental Protection Agency
- Universities conducting research and training personnel at BS, MS, and PhD levels:
 - University of Ghana
 - University of Cape Coast
 - University of Natural Resources and Energy
 - Kwame Nkrumah University of Science and Technology
 - University of Development Studies
 - Agriculture Colleges

Potential NGO Collaborators⁴⁰⁷

- Universities and Water Research Council
- Water Research Institute, Aquaculture Research, and Development Centre at Akosombo
 - research and development
 - technical support
 - sale of fish seed to producers
- URI Coastal Resources Center

⁴⁰⁵ Marinus and Ronner, "What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica."

⁴⁰⁶ Kizito et al., "Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana."

⁴⁰⁷ Kizito et al.

- Two local community-led NGOs aiming to protect Ghana’s oyster stock have already collaborated with USAID
 - Densu Oyster Pickers’ Association
 - Development Action Association

Most Promising Supporting Digital Agriculture Technologies

- Smart contracting for transparent and equitable sustainability certification
- Barcoding and blockchain for certification labeling and product tracing
- IoT and remote sensing for monitoring water resources
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision-making in the face of extreme weather events⁴⁰⁸
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best livestock practices and disseminate research and development innovations
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

DELIVERY- SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides implementation experience, a knowledge base, and lessons learned. Related projects underway include:

- USAID: Ghana’s Sustainable Fisheries Management Project⁴⁰⁹
 - 2014–2019, US\$24 million
- UNDP: Strengthening Resilience of Rural Women Through Dry Season Farming in Ghana (4 years)⁴¹⁰
- UNEP and GEF Trust fund: Strengthening of the Enabling Environment, Ecosystem-based Management, and Governance to Support Implementation of the Strategic Action Programme of the Guinea Current Large Marine Ecosystem⁴¹¹
 - 2017–ongoing, US\$51.8 million

Other Relevant Completed Projects:

- World Bank: Ghana Fourth Agricultural Development Policy Operation⁴¹²
 - 2012–2018, US\$50 million
 - Remaining need to enhance license issuance to fishing vessels to reduce illegal fishing
- World Bank: Ghana - West Africa Regional Fisheries Program (GEF)⁴¹³
 - 2011–2018, US\$53.8 million

⁴⁰⁸ The World Bank Group, “Agriculture Observatory.”

⁴⁰⁹ USAID, “Sustainable Fisheries Management Project (SFMP),” USAID Biodiversity Conservation Gateway, October 2014, <https://rmpportal.net/biodiversityconservation-gateway/legality-sustainability/fisheries-development/project-search/add-a-project-activity/usa-id-ghana-sustainable-fisheries-management-project-sfmp>.

⁴¹⁰ UNDP, “Strengthening Resilience of Rural Women through Dry Season Farming in Ghana,” accessed October 19, 2019, <https://www.gh.undp.org/content/ghana/en/home/presscenter/articles/2019/strengthening-resilience-of-rural-women-through-dry-season-farmi.html>.

⁴¹¹ Global Environment Facility, “Strengthening of the Enabling Environment, Ecosystem-Based Management and Governance to Support Implementation of the Strategic Action Programme of the Guinea Current Large Marine Ecosystem,” October 31, 2017, <https://www.thegef.org/project/strengthening-enabling-environment-ecosystem-based-management-and-governance-support>.

⁴¹² The World Bank, “Ghana - Fourth Agriculture Development Policy Operation Project” (The World Bank, September 28, 2015), <http://documents.worldbank.org/curated/en/863071467987836148/Ghana-Fourth-Agriculture-Development-Policy-Operation-Project>.

⁴¹³ The World Bank, “Ghana - West Africa Regional Fisheries Program (GEF),” Projects and Operations, August 25, 2019, <http://www.projects.worldbank.org/P124812/ghana-west-africa-regional-fisheries-program-gef?lang=en>.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- Remaining gaps: disease outbreak early warning systems and infection detention programs; smallholder capacity building; closing the gap between the number of illegal fishing offenses and number of prosecutions; reducing instances of penalty waivers without clear reason

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- Ministry of Fisheries and Aquaculture Development
- Fisheries Commission

International Financing Opportunities

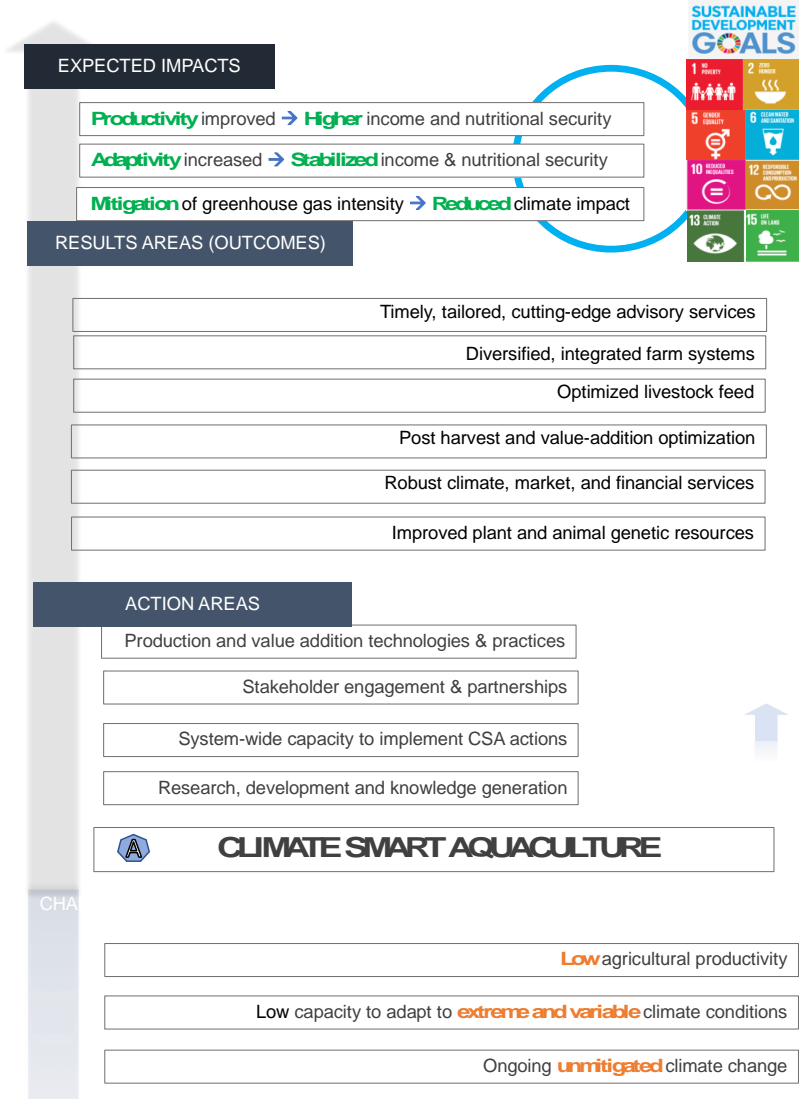
Several multilateral donors have been invested in the aquaculture sector to date, including:

- USAID
- FAO
- World Bank

Potential Private Sector Collaborators Commercial fish feed producers

- Commercial fish feed producers
- Commercial fish seed/fingerling producers
- Large-scale aquaculture operations

THEORY OF CHANGE



A-8. Knowledge systems and advisory services supporting climate-smart agriculture

PROJECT SUMMARY

OBJECTIVE: Establish robust research and extension services, leveraging appropriate ICT to augment farmer productivity, adaptivity, and mitigation in the face of climate change.

PROJECT HIGHLIGHTS: A national-scale program; foundational to CSA and sound agricultural progress across Ghana; supports all 3 CSA pillars; strong economic and financial support; highly aligned with national needs and strategies

REGIONS: National-scale project

PROJECTED BENEFICIARIES: 500,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation, Mitigation

KEY CSA INVESTMENT ACTIVITIES:

- Evidence-based research⁴¹⁴
- Extension services⁴¹⁵
- ICT advisory services,⁴¹⁶ particularly climate information services⁴¹⁷
- Capacity building

JUSTIFICATION

Strong agricultural research and extension networks are the primary predictor of agricultural productivity growth in Sub-Saharan Africa.⁴¹⁸ Development and dissemination of new technologies accounts for 51 percent of productivity gains; improved trade and marketing policies account for 20 percent; and reductions in conflict for 18 percent.⁴¹⁹ Extension programs in Ghana have been shown to increase farm income by 11–111 percent, increase household income by 23–85 percent, and increase per capita income by 21–110 percent.⁴²⁰

Climate information services are particularly helpful to farmers facing erratic weather patterns. Climate information services lend themselves well to mobile-based services⁴²¹ and community information sharing.⁴²² Timing of advisory services⁴²³ and the integration of top-down/value-chain/business approaches with bottom-up/smallholder/traditional approaches are crucial to effectiveness.⁴²⁴ Willingness-to-pay is another important factor for consideration; in Ghana, 85 percent of farmers are

⁴¹⁴ CIAT, “CSAIP Inception Report.”

⁴¹⁵ World Bank, “Transforming Agriculture for Economic Growth, Job Creation and Food Security”; CIAT, “CSAIP Inception Report.”

⁴¹⁶ CIAT, “CSAIP Inception Report.”

⁴¹⁷ Naab, Abubakari, and Ahmed, “The Role of Climate Services in Agricultural Productivity in Ghana”; Potsdam Institute for Climate Impact Research, “Climate Risk Profile: Ghana.”

⁴¹⁸ International Food Policy Research Institute (IFPRI), “Public Agricultural Spending and Growth in Ghana.”

⁴¹⁹ World Bank, “Transforming Agriculture for Economic Growth, Job Creation and Food Security.”

⁴²⁰ Gideon Danso-Abbeam, Dennis Sedem Ehiakpor, and Robert Aidoo, “Agricultural Extension and Its Effects on Farm Productivity and Income: Insight from Northern Ghana,” *Agriculture & Food Security* 7, no. 1 (October 19, 2018): 74, <https://doi.org/10.1186/s40066-018-0225-x>.

⁴²¹ Prince Maxwell Etwire et al., “An Assessment of Mobile Phone-Based Dissemination of Weather and Market Information in the Upper West Region of Ghana,” *Agriculture & Food Security* 6, no. 1 (April 10, 2017): 8, <https://doi.org/10.1186/s40066-016-0088-y>.

⁴²² Innovations for Poverty Action, “Evidence for Agriculture in Ghana” (Accra, Ghana: IFPRI, USAID, and ESRC, 2015).

⁴²³ Innovations for Poverty Action.

⁴²⁴ Stan Karanasios and Mira Slavova, “How Do Development Actors Do ‘ICT for Development’? A Strategy-as-practice Perspective on Emerging Practices in Ghanaian Agriculture,” *Information Systems Journal* 29, no. 4 (July 1, 2019): 888–913, <https://doi.org/10.1111/isj.12214>; Mira Slavova and Stan Karanasios, “When Institutional Logics Meet Information and Communication Technologies: Examining Hybrid Information Practices in Ghana’s Agriculture,” *Journal of the Association for Information Systems* 19, no. 9 (September 30, 2018), <https://aisel.aisnet.org/jais/vol19/iss9/4>; Naab, Abubakari, and Ahmed, “The Role of Climate Services in Agricultural Productivity in Ghana.”

willing to register at a cost of GHS 1; 50 percent would register for GHS 2; and just 19 percent would register for GHS 3.⁴²⁵

Ghana has an extensive agricultural research network. It includes 10 Council for Scientific and Industrial Research (CSIR) institutes, the Cocoa Research Institute of Ghana (CRIG), the Biotechnology Nuclear Agricultural Research Institute (BNARI), the Marine Fisheries Research Division (MFRD), and multiple education institutions. The CSIR provides the main institutional framework for agricultural research and development.⁴²⁶

Simply having access to and using a mobile phone significantly improves Ghanaian farmers' livelihoods. There are 140 mobile subscriptions per 100 inhabitants in Ghana.⁴²⁷ An estimated 87 percent of farmers own mobile phones, versus just 38 percent in 2014.⁴²⁸ Farmers leverage mobile phones to create informal peer networks, often using WhatsApp or Telegram.⁴²⁹ These peer networks are used to negotiate bulk input and sale prices and sell produce beyond their own communities. About 80 percent self-report that owning a mobile makes it easier to communicate with intermediaries and other customers; 68 percent report selling at higher prices, and 89 percent report improved incomes. Almost 96 percent of farmers use their mobile for accessing market information, 39 percent for accessing rural support institutions, and 46 percent for accessing inputs and tools. About 18 percent use their phone to contact financial institutions and 13 percent to contact extension agents. At the beginning of the seasons, farmers often contact extension agents to inquire about onset of rains, planting times, input sources, and input availability. Later in the season, the most common interactions are reporting pest and diseases.

Digital agricultural innovations show significant promise in supporting agricultural extension. For example, CocoaLink's timely, practical push-SMS services to cocoa farmers significantly increase productivity across both large populations and multiple production years.⁴³⁰ The organization responded to demands for a non-Android based service; now internet users can access CocoaLink through Facebook messenger to ask questions and access articles and quizzes.⁴³¹ This suggests an important opportunity to significantly broaden the reach of governmental extension services in an highly economically efficient manner by providing advice, climate, market, and pest/disease information to farmers digitally.⁴³²

Community social networks hold a key role in Ghanaian farmers' information sharing and access. Focal farmers, opinion leaders, NGOs, and religious leaders, in addition to extension agents, have a strong influence farmers' decisions.⁴³³ Advanced value chain collaboration has been shown to have a much greater positive impact than conventional value chain collaboration in Ghana.⁴³⁴ Climate information

⁴²⁵ G. Palloni et al., "Paying for Digital Information: Assessing Farmers Willingness to Pay for a Digital Agriculture and Nutrition Service in Ghana," *AgEcon Search*, 2018, <https://doi.org/10.22004/ag.econ.277451>.

⁴²⁶ World Bank, "Transforming Agriculture for Economic Growth, Job Creation and Food Security."

⁴²⁷ 2017 Global ICT Development Index, "Ghana," International Telecommunications Union, 2017, <https://www.itu.int/net4/ITU-D/idi/2017/index.html#idi2017economytab&GHA>.

⁴²⁸ Alex Barimah Owusu, Paul W. K. Yankson, and Stephen Frimpong, "Smallholder Farmers' Knowledge of Mobile Telephone Use: Gender Perspectives and Implications for Agricultural Market Development," *Progress in Development Studies* 18, no. 1 (January 2018): 36–51, <https://doi.org/10.1177/1464993417735389>.

⁴²⁹ Nyamwaya Munthali et al., "Innovation Intermediation in a Digital Age: Comparing Public and Private New-ICT Platforms for Agricultural Extension in Ghana," *NJAS - Wageningen Journal of Life Sciences*, Diagnostics of case studies on environmental virtual observatories for connective action, 86–87 (November 1, 2018): 64–76, <https://doi.org/10.1016/j.njas.2018.05.001>.

⁴³⁰ The Hershey Company, "Three-Year Study Concludes That CocoaLink 'Significantly Improved the Livelihoods' of Ghanaian Cocoa Farmers."

⁴³¹ Farmerline LTD, "Farmerline Launches New CocoaLink Service."

⁴³² Owusu, Yankson, and Frimpong, "Smallholder Farmers' Knowledge of Mobile Telephone Use."

⁴³³ Sidik Sulemana Baba, "Effectiveness of Knowledge Management Approaches on Agricultural Extension Services Delivery in Selected Districts of Northern Region" (Thesis, Ghana, University for Development Studies, 2018), <http://udspace.uds.edu.gh:80/handle/123456789/1933>.

⁴³⁴ Howard Deans, Mirjam A. F. Ros-Tonen, and Mercy Derkyi, "Advanced Value Chain Collaboration in Ghana's Cocoa Sector: An Entry Point for Integrated Landscape Approaches?," *Environmental Management* 62, no. 1 (July 1, 2018): 143–56, <https://doi.org/10.1007/s00267-017-0863-y>.

relayed through SMS to select farmers has been shown to proliferate through communities in a matter of hours.⁴³⁵

PROBLEM STATEMENT

Increasing demand and limited resources have deteriorated Ghana's free public extension services in spite of several reforms. Lack of knowledge is the single biggest barrier to innovation among Ghanaian farmers.⁴³⁶ Despite many educational institutions that train individuals to the BS, MS, and PhD level in agricultural studies,⁴³⁷ the current ratio of agricultural extension agents to farmers is approximately 1:807.⁴³⁸ The World Bank's suggested ratio is approximately 1:800.⁴³⁹ Efforts to augment public service delivery using new ICTs, such as decentralized data collection, monitoring, and enhanced connectivity, have not yet demonstrated impacts.⁴⁴⁰ Local private sector aggregators and buyers have begun to fill the gap, particularly with traditional (mobile) ICT-based services.⁴⁴¹ Participatory video approaches⁴⁴² and leveraging social networking⁴⁴³ have also been suggested as means for extending the reach of public services.

Significant access inequalities in the current system perpetuate poverty and poor productivity. For example, farmers who are less familiar with ICT may avoid using services out of a fear they will be charged. If the mobile operator used by the service provider does not have good coverage or a prevalent customer base in the region, the SIM card may not even be used.⁴⁴⁴ Gender norms, patriarchal values, time poverty, and illiteracy may also reduce access, particularly for women. Seniority, religion, class, and position within the household further reconfigure advisory services access.⁴⁴⁵

Even farmers who have access to extension services are often limited in their ability to receive and implement advisory recommendations by external circumstances. Restrictive land tenure, a lack of profitable markets and safe harvest storage, poor financial services, weak farmer groups, and low household incomes make it impossible for many farmers to take risks and change established practices.⁴⁴⁶ Consequently, advisory services increase these farmers' knowledge, but does not improve their outcomes.⁴⁴⁷ In contrast, those with extensive social networks, many years of experience, large farm sizes,

⁴³⁵ Innovations for Poverty Action, "Evidence for Agriculture in Ghana."

⁴³⁶ I. Barnett et al., "External Evaluation of Mobile Phone Technology-Based Nutrition and Agriculture Advisory Services in Africa and South Asia," Mixed Methods Baseline Report, Ghana (Oxford Policy Management: Institute for Development Studies, February 1, 2019), https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/14321/Mixed_method_baseline_report_Ghana_FINAL_APPROVED.pdf?sequence=178&isAllowed=y.

⁴³⁷ World Bank, "Transforming Agriculture for Economic Growth, Job Creation and Food Security."

⁴³⁸ Baba, "Effectiveness of Knowledge Management Approaches on Agricultural Extension Services Delivery in Selected Districts of Northern Region"; Etwire et al., "An Assessment of Mobile Phone-Based Dissemination of Weather and Market Information in the Upper West Region of Ghana," April 10, 2017.

⁴³⁹ Gershon Feder, Sushma Ganguly, and Jock R. Anderson, *The Rise And Fall Of Training And Visit Extension*, Policy Research Working Papers (Agriculture and Rural Development Department: The World Bank, 2006), <https://doi.org/10.1596/1813-9450-3928>; Magdalena Blum and Judit Szonyi, "Investment Requirements in Extension to Achieve Zero Hunger and Adapt to Climate Change" (FAO, 2012).

⁴⁴⁰ Munthali et al., "Innovation Intermediation in a Digital Age."

⁴⁴¹ Sybil Chidiac, "Achieving Impact at Scale Through ICT-Enabled Extension Services in Ghana," Final Joint Technical Narrative Report (Accra, Ghana: Grameen Foundation USA, March 30, 2018), <https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57315/IDL-57315.pdf?sequence=2>.

⁴⁴² Baba, "Effectiveness of Knowledge Management Approaches on Agricultural Extension Services Delivery in Selected Districts of Northern Region."

⁴⁴³ Alirah Emmanuel Weyori et al., "Agricultural Innovation Systems and Farm Technology Adoption: Findings from a Study of the Ghanaian Plantain Sector," *The Journal of Agricultural Education and Extension* 24, no. 1 (January 1, 2018): 65–87, <https://doi.org/10.1080/1389224X.2017.1386115>.

⁴⁴⁴ Barnett et al., "External Evaluation of Mobile Phone Technology-Based Nutrition and Agriculture Advisory Services in Africa and South Asia."

⁴⁴⁵ Hanson Nyantakyi-Frimpong, "Combining Feminist Political Ecology and Participatory Diagramming to Study Climate Information Service Delivery and Knowledge Flows among Smallholder Farmers in Northern Ghana," *Applied Geography* 112 (November 1, 2019): 102079, <https://doi.org/10.1016/j.apgeog.2019.102079>.

⁴⁴⁶ Barnett et al., "External Evaluation of Mobile Phone Technology-Based Nutrition and Agriculture Advisory Services in Africa and South Asia."

⁴⁴⁷ Innovations for Poverty Action, "Evidence for Agriculture in Ghana."

more secure land tenure, good access to financial services, group memberships, and greater general knowledge are much more likely to participate in extension programs and to adopt new practices.⁴⁴⁸ These farmers are also much more likely to view their farm as a business rather than a cultural way of life.⁴⁴⁹

There is significant segregation in Ghana in mobile phone access. Age, sex, education level, years of experience, and size of holdings hold sway over mobile phone usage.⁴⁵⁰ There is a gender imbalance in phone ownership: 93 percent of male farmers and 80 percent of female farmers own mobile phones. Of the 13 percent of farmers who do not own mobile phones, women compose 9 percent. Male farmers have, on average, 5 years of experience using mobile technology, while women farmers have just 3 years. Even accounting for those that already own phones, close to 28 percent of female farmers report having no knowledge or experience using phones, versus just 5 percent of male farmers.⁴⁵¹ Women have statistically lower willingness to pay for mobile services than men, likely reflecting women farmers' lower household income.⁴⁵² Geographic location also plays a major role in degree of mobile access; network and infrastructure failure is the major constraint in use of mobile phones.⁴⁵³ Some farmers leverage poor networks to generate secondary income by operating local call centers.⁴⁵⁴ Both men and women farmers rate mobile phone-based dissemination of information as a useful alternative to the conventional agent-based extension services in northern Ghana.⁴⁵⁵

ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

Supporting farmer knowledge is foundational to CSA efforts. While direct returns to any individual farmer are relatively low, as shown by a 10 percent change in income in Table KA-1, across the whole country they add up to a communal benefit for a large number (500,000) of people. The project demonstrates high benefits relative to costs, as shown by the BCR. The 'risk' element in this project is particularly high, as reflected in the ROI and BCR, which show particularly strong results if risks are excluded.

Table KA-1: Knowledge and Advisory Services Cost-Benefit Analysis With and Without Climate Risks

Mean No. Beneficiaries	Change in Yield (%) ^a	NPV(US\$, millions) ^b	Chance Positive NPV (%) ^b	ROI ^b	BCR (SD)
With Climate and Pest Risks					
500,000	21	198.1	58	4.74	2.99 (14.31)
Without Climate and Pest Risks					
500,000	21	331.0	61	7.90	4.99 (17.12)

Note: a. Average percentage change between beneficiaries with vs without project. b. Average of 100 model runs.

⁴⁴⁸ Andres et al., "Social Network to Inform and Prevent the Spread of Cocoa Swollen Shoot Virus Disease in Ghana"; Danso-Abbeam, Ehiakpor, and Aidoo, "Agricultural Extension and Its Effects on Farm Productivity and Income."

⁴⁴⁹ Danso-Abbeam, Ehiakpor, and Aidoo, "Agricultural Extension and Its Effects on Farm Productivity and Income."

⁴⁵⁰ Benjamin Yao Foltse et al., "The Determinants of Mobile-Phone Usage among Small-Scale Poultry Farmers in Ghana," *Information Development* 35, no. 4 (September 1, 2019): 564–74, <https://doi.org/10.1177/0266666918772005>.

⁴⁵¹ Owusu, Yankson, and Frimpong, "Smallholder Farmers' Knowledge of Mobile Telephone Use."

⁴⁵² Palloni et al., "Paying for Digital Information."

⁴⁵³ Foltse et al., "The Determinants of Mobile-Phone Usage among Small-Scale Poultry Farmers in Ghana," September 1, 2019.

⁴⁵⁴ Owusu, Yankson, and Frimpong, "Smallholder Farmers' Knowledge of Mobile Telephone Use."

⁴⁵⁵ Prince Maxwell Etwire et al., "An Assessment of Mobile Phone-Based Dissemination of Weather and Market Information in the Upper West Region of Ghana," *Agriculture & Food Security* 6, no. 1 (April 10, 2017): 8, <https://doi.org/10.1186/s40066-016-0088-y>.

Table KA-2: Financial Analysis

Technology	Change with Advisory Services		
	Yield	Gross Returns	Costs
Millet			
Advisory services	8.5 (6.8)		
Mean of all Technologies	8.5 (6.8)		

Note: Values are the percentage change with and without project. Values derived from the ERA and other secondary sources.

Table KA-3. Values and Assumptions for Estimating the Number of Beneficiaries for Advisory Services in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Advisory services	50,000	100

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

Model Assumptions

- Percentage of farmers using evidence-based research, extension agents, and ICT advisory services—current 55 percent; mobile phone alone: 65 percent
- Assumptions on technology were for a time horizon of 5 years, with 3 years as the time to reach half of adoption rate.

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, advisory services has the following strong or supportive alignments:

- Strong alignment to seven NDC goals: cocoa emission reduction; conservation agriculture; postharvest storage and processing; livestock and aquaculture productivity; governance reform; water distribution and access; livelihood diversity
- Supportive to five NDC goals: reforestation/afforestation; enforcing felling standards; enrichment planting; wildfire management; actively manage natural spaces

Key Contributors to Project Success⁴⁵⁶

- Robust research network
- University degree programs in agricultural studies to produce qualified agricultural extensionists
- Good mobile phone penetration
- Strong informal community networks and the opportunity to leverage them for advisory services

⁴⁵⁶ Partey et al., "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana."

Key Risks/Barriers to Success⁴⁵⁷

- Segregation, particularly in terms of gender, in terms of access to (a) advisory services and (b) capacity for use of ICT
- External circumstances that dissuade or prevent farmers from implementing recommendations such as restrictive land tenure, unreliable access to profitable markets, lack of safe harvest storage, and dearth of financial services such as loans and credit
- Strong social and cultural norms influence adoption of innovative practices

A further assessment of barriers to advisory services was provided by an in-country panel of experts. Expert opinion ranked, from highest to lowest, key barriers as technology cost, synergy with government plans, finance, gender inclusivity, and support from government and other organizations. Mechanization and access to information and inputs were the least-ranked barriers. Harmonization of government policies and program can ensure maximum impact and reduce effort duplication. Reduction in technology cost through government subsidy programs will stimulate uptake by smallholder farmers, creating the need for capacity building of extension officials to effectively disseminate extension information to farmers. This directly supports their increased productivity and improves welfare outcomes.

Relevant Policies⁴⁵⁸

- Ghana ICT for Accelerated Development (ICT4AD) Policy (2003)
- National Communications Authority Act 769 (2008)
- National Information Technology Agency Act 771 (2008)
- National ICT Policy and Plan Development Committee

Key Policy Gaps⁴⁵⁹

- Gap between strong research programs and dissemination of findings to end-users
- Lack of resources for providing consistent advisory services to smallholders
- Lack of promotion of financial services for smallholders to enable risk-taking and innovation

Key Policy Distortions

- Land tenure curbs innovative practices
- Poor market integration and postharvest access curbs innovative practices
- Private sector dominates information sharing; government platforms are inefficient

Public Institutional Framework⁴⁶⁰

- Ministry of Food and Agriculture
- Council for Scientific and Industrial Research Institutes
- Cocoa Research Institute of Ghana
- Biotechnology Nuclear Agricultural Research Institute
- Marine Fisheries Research Division
- Public University Agricultural Research Departments

Potential NGO Collaborators⁴⁶¹

- Grameen Foundation
- Farm Radio International

⁴⁵⁷ Marinus and Ronner, "What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica."

⁴⁵⁸ Rhebergen et al., "Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana."

⁴⁵⁹ Ghana Cocoa Forest REDD+ Programme, "Forest Carbon Partnership Facility (FCPF) Carbon Fund"; Bunn, Climate Smart Cocoa in Ghana.

⁴⁶⁰ Kizito et al., "Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana."

⁴⁶¹ Kizito et al.

- Digital Green
- Association of Church-based Development NGOs⁴⁶²
- Esoko

Most Promising Supporting Digital Agriculture Technologies

- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best practices and disseminate research and development outputs
- Mobile finance services and digitized farm records to support credit line establishment
- Smart contracting for transparent and equitable land tenure processes
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support management decisions⁴⁶³
- Mobile platforms—enabled by big data, machine learning, and mobile technology—to support peer knowledge exchange, input supply, and product sales at fair market rates

DELIVERY- SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides, implementation experience, a knowledge base, and lessons learned. Related projects underway include:

- GIZ: Strengthening Advisory Capacities for Land Governance in Africa⁴⁶⁴
 - 2014–2021, €22.5 million
 - Targets strengthening practice-oriented research, training, and education capacities at the university level across the continent of Africa

Other Relevant Completed Projects:

- Government of Ghana: Ghana E-Agriculture Project⁴⁶⁵
 - 2014–2016
 - Implemented by Ministry of Food and Agriculture
 - Enhanced farmer information access on best farming practices, trusted suppliers, and reduced transaction costs in acquiring input
 - 120,000 subscribers
- GIZ: Supporting agricultural technical vocation education and training⁴⁶⁶
 - 2017–2019, €13 million
 - Trained 570 farmers from 19 communities on pineapple and citrus fruits value chains
 - Was able to integrate sound agricultural practices into Agricultural Technical Vocational Education and Training
- World Bank: West Africa Agricultural Productivity Program (WAAPP)⁴⁶⁷
 - 2008–2018, US\$60 million in Phase 2A and US\$15 million in Phase 1A (in Ghana only)
 - Ghana e-agriculture project was a subset of the projects
 - Targeted root and tuber and guinea fowl farmers in Ghana

⁴⁶² Danso-Abbeam, Ehiakpor, and Aidoo, “Agricultural Extension and Its Effects on Farm Productivity and Income.”

⁴⁶³ The World Bank Group, “Agriculture Observatory.”

⁴⁶⁴ GIZ, “Strengthening Advisory Capacities for Land Governance in Africa,” 2014, <https://www.giz.de/en/worldwide/38449.html>.

⁴⁶⁵ Ministry of Food and Agriculture, Republic of Ghana, “E-Agriculture Programme,” Food and Agriculture Organization of the United Nations, March 15, 2017, <http://www.fao.org/e-agriculture/news/ghana-e-agriculture-programme-ministry-food-and-agriculture-republic-ghana>.

⁴⁶⁶ giz, “CAADP: Supporting Agricultural Technical Vocational Education and Training (ATVET),” 2017, <https://www.giz.de/en/worldwide/15974.html>.

⁴⁶⁷ West Africa Agricultural Productivity Program, “Who We Are,” 2015, <http://www.waapp-ppao.org/en/content/who-we-are>.

ANNEX A: PRIORITIZED INVESTMENT OPPORTUNITIES

- World Bank: West Africa Agricultural Transformation Program (WAATP)⁴⁶⁸
 - US\$277 million, dropped

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- Ministry of Food and Agriculture provides ongoing investments in the extension system

International Financing Opportunities

- Canadian International Food Security Research Fund⁴⁶⁹

Potential Private Sector Collaborators

- Various private sector actors prepared to invest in continued productivity within their value chains

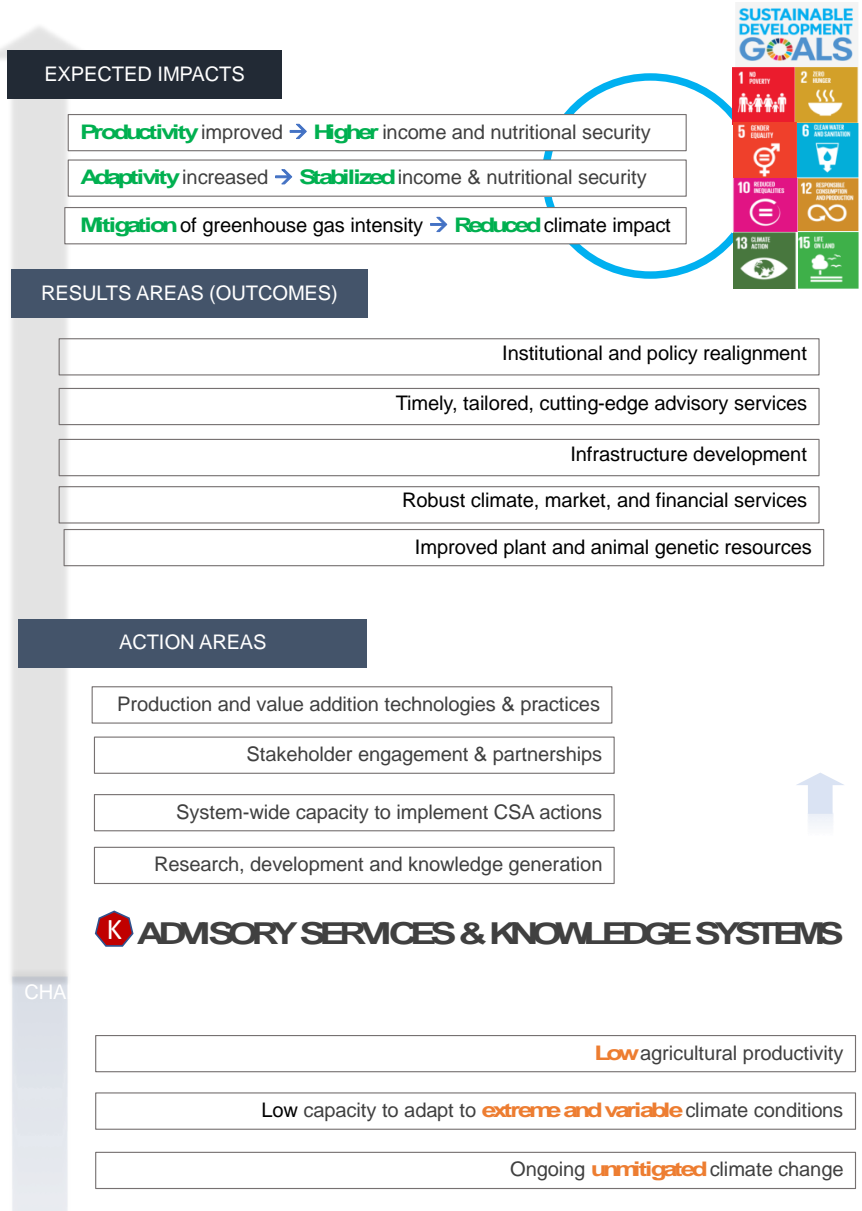
Potential Private Sector Financing

- Private sector actors are invested in providing funding for the advisory services in their particular value chains to ensure continued productivity as an investment in their own business profitability

⁴⁶⁸ Ministry of Food and Agriculture, “West Africa Agricultural Transformation Program,” Environmental and Social Management Framework (Republic of Ghana: World Bank, May 9, 2018), <http://documents.worldbank.org/curated/en/697441526656174464/pdf/WAATP-Ghana-ESMF-WAATP-MoFA-May-2018.pdf>.

⁴⁶⁹ Chidiac, “Achieving Impact at Scale Through ICT-Enabled Extension Services in Ghana.”

THEORY OF CHANGE



A-9. Integrated water resource management for rice

PROJECT SUMMARY

OBJECTIVE: Fully leverage Ghana’s water resources in sustainable ways to improve productivity, nutritional security, climate resiliency, and ecological health.

PROJECT HIGHLIGHTS: Rice is nutritious and in high demand; is resilient to climate impacts; needs water to grow and improved farming techniques; project increases small farmer income by 44 percent; project provides the basis for introducing new water management strategies into rice production

REGIONS: National

PROJECTED BENEFICIARIES: 140,000 smallholder farmers and their families

CSA PILLARS: Production, Adaptation

KEY CSA INVESTMENT ACTIVITIES:

- Water harvesting
- Irrigation systems
- Water management for rice

JUSTIFICATION

Ghana has abundant water resources. The current available surface and groundwater resources in Ghana could be sufficient to farm all of the potential arable land if rain and irrigation systems were fully operational.⁴⁷⁰ Water harvesting and irrigation practices improve productivity and efficiency;⁴⁷¹ irrigated agriculture represents about 20 percent of the world’s agricultural land and contributes about 40 percent of global crop production.⁴⁷² The government of Ghana is implementing strategies to encourage innovation in sustainable agricultural water use.⁴⁷³

Multiple water management innovations have been proposed for increasing water-resource-use efficiency in Ghana. These include, among others:

- roof rainwater harvesting⁴⁷⁴
- flood recession agriculture⁴⁷⁵
- managed aquifer recharge⁴⁷⁶
- supplemental irrigation⁴⁷⁷
- irrigation-aquaculture integrated systems⁴⁷⁸

⁴⁷⁰ Nizar Abou Zaki et al., “An Index-Based Approach to Assess the Water Availability for Irrigated Agriculture in Sub-Saharan Africa,” *Water* 10, no. 7 (July 2018): 896, <https://doi.org/10.3390/w10070896>.

⁴⁷¹ John Kanburi Bidzakin et al., “Impact of Irrigation Ecology on Rice Production Efficiency in Ghana,” *Advances in Agriculture* 2018 (June 12, 2018): 1–10, <https://doi.org/10.1155/2018/5287138>.

⁴⁷² Mia Signs and Matthew McCartney, “Fish in Irrigation Systems: An Ancient Practice May Be the Way of the Future!,” CGIAR Water, Land and Ecosystems, *Thrive* (blog), September 2, 2019, <https://wle.cgiar.org/thrive/2019/09/02/fish-irrigation-systems-ancient-practice-may-be-way-future>.

⁴⁷³ Henry Kofi Mensah and Bachar Ibrahim, “Alternate Solutions Towards Sustainable Irrigated Agriculture in Ghana: Review of Literature,” 2017.

⁴⁷⁴ Mavis Akuffobe-Essilfie et al., “Promoting Rainwater Harvesting for Improving Water Security: Analysis of Drivers and Barriers in Ghana,” *African Journal of Science, Technology, Innovation and Development* 0, no. 0 (April 17, 2019): 1–9, <https://doi.org/10.1080/20421338.2019.1586113>.

⁴⁷⁵ Francis Kokutse, “Irrigation Earns Flood-Prone Farmers US\$4,344 a Hectare,” *The Trust Project*, July 26, 2019, <http://www.scidev.net/index.cfm?originalUrl=/sub-saharan-africa/farming/news/irrigation-earns-flood-prone-farmers-hectare.html&>.

⁴⁷⁶ Lydia Kwoyiga and Catalin Stefan, “Institutional Feasibility of Managed Aquifer Recharge in Northeast Ghana,” *Sustainability* 11, no. 2 (January 2019): 379, <https://doi.org/10.3390/su11020379>.

⁴⁷⁷ Kwoyiga and Stefan.

⁴⁷⁸ Signs and McCartney, “Fish in Irrigation Systems: An Ancient Practice May Be the Way of the Future!”

Water harvesting or irrigation are not appropriate interventions across all scenarios.⁴⁷⁹ The feasibility and potential impacts of such programs vary widely across geography, time (given growing climate change impacts), the population served (economies of scale), and the type of water harvesting/irrigation system used. For example, approximately 9 percent of Ghana is currently suitable for irrigation using simple groundwater lifting technologies. However, about 10 percent of this currently suitable area will become unfavorable for surface irrigation by 2050; this will increase to 17 percent by 2070.⁴⁸⁰ With regard to population served, the per capita expenditure, depending on local population density, varies as much as 1,900 percent mechanized boreholes and by more than 400 percent for hand-pump boreholes.⁴⁸¹

Robust extension and finance services are crucial to the success of water harvesting and irrigation systems. For example, rice farmer training in northern Ghana increased labor efficiency by 7.3 kg/worker/day, and total output by 797 kg.⁴⁸² However, training alone is not enough: many farmers are unable to implement new knowledge without access to financing.⁴⁸³ One study found that farmers trained in a variety of small-scale irrigation technologies chose to implement low-cost technologies that improved profits by 154 percent rather than capital-intensive options that increased profits by 608 percent simply due to lack of access to financing services.⁴⁸⁴

In some cases, improved use efficiency of existing water sources removes the need for new technologies. Fully utilizing reservoir storage capacity, maintaining infrastructure, reducing water conveyance network losses, and optimizing field-level management has been shown to improve water use efficiency by 58–68 percent in existing Ghanaian irrigation systems.⁴⁸⁵ Farmer capacity building through extension and sufficient institutional resources for maintaining and improving infrastructure are crucial to fully leveraging existing systems and technologies.

Rice systems are particularly water resource intensive and represent an important opportunity to leverage integrated water management practices. Ghanaian rice farmers using irrigation are technically, allocatively, and economically more efficient in their production practices.⁴⁸⁶ Flood recession agriculture, widely practiced in other arid regions of West Africa, may be particularly promising for water- and fertilizer-constrained farmers in flood-prone areas (Figure RI-1).⁴⁸⁷

Integrating aquaculture with water harvesting and irrigation systems could offer synergetic benefits to both systems. Irrigation infrastructure can impede river flow, create oxygen-poor reservoirs, and obstruct breeding grounds. Building infrastructure with an eye toward multiple benefits, multiple users, and multiple products (for example, rice-aquaculture systems) could make significant strides toward national productivity, sustainability, and climate-smart goals. Importantly, such systems also support both biodiversity and nutritional security and diversity. Fisheries also support pest control, reducing the need for chemical inputs and the associated environmental impacts.⁴⁸⁸

⁴⁷⁹ Potsdam Institute for Climate Impact Research, “Climate Risk Profile: Ghana.”

⁴⁸⁰ Abeyou W. Worqlul et al., “Effect of Climate Change on Land Suitability for Surface Irrigation and Irrigation Potential of the Shallow Groundwater in Ghana,” *Computers and Electronics in Agriculture* 157 (February 1, 2019): 110–25, <https://doi.org/10.1016/j.compag.2018.12.040>.

⁴⁸¹ Mehran Eskandari Torbaghan and Michael Burrow, “Small Town Water Supply Infrastructure Costs,” April 2019, <https://opendocs.ids.ac.uk/opendocs/handle/123456789/14487>.

⁴⁸² Benjamin Tetteh Anang and Joseph A. Awuni, “Effect of Training on Small Scale Rice Production in Northern Ghana,” *Applied Studies in Agribusiness and Commerce* 12, no. 3–4 (December 31, 2018): 13–20, <https://doi.org/10.22004/ag.econ.292388>.

⁴⁸³ Anang and Awuni.

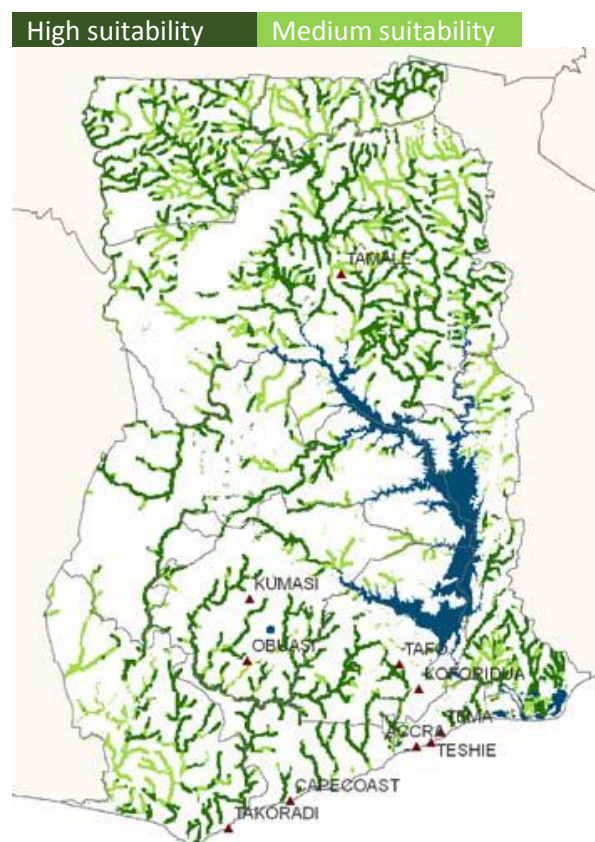
⁴⁸⁴ Bedru B. Balana et al., “Economic and Food Security Effects of Small-Scale Irrigation Technologies in Northern Ghana,” *Water Resources and Economics*, March 21, 2019, 100141, <https://doi.org/10.1016/j.wre.2019.03.001>.

⁴⁸⁵ Ephraim Sekyi-Annan et al., “Performance Evaluation of Reservoir-Based Irrigation Schemes in the Upper East Region of Ghana,” *Agricultural Water Management* 202 (April 1, 2018): 134–45, <https://doi.org/10.1016/j.agwat.2018.02.023>.

⁴⁸⁶ Bidzakin et al., “Impact of Irrigation Ecology on Rice Production Efficiency in Ghana.”

⁴⁸⁷ Kokutse, “Irrigation Earns Flood-Prone Farmers US\$4,344 a Hectare.”

⁴⁸⁸ Signs and McCartney, “Fish in Irrigation Systems: An Ancient Practice May Be the Way of the Future!”

Figure RI-1: Biophysical Suitability for Inland Valley Bottom Rice Management⁴⁸⁹

PROBLEM STATEMENT

The vast majority of Ghana's agriculture depends on rainfall, which is becoming increasingly erratic and difficult to predict as climate change progresses. Pollution, population growth, high evapotranspiration, and environmental degradation have also reduced water availability. Deliberate water management, conservation, and resource-use efficiency are necessary to create resiliency in the face of droughts, floods, and land degradation induced by climate change.⁴⁹⁰ Robust infrastructure, effective farmer training, farmer access to financial services, augmented institutional capacity to deliver extension services, and strong inter-ministerial and intersectoral collaboration will be crucial components of successful efforts.⁴⁹¹ Notably, there are also largely untapped synergies between national gender equality goals and irrigation policy goals.⁴⁹²

Even where irrigation and water harvesting innovation is appropriate, significant challenges remain. Barriers to successful adoption of irrigation and water harvesting systems include limited farmer capacity, limited information on installing and maintaining systems, high system cost, limited institutional support,

⁴⁸⁹ AgWater Solutions, "Mapping and Assessing the Potential for Investments in Agricultural Water Management," Brief, Country Investment (FAOWater), accessed October 30, 2019, http://awm-solutions.iwmi.org/wp-content/uploads/sites/12/documents/Country_Docs/Ghana/ghana-country-investment-brief.pdf.

⁴⁹⁰ Amankwah Emmanuel and Mensah Jackson Napoleon, "Rainwater Harvesting - A Potential Safety Net for Water Security in Ghana," *Asian Journal of Environment & Ecology*, September 25, 2019, 1–10, <https://doi.org/10.9734/ajee/2019/v10i230115>.

⁴⁹¹ Mensah and Ibrahim, "Alternate Solutions Towards Sustainable Irrigated Agriculture in Ghana."

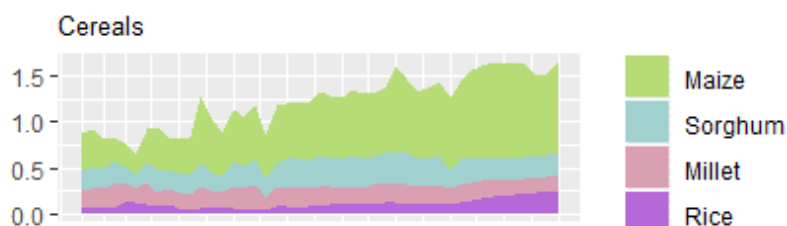
⁴⁹² Barbara C. M. van Koppen, Lesley Hope, and W. Colenbrander, "Gender Aspects of Smallholder Private Groundwater Irrigation in Ghana and Zambia," *Water International* 38, no. 6 (2013): 840–51.

and negative perceptions of system sustainability and portability.⁴⁹³ Cultural rules, norms, traditions, and taboos, as well as traditional practices and knowledge, may also challenge irrigation and water harvesting strategies.⁴⁹⁴

CLIMATE MODELING

Climate change will drastically alter what crops are suitable for a given place, reducing suitability across large areas, and even entire countries, as well as creating pockets of increased suitability. At a global scale, these shifts will be significant in determining what countries can grow what crops, which in turn will affect international trade. At the same time, government GHG mitigation policies, together with demographic and economic growth trajectories, will impact demand and consumption. The complex interplay of all these factors was modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).⁴⁹⁵

Figure RI- 2: Area Harvested in Cereals Including Rice in Ghana 1973–2017 (million ha)



While the area in rice production has increased greatly, the area planted to rice has only grown a small amount, despite a high demand as shown in Figure RI-2. This suggests that expansion of rice may be water-limited. Table RI-1 shows an expansion of area in rice under both climate scenarios. Compared to other cereals, rice is relatively resilient to climate change. Because Ghanaian rice, even with a high yield gap, does better than rice in other countries given climate change; it does well in net trade, even under the worst of the climate scenarios.

Table RI-1: Percentage Difference in Ghana of Rainfed Rice Area and Yields over a No-Climate Change Reference Scenario for 2030 and 2050, under Different Representative Carbon Concentration Scenarios (RCPs), with BAU Demographic and Economic Growth Trajectories (SSP2)

Percent Difference from No-Climate Change Scenario	Area Harvested				Yield			
	Low Emissions (RCP 4.5)		High Emissions (RCP 8.5)		Low Emissions (RCP 4.5)		High Emissions (RCP 8.5)	
	2030	2050	2030	2050	2030	2050	2030	2050
Crop								
CER-Rice	1.19	2.29	1.81	3.63	-1.25	-2.60	-0.80	-1.71

More importantly, the investments for CSA water resource management and irrigation further boost the importance of rice as a climate-resilient crop as shown in Figure RI-3. Rice shows increased yield and net trade both with and without CSA investments and regardless of climate change baselines. The possibility

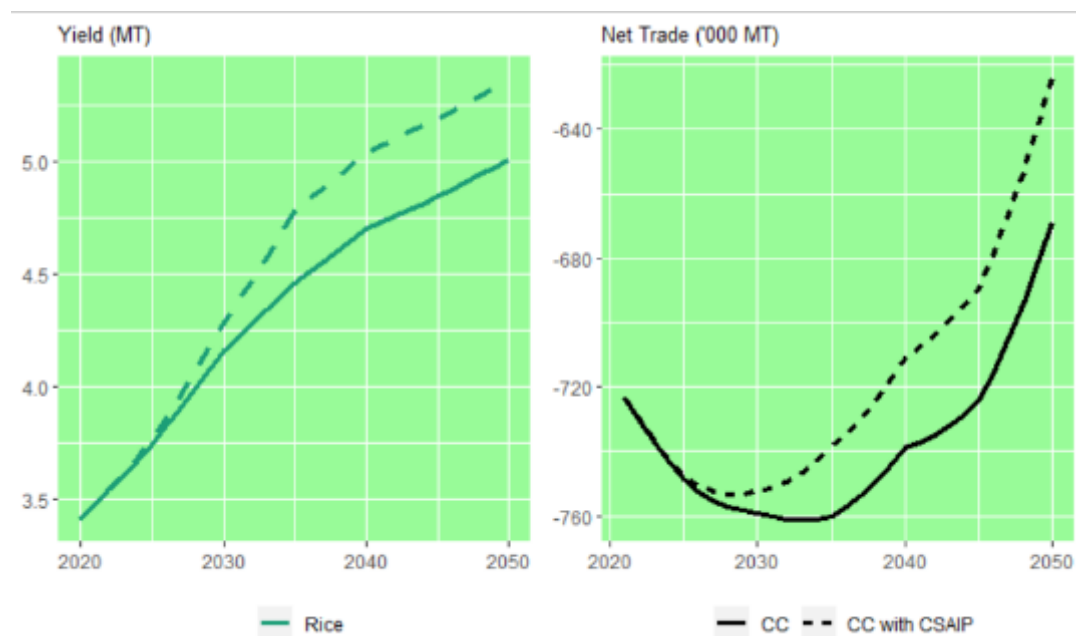
⁴⁹³ Akuffobe-Essilfie et al., “Promoting Rainwater Harvesting for Improving Water Security.”

⁴⁹⁴ Kwoyiga and Stefan, “Institutional Feasibility of Managed Aquifer Recharge in Northeast Ghana.”

⁴⁹⁵ IMPACT is a model of the global agricultural sector that takes account of climate change as well as economic agency. See Robinson et al. (2015a, b) for details.

for CSA investments to make rice more climate resilient while closing yield gaps makes it an important crop for food security.

Figure RI-3: Potential Impact of the Water Harvesting Technologies and Irrigation CSAIP on Irrigated Rice Yields and Balance of Trade, Modeled using IMPACT under a BAU SSP 2 and a Pessimistic Representative Carbon Concentration Scenario (RCP 8.5)



ECONOMIC AND FINANCIAL ANALYSIS

ESTIMATES OF IMPACTS: PRODUCTION, RESILIENCE, EMISSIONS

The CSA irrigated rice project provides a 44 percent increase in income for 80,000 smallholder farmers. The proposed investment of US\$40,000,000 (see Table RI-4) delivers a strong NPV without risks, however there is a good chance for a positive NPV both with and without risks. The ROI and BCA reflect the high costs of implementation for a relatively low number of beneficiaries. However, given the demand for rice and the potential to use this investment as a demonstration project, it is possible to assume that some private sector involvement might be possible. Rice’s resilience to climate change also makes it an important crop, and one that allows a transition away from some of the cereals (for example, millet and sorghum) that will have lower yields in the future.

Table RI-2: Irrigated Rice CBA With and Without Climate Risks

Mean No. Beneficiaries	Change in Yield (%) ^a	NPV(US\$, millions) ^b	Chance Positive NPV (%) ^b	ROI ^b	BCR (SD)
With Climate and Pest Risks					
140,000	44	143.7	89	2.32	1.54 (2.36)
Without Climate and Pest Risks					
140,000	44	171.1	90	2.78	1.84 (2.47)

Note: a. Average percentage change between beneficiaries with vs. without project. b. Average of 100 model runs.

Table RI- 3: Financial Analysis

Technology	Change with Water Harvesting and Irrigation for Rice		
	Yield	Gross Returns	Costs
Rice			
SRI, AWD, Rice Management	46.8 (9.0)	49.2 (12.7)	2.6 (6.7)
Irrigation	45.9 (38.3)	46.2 (95.4)	
Water Harvesting	39.7 (2.5)		
Mean of all Technologies	44.1 (3.9)	47.7 (2.1)	

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

Table RI-4: Values and Assumptions for Estimating the Number of Beneficiaries for Water Harvesting and Irrigation in the Ghana CSAIP

Investment	Budget (US\$, thousands)	Cost/Beneficiary (US\$)
Water-Rice	70,000	500

ESTIMATED PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary (see Annex E). Outside this range, the project is either unrealistic (if on the low end) or not cost efficient (if above the high end).

Model Assumptions: Rice was analyzed. The assumptions on yield and farmer adoption rates were:

- Rice - current: 4–5 tons/ha; potential yield with project: 6–7 tons/ha; farmer adoption: 41 percent
- Assumptions on technology were for a time horizon of 5 years, with 2.8 years as the time to reach half of adoption rate.

ENABLING ENVIRONMENT: SITUATION ANALYSIS

Alignment to NDC

Of the 12 identified goals of the NDC that are potentially related to CSA, water resource management has the following strong or supportive alignments:

- Strong alignment to five NDC goals: wildfire management; conservation agriculture; livestock and aquaculture productivity; actively manage natural space; water distribution and access
- Supportive to one NDC goal: governance reform

Key Contributors to Project Success⁴⁹⁶

- Abundant national water resources
- Governmental support for integrated water management strategies
- Research community engagement in water management innovation
- Strong synergies between national gender equality policy and national water management policy

⁴⁹⁶ Partey et al., “Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana.”

Key Risks/Barriers to Success⁴⁹⁷

- Competition for resources (for example, urban areas, aquaculture)
- Erratic and extreme precipitation due to climate change
- Capital-intensive nature of water management technologies
- Poor access to farmer-focused extension and finance services to support effective water management
- Limited institutional capacity to maintain infrastructure and provide crucial services to farmers
- Traditional cultural norms and taboos
- High variability in suitable interventions across time, space, and economies of scale
- Low financial commitment by farmers for maintenance

Relevant Policies⁴⁹⁸

- Adaptation Fund, “Increased Resilience to Climate Change in Northern Ghana Through the Management of Water Resources and Diversification of Livelihoods”

Key Policy Gaps⁴⁹⁹

- Limited institutional capacity to maintain infrastructure
- Lack of finance services for farmers to support innovation
- Lack of coordination between the national government and the private sector

Key Policy Distortions

- Limited extension services to support innovation
- Capital-intensive water harvesting and irrigation investments are infeasible for most farmers
- Lack of alternative water supply regulation
- Unclear institutional mandates on irrigation development

Public Institutional Framework⁵⁰⁰

- Ministry of Food and Agriculture
- Ghana Irrigation Development Authority (GIDA)
- Irrigation Company of Upper Region (ICOUR)
- Ministry of Fisheries and Aquaculture Development
- Fisheries Commission
- Environmental Protection Agency
- Universities conducting research and training personnel at BS, MS, and PhD levels:
 - University of Ghana
 - University of Cape Coast
 - University of Natural Resources and Energy
 - Kwame Nkrumah University of Science and Technology
 - University of Development Studies
 - Agriculture Colleges

Potential NGO Collaborators⁵⁰¹

- International Water Management Institute Innovation Lab for Small Scale Irrigation

⁴⁹⁷ Marinus and Ronner, “What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica.”

⁴⁹⁸ Rhebergen et al., “Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana.”

⁴⁹⁹ Ghana Cocoa Forest REDD+ Programme, “Forest Carbon Partnership Facility (FCPF) Carbon Fund”; Bunn, Climate Smart Cocoa in Ghana.

⁵⁰⁰ Kizito et al., “Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana.”

⁵⁰¹ Kizito et al.

- CGIAR Research Program on Water, Land, and Ecosystems
- Finance cooperatives
- International Food Policy Research Institute
- Water Research Institute, Aquaculture Research, and Development Centre at Akosombo

Most Promising Supporting Digital Agriculture Technologies

- Mobile finance services and digitized farm records to support credit line establishment for investing in small scale water harvesting technology
- Smart contracting for transparent and equitable land tenure processes, enabling farmers to secure land on which to install water harvesting technology
- Mobile extension services—enabled by big data, machine learning, and mobile technology—to support best water management practices and disseminate research and development innovations
- Climate information services—enabled by weather stations, big data, machine learning, and mobile technology—to support decision making in the face of extreme weather events⁵⁰²
- Remote sensing, drones, GPS, and GIS for informing the establishment and management of water reservoirs
- IoT and remote sensing for monitoring water resources

DELIVERY - SYNTHESSES OF IMPLEMENTATION EXPERIENCE AND BEST PRACTICE

A strong foundation of related projects provides implementation experience, a knowledge base, and lessons learned. Related projects underway include:

- World Bank: Ghana Commercial Agriculture⁵⁰³
 - 2012–2020, US\$100 million
 - Additional funding of US\$50 million to support the rehabilitation and modernization of irrigation schemes and reforming irrigation institutions and management
- World Bank: Greater Accra Resilient and Integrated Development Project⁵⁰⁴
 - 2019–2025, US\$200 million
 - This project focuses on structural measures to mitigate flood impacts in the Odaw river basin
- World Bank: Sustainable Land Water Management⁵⁰⁵
 - 2010–2020, additional US\$14.7 million
 - To support protection of riparian zones and provide corridors for local biodiversity
- UNDP: Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods⁵⁰⁶
 - 2016–2020, US\$8.29 million
 - Directly benefits 60,000 people and indirectly benefits 8.5 million along the Volta River Basin

⁵⁰² The World Bank Group, “Agriculture Observatory.”

⁵⁰³ The World Bank, “Ghana - Commercial Agriculture Project” (The World Bank, May 8, 2018),

<http://documents.worldbank.org/curated/en/520451527996621206/Ghana-Commercial-Agriculture-Project>.

⁵⁰⁴ The World Bank, “Ghana - Greater Accra Resilient and Integrated Development Project” (The World Bank, May 9, 2019),

<http://documents.worldbank.org/curated/en/675901559440929710/Ghana-Greater-Accra-Resilient-and-Integrated-Development-Project>.

⁵⁰⁵ The World Bank, “Ghana: Second Additional Financing for Sustainable Land and Water Management Project,” Projects and Operations, May 20, 2016, <http://www.projects.worldbank.org/P157595?lang=en>.

⁵⁰⁶ Adaption Fund, “Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods,” Projects and Programmes, September 9, 2019, <https://www.adaptation-fund.org/project/increased-resilience-to-climate-change-in-northern-ghana-through-the-management-water-resources-and-diversification-of-livelihoods/>.

Other Relevant Completed Projects: None

FINANCING AND MAXIMIZING FINANCE FOR DEVELOPMENT

Public Financing Opportunities

- The Government of Ghana is investing in strategies to improve water resource management.

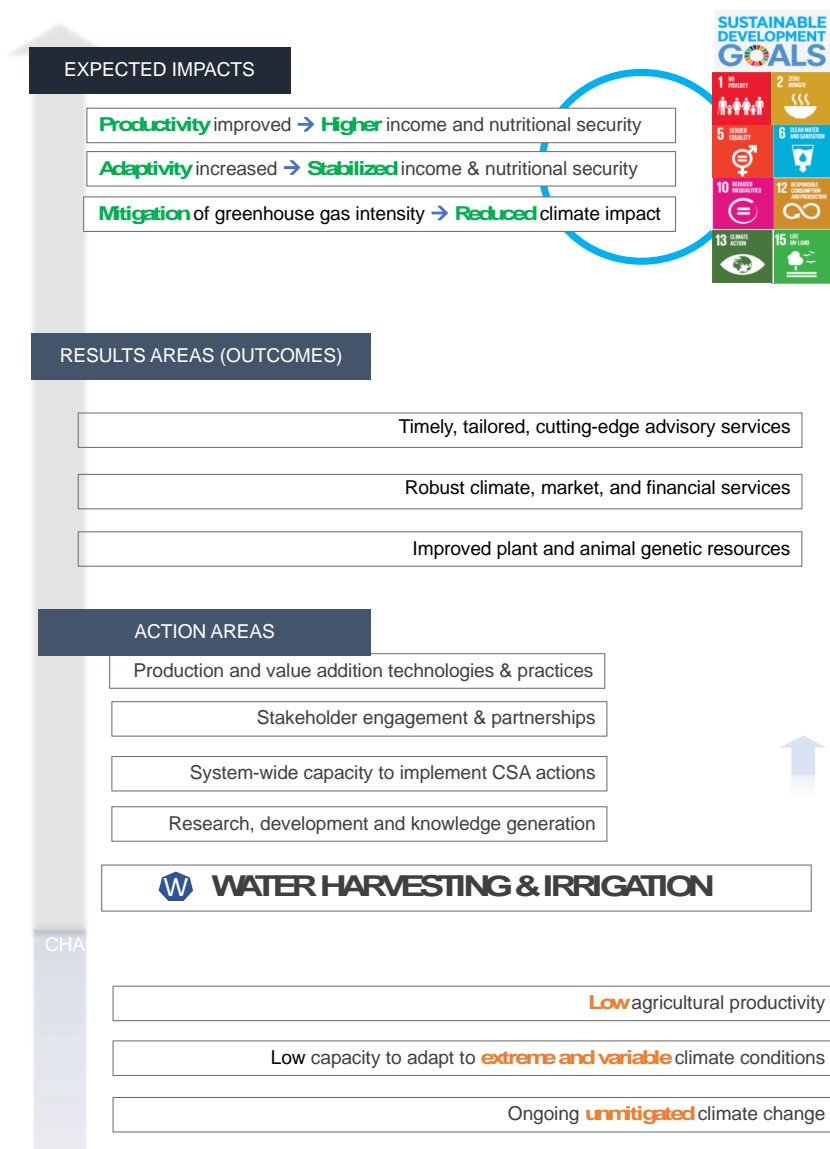
International Financing Opportunities

- Several international donors and NGOs are investing in improving water management in Ghana

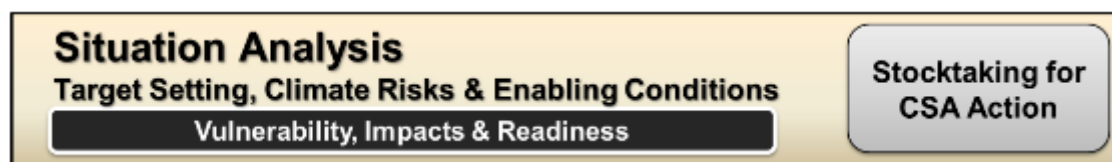
Private Financing Opportunities

- Collaboration with aquaculture and rice industry stakeholders may offer private sector resources

THEORY OF CHANGE



ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA



A supportive policy context, enabling conditions, and financing are critical components of the situation analysis for CSA investments. This section briefly highlights:

- B-1. International and Regional Commitments, Frameworks, and Plans**
- B-2. National Policies, Plans, and Strategies**
- B-3. Select CSA Projects in Ghana Ending in or Before 2019**
- B-4. Potential Financing Sources and Mechanisms for CSAIP in Ghana**

B-1. Ghana's International and Regional Commitments, Frameworks, and Plans

- **UN Framework Convention on Climate Change (UNFCCC)**
- **Nationally Determined Contributions (2016–2019) and (2020–2030):** Ghana has two goals for mitigation and adaptation. The first is to unconditionally lower GHG emission by 15 percent relative to the BAU scenerio emission of 73.95 MtCO₂ equivalent. The second is to increase resillience and decrease vulnerabilities for enhanced sustainable development. Ghana submitted its NDCs for adaption and mitigation in 2015. In 2019, Ghana declared its intention to enhance its NDC commitments in 2020.
- **Comprehensive Africa Agriculture Development Program (CAADP):** Ghana received (a) technical and financial assistance to develop concept notes and project proposals for submission to the Green Climate Fund, (b) training on the agriculture components of the NDCs, and (c) support in bolstering national planning and policy process via integration of climate change action into its national agricultural investment plans.⁵⁰⁷ Specifically, 6,700 women working in the fisheries industry were supported to improve the marketing of quality products, obtain access to international markets, and ameliorate the livelihoods of fishing communities.
- **2014 Malabo Declaration on The Transformation of Agriculture:**⁵⁰⁸ This declaration is a commitment to achieve the objectives set forth by the CAADP.
- **ECOWAS Regional Agricultural Policy of West Africa (ECOWAP):** ECOWAP + 10 has a vision of a modern and sustainable agriculture based on the effectiveness and efficiency of family farms and the promotion of agricultural enterprises through the involvement of the private sector. It monitors the implementation of the New Partnership for Africa's Development (NEPAD), especially the CAADP.⁵⁰⁹

⁵⁰⁷ AUDA-NEPAD, "Ghana," NEPAD Transforming Africa, 2019, <https://www.nepad.org/taxonomy/term/138>.

⁵⁰⁸ AUDA-NEPAD, "Tracking Progress: Ghana."

⁵⁰⁹ ECOWAS Commission, "Regional Agricultural Policy for West Africa," 2010, https://www.diplomatie.gouv.fr/IMG/pdf/01_ANG-ComCEDEAO.pdf.

- **UN Sustainable Development Goals (SDGs)** are a universal call to end poverty, protect the planet, and foster peace and prosperity by 2030.⁵¹⁰
- **Sahel and West Africa Program (SAWAP)** supported Ghana to the tune of US\$13.25 million for enhancing sustainable land and water management.
- **West Africa Agricultural Productivity Program (WAAPP):** The objective of this program is to increase productivity in West Africa’s major agricultural sectors in ways that are aligned with national and regional priorities.
- **Climate Change Fund** focuses on fostering resilience to climate change by building national, regional, and continental capacity through technical and financial assistance to African Union member states.
- **Alliance for Accelerating Excellence in Science in Africa (AESA)** supports African researchers broadly; its Centre for Cell Biology of Infectious Pathogens is based in Ghana.
- **African Science, Technology, and Innovation Indicators (ASTII)** provided in-country training in Ghana on data collection, management, analysis, and dissemination in science, technology, and innovation.
- **Rural Futures** aims to reduce rural poverty and employment challenges.
- **Africa Kaizen Initiative** uses human-oriented approaches to foster teamwork, self-reliance, creativity, and ingenuity.
- **African Forest Landscape Restoration Initiative** is a country-led effort to restore 100 million ha of deforested and degraded landscapes across Africa by 2030. Ghana has thus far committed to restoring 2 million ha.⁵¹¹

B-2. National Policies and Plans

Ghana has a long list of policies and plans that acknowledge climate change or are directly linked to adaptation or mitigation. Many other plans have direct endorsements for CSA. All of these are shown in Table B-1 which lists national policies and plans with some alignment and link to climate change, adaptation, mitigation, and CSA. In addition to Ghana’s NDC commitments, the following five policies are the most broadly supportive for the CSAIP:

- **National Climate Change Policy (NCCP)** was developed to ensure a climate-resilient and climate-compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana. Its main objectives are effective adaptation, social development, mitigation.
- **National Climate Change Adaptation Strategy (NCCAS)** defines the country’s strategic blueprint for adjusting Ghana’s economy to expected climatic stimuli and their effects for the period 2010–2020. Its primary objective is “to enhance Ghana’s current and future development by strengthening its adaptive capacity with regard to climate change impacts and building the resilience of the society and ecosystems.” The NCCAS has formulated some objectives and proposed some programs geared specifically toward minimizing vulnerability and increasing

⁵¹⁰ UN Communications Groups 2017.

⁵¹¹ AUDA-NEPAD, “Ghana.”

resilience to climate change impacts for the poor and vulnerable in addition to enhancing national capacity to adapt to climate change.

Table B-1: Comprehensive Relationships Between Ghanaian National Policies, Plans, Strategies, and Frameworks and Climate Change, Mitigation Action, Adaptation Action, and/or CSA

POLICY, STRATEGY, PLAN, OR FRAMEWORK Name and Abbreviation	DATE	CLIMATE CHANGE	ADAPTATION	MITIGATION	CSA
National Climate Change Policy - NCCP - 2013	2013				
National Climate Change Adaptation Strategy - NCCAS	2010–2020				
National Climate Smart Agriculture Food and Security Action Plan - CSA-FSAP	2016–2020				
Nationally Determined Contributions - NDC	2016–2030				
Climate Change and Green Economy Learning Strategy - CCGELS	2016				
National Climate Change Master Plan Action Programs for Implementation	2015–2020				
Forest and Wildlife Policy - FWP	2012				
National Water Policy - NWP	2007				
National Adaptation Plan Framework - NAP	2018				
Shared Growth and Development Agenda - GSGDA	2010–2017				
REDD++ Strategy	2016–2035				
Investing for Food and Jobs - IFJ	2018–2021				
National Environmental Policy - NEP	2009–2012				
National Biodiversity Action Plan and Strategy - NBSAP	2016				
Tree Crops Policy - TCP	2020				
Cocoa and Forest initiative National Implementation Plan	2018–2020				
National Energy Policy	2010				
National Community Water and Sanitation Strategy - NCWSS	2014				
Food and Agriculture Sector Development Policy - FASDEP II	2002–2012				
Medium-Term Agricultural Sector Investment Plan- METASIP	2011–2017				
Agenda for Jobs	2018–2021				
Gender and Agriculture Development Strategy - GAD II	2016				
Livestock Development Policy and Strategy	2016				
Shared Growth Development Agenda - GSGDA II	2015				
Irrigation Development Policy, Strategies & Regulatory Measures	2010				
National Seed Plan	2015				
Private Sector Development Strategy - PSDS	2010				
Growth and Poverty Reduction Strategy - GPRS II	2006–2009				
Planting for Food and Jobs Strategic Plan - PFJ	2017–2020				
Global Food Security Strategy - GFSS	2018				

- **National Climate Smart Agriculture Food and Security Action Plan - CSA-FSAP (2016–2020)** facilitates and operationalizes the National Climate Change Policy for effective integration of climate change resiliency into the development of policies and programs in the food and agriculture sector. The action plan aims to develop climate-resilient agriculture and food systems for all agroecological zones, to develop human resource capacity for climate-resilient agriculture, and to elaborate on the implementation framework and the specific CSA activities to be carried out at the respective levels of governance.
- **Climate Change and Green Economy Learning Strategy - CGELS** - was developed in 2016 to promote climate change education, awareness, and learning in Ghana. It is a capacity-building component of the Climate Change Master Plan that seeks to promote awareness creation and to contribute to national capacity for the implementation of Ghana’s Intended Nationally Determined Contribution (INDC) under the Paris Agreement.
- **National Climate Change Master Plan Action Programs for Implementation** puts in place robust measures needed to address most, if not all, of the challenges posed by climate change and climate vulnerability. It consequently guides future national development planning frameworks to ensure that Ghana has a climate resilient economy and low carbon development.

There are a number of other policies with strong or partial alignment to at least two of the four components, including:

- **Forest and Wildlife Policy - FWP**
- **National Water Policy - NWP**
- **National Adaptation Plan Framework - NAP**
- **Shared Growth and Development Agenda - GSGDA**
- **REDD++ Strategy**
- **Investing for Food and Jobs - IFJ**
- **National Community Water and Sanitation Strategy - NCWSS**
- **Food and Agriculture Sector Development Policy - FASDEP II 2007–2012 (FASDEP II)** builds on the (FASDEP I) to modernize agriculture, culminating in a structurally transformed economy as evidenced by food security, employment opportunities, and reduced poverty.

Other policies that provide partial alignment or recognition to one component, often climate change, are listed in Table B-2.

Table B-2: Policies Providing Partial Alignment to Climate Change, Mitigation, Adaptation, or CSA

National Environmental Policy - NEP	2009–2012
National Biodiversity Strategy and Action Plan, NBSAP	2016
Tree Crops Policy	2012
Cocoa and Forest Initiative National Implementation Plan	2018–2020
National Energy Policy	2010
Medium-Term Agricultural Sector Investment Plan - METASIP	2011–2017
Agenda for Jobs	2018–2021
Gender and Agriculture Development Strategy - GAD II	2016
Livestock Development Policy and Strategy	2016
Shared Growth Development Agenda - GSGDA II	2015

Irrigation Development Policy, Strategies & Regulatory Measures	2010
National Seed Plan	2015
Private Sector Development Strategy - PSDS	2010
Growth and Poverty Reduction Strategy - GPRS II	2006–2009
Planting for Food and Jobs Strategic Plan - PFJ	2017–2020
Global Food Security Strategy - GFSS	2018

B-3. Select CSA Related Projects in Ghana

Table B-3: Select Current CSA Projects in Ghana

Fund	Project	CSA Relevance	(US\$, millions)	Term
World Bank	West Africa Agricultural Transformation Program (WAATP)	Strengthens regional agricultural innovation systems to enhance adoption of climate-smart practices	277.00	2018–2022
	Ghana Commercial Agriculture Project	Increases access to inputs for climate resilience	50.00	2019–2020
	Ghana Forest Investment Program (FIP)	Reduces forest loss and degradation	19.39	2019–2023
AfDB	Ghana Cocoa Sector Institutional Support Project	Improvement of cocoa value chain through irrigation, storage, processing, and promoting local consumption	600.00	2018–2024
Department for International Development	Africa Agriculture Development Company (AgDevCo)	Provides capital and technical assistance in rural areas and contributes to farmers' resilience to climate change	190.17	2013–2023
European Union, German Government.	Market Oriented Agriculture Project	Creates an environment for agricultural investments	175.38	2017–2021
IFAD	Adaptation for Smallholder Agriculture Program (ASAP)	Enhances profitability and resilience to climate change among smallholder farmers	113.00	2012–2023
International Fund for Agricultural Development	Ghana Agricultural Sector Investment Program	Promotes and mainstreams climate change resilient approaches	77.99	2014–2021
GEF Trust Fund	Sustainable land and water management – Second additional financing (Food IAP)	Expands area under sustainable land and water management practices	12.77	2015–2020
Dutch embassy	HortiFresh Project	Enhances competitiveness of fruit and vegetable sector for inclusive economic growth	9.90	2018–2021
Adaptation Fund	Increased resilience to climate change in Northern Ghana through water resources management and diversification of livelihoods	Enhances resilience and adaptive capacity against climate risks for communities with regard to water resources	8.30	2016–2020
Mondelēz International Cocoa Life	Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II) project	Adopts sustainable environment and climate change cocoa production and conserves natural resources	1.85	2016–2020

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

UNDP, Government of Germany	NDC Support Program	Advances implementation of Paris agreement on climate change	1.70	2017– 2020
Danish International Development Agency	Climate-Smart Cocoa Systems for Ghana (CLIMCOCOA)	Assesses the role of agroforestry as a model for CSA in cocoa production	1.48	2016– 2020
Japanese government	Climate resilience and food security through sustainable agroforestry cocoa production within Ghana	Promotes sustainable biodiversity and reclaims mine-degraded lands among smallholder cocoa farmers	0.80	2019– 2020
Food and Agricultural Organization	Promotion of conservation agriculture and IPM for sustained soil fertility and productivity	Enhances sustainability of natural resource base, specifically soils	0.41	2019– 2021

There are many donors (bilaterals, multilaterals, NGOs) working in Ghana on issues related to climate change, agriculture, and water or food security. Here are a sample of projects that have recently been, or are currently being, implemented in Ghana. The agricultural CSAIP investments that are potentially relevant are shown in italics.

- **World Bank *Ghana Commercial Agriculture Project*** seeks to use public-private partnerships (PPPs) in commercial agriculture in the Accra Plains and Savannah Accelerated Development Authority (SADA) zone to increase access to land, private sector finance, and input and output markets by smallholder farms.
- **The Nationally Determined Contributions Support Program** (US\$1,695,372; 2017–2020) is sponsored by the UNDP and Government of Germany and supports Ghana in achieving the NDCs via technical and institutional capacity building.
- **African Development Bank (AfDB)** supports a transition toward CSA and food systems in West Africa.
- **Adaptation Fund (AF)** Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods.
- **Food and Agriculture Organisation (FAO)** supports the promotion of conservation agriculture and IPM for sustained soil fertility and productivity.
- **International Fund for Agricultural Development (IFAD) *Ghana Agricultural Sector Investment Program*** promotes and mainstreams climate change resilience approaches in Ghana, particularly in the northern regions. It is financed through the Adaptation for Smallholder Agriculture Programme.
- **United Nation Development Programme (UNDP) *Strengthening Resilience of Rural Women Through Dry Season Farming in Ghana.***

B-4. Potential Financing Sources and Mechanisms for CSAIP in Ghana

Table B-4: Examples of Financial Mobilization in Ghana

FOCUS AREAS	TIMING	ELIGIBILITY CRITERIA	LIMITATIONS
MULTILATERAL/ INTERNATIONAL FINANCIAL POSSIBILITIES			

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

ADAPTATION FUND			
<p>The nine diverse sectors:</p> <ul style="list-style-type: none"> • Agriculture • Coastal Zone Management • Disaster Risk Reduction • Food Security • Forests • Multisector Projects • Rural Development • Urban Development • Water Management 	<ul style="list-style-type: none"> • A one-step approval process • A two-step approval process 	<ul style="list-style-type: none"> • Developing countries party to the Kyoto Protocol • Developing countries that are particularly vulnerable to the adverse effects of climate change • Proposals go directly to the Adaptation Fund Board Secretariat (AFBSEC) 	<ul style="list-style-type: none"> • Small-size projects/programs: Up to UD\$1 million • Regular projects/programs: more the UD\$1 million
GLOBAL ENVIRONMENT FACILITY			
<ul style="list-style-type: none"> ○ Biodiversity ○ Climate Change Mitigation ○ Land Degradation ○ International Waters ○ Chemicals & Waste (GEF 7) ○ Sustainable Cities ○ Sustainable Forest Management 	<ul style="list-style-type: none"> • Project Identification Forms (PIF) are submitted on a rolling basis 	<ul style="list-style-type: none"> • Ratified by and conforms to the eligibility criteria decided by the Conference of the Parties of each convention • Eligible to receive World Bank (IBRD and/or IDA) financing or UNDP technical assistance • National priority 	<ul style="list-style-type: none"> • Full-sized Project (FSP): above UD\$2 million • Medium-sized Project (MSP): less than UD\$2 million • Enabling Activity (EA): Above US\$1 million • Program Project Preparation Grant (PPG)
GREEN CLIMATE FUND			
<ul style="list-style-type: none"> • 50:50 balance between mitigation and adaptation • Specific areas: <ul style="list-style-type: none"> ○ REDD+ ○ Forestry ○ Resilience Agriculture ○ Renewable Energy ○ Waste to Energy 	<ul style="list-style-type: none"> • On call • Readiness: October • 2 months before board meetings 	<ul style="list-style-type: none"> • Signed/ratified the Paris Agreement • Developing Country/ Least Developing Country • Set up a National Designated Authority (NDA) • Country Program • Implementing Entity/Delivery Partner • Developed proposal using GCF template (readiness or fully developed) 	<ul style="list-style-type: none"> • Readiness: US\$1 million per year per country • Simplified Approval Process (SAP) up to US\$10 million • Project Preparation Facility up UD\$1.5 million • Projects: <ul style="list-style-type: none"> • Micro - above US\$10 million • Small - above US\$20 million • Medium - above US\$50 million • Large- above US\$250 million
ADAPTATION OF AFRICAN AGRICULTURE			
<p>Three pillars of enhancing food security:</p>	<ul style="list-style-type: none"> • Makes capacity-building grants 	<ul style="list-style-type: none"> • Advocacy to secure financing for projects of agricultural 	<ul style="list-style-type: none"> • Strengthening the financing capacities of

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

<ul style="list-style-type: none"> ○ sustainably increasing production ○ enhancing resilience to climate change ○ mitigating greenhouse gas emissions 	<p>available on a competitive basis to boundary organizations and regional collaborative on an annual basis</p>	<p>adaptation in African countries.</p> <ul style="list-style-type: none"> • Promotion of innovative solutions to respond to Africa’s top priority needs 	<p>African farmers via micro-credit generalization to smallholder farmers, meso-credit development to medium-sized farms, and mobile banking solutions deployment</p>
CLIMATE RESILIENCE FUND⁵¹²			
<ul style="list-style-type: none"> • Climate change adaptation and resilience • Sustainability • Conservation • Governance 	<ul style="list-style-type: none"> • Funding programs with annual recurring deadlines 	<ul style="list-style-type: none"> • Implement adaptation projects in the community 	<ul style="list-style-type: none"> • Cost-sharing a percentage of the total project costs • A minimum of US\$5,000 and a maximum of US\$1,000,000 depending on organization’s annual budget
SPECIAL CLIMATE CHANGE FUND			
<ul style="list-style-type: none"> • Adaptation • Technology transfer and capacity building • Energy • Transport • Industry • Agriculture • Forestry and waste management • Economic diversification 	<ul style="list-style-type: none"> • Separate financing windows for <ul style="list-style-type: none"> ○ Technology transfer ○ Mitigation ○ Economic diversification 	<ul style="list-style-type: none"> • Ratified and conforms Convention • Vulnerable developing countries 	<ul style="list-style-type: none"> • Yearly • GEF receives about US\$250 million in requests for adaptation support
WORLD BANK- CLIMATE CHANGE ACTION PLAN			
<ul style="list-style-type: none"> • To promote sustainable and more inclusive economic growth, create jobs, deliver more decentralized public services • Oil and gas • Collaboration outside of the national government • Knowledge and expertise 	<ul style="list-style-type: none"> • On call 	<ul style="list-style-type: none"> • Country Engagement 	<ul style="list-style-type: none"> • IBRD/IDA • IFC
UNITED NATION DEVELOPMENT PROGRAMME			
<ul style="list-style-type: none"> • Food security and nutrition 	<ul style="list-style-type: none"> • 5 years (2018-2022) 	<ul style="list-style-type: none"> • Country signed and ratified UN protocol 	<ul style="list-style-type: none"> • Funds are distributed by calendar year and in accordance with the

⁵¹² “Climate Resilience Funding Guide,” Climate Resilience Fund, accessed October 8, 2019, <https://www.climate-resiliencefund.org/%20http://www.mfpp.org/wp-content/uploads/2017/07/Climate-Resilience-Funding-Guide.pdf>.

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

<ul style="list-style-type: none"> • Sustainable environment, energy, and human settlements • Human development and productive capacity for improved social services • Transparent and accountable governance 			<p>United Nations Development Program</p> <ul style="list-style-type: none"> • Direct cash transfer or reimbursement
INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT			
<ul style="list-style-type: none"> • Help rural people grow and earn more • Promotes gender equality and inclusiveness, builds the capacity of local organizations and communities, and strengthens resilience to climate change • Value for money and a commitment to transparency, accountability and results 	3 years	<ul style="list-style-type: none"> • Replenishment consultation 	<ul style="list-style-type: none"> • Concessional partner loans (CPLs) and under the Sovereign Borrowing Framework (SBF) • A borrowing limit of 50% of replenishment contributions (excluding the grant element of CPLs) was agreed
FOOD AND AGRICULTURE ORGANIZATION			
<ul style="list-style-type: none"> • Food and nutrition Security • Environment sustainable natural resources management • Rural development and resilient livelihoods 	<ul style="list-style-type: none"> • 5 years (2018-2022) 	<ul style="list-style-type: none"> • Technical Cooperation Program (TCP) • Special attention given to: <ul style="list-style-type: none"> ○ Low-Income Food-Deficit Countries (LIFDCs) ○ Least Developed Countries (LDCs) ○ Landlocked Developing Countries (LLDCs) and/or ○ Small Island Developing States (SIDS) 	<ul style="list-style-type: none"> • Middle-income economies can receive TCP funding on a grant basis • High-income economies can access TCP funding on a cost-recovery basis • TCP emergency assistance on a full-grant basis
ENERGY AND CLIMATE FUND⁵¹³			
<ul style="list-style-type: none"> • Provides finance for: <ul style="list-style-type: none"> ○ Energy efficiency ○ Climate and environment action ○ Carbon-free emissions ○ Research and development for energy 	<ul style="list-style-type: none"> • Funding was incepted in 2010 but is set to continue after 2022 until when nuclear power is no longer in use • Funding is agreed upon annually 	<ul style="list-style-type: none"> • Trade and industry sector 	<ul style="list-style-type: none"> • Auctioning of greenhouse gas emissions certificates

⁵¹³ IEA, "Policies and Measures," accessed October 8, 2019, <https://www.iea.org/policiesandmeasures/>.

AFRICAN DEVELOPMENT BANK (AfDB)⁵¹⁴			
<ul style="list-style-type: none"> • Promote economic development and reduce poverty through: <ul style="list-style-type: none"> ○ Concessional loans and grants ○ Guarantees ○ Technical assistance ○ Capacity building ○ Policy advice 	<ul style="list-style-type: none"> • Funds replenished every 3 years by donor countries 	<ul style="list-style-type: none"> • Fragile states • Low income Regional Member Countries (RMCs) • Countries increasing in their economic capacity 	<ul style="list-style-type: none"> • Loans and grants given on criteria of a debt distress risk classification
ALLIANCE FOR GREEN REVOLUTION AFRICA (AGRA)⁵¹⁵			
<ul style="list-style-type: none"> • Investment in agricultural projects through grants in areas of: <ul style="list-style-type: none"> ○ Seed supply ○ Fertilizer ○ Value chains ○ Farmer awareness ○ Markets ○ Finance ○ Capacity building 	<ul style="list-style-type: none"> • Operational for the past 10 years • Call for proposals 	<ul style="list-style-type: none"> • Government and its ministries • NGOs • Educational institutions • Financial institutions • Agro-dealers • Private sector • Research institutions • Farmer organizations 	<ul style="list-style-type: none"> • Sometimes, organizations are identified based on their suitability for attaining AGRA’s goal
BI-LATERAL AGENCIES			
GERMAN MINISTRY FOR ECONOMIC COOPERATION AND DEVELOPMENT (BMZ)⁵¹⁶			
<ul style="list-style-type: none"> • Climate change and development • Women and technology • Child labor • Poverty alleviation 	<ul style="list-style-type: none"> • Each year BMZ issues grants to organizations 	<ul style="list-style-type: none"> • Civil societies in Germany and developing countries 	<ul style="list-style-type: none"> • Funding is given for projects whose aims can be achieved within the intended budget • Projects should be at most four years • Funding covers at most 75% of the total eligible project expenditure • Compulsory evaluation
DANIDA⁵¹⁷			
<ul style="list-style-type: none"> • Support long-term poverty alleviation and improved standards of living through financing projects on: 	<ul style="list-style-type: none"> • Annual calls for proposals are made through a competitive process 	<ul style="list-style-type: none"> • Developing countries undertaking projects in the thematic areas of agriculture, natural resources, environment, and energy 	<ul style="list-style-type: none"> • TPs report has to assess whether assistance from the Danish government is in line

⁵¹⁴ African Development Bank, “About the ADF,” Text, April 2, 2019, <https://www.afdb.org/en/about-us/corporate-information/african-development-fund-adf/about-the-adf>.

⁵¹⁵ AGRA, “Ghana,” Where We Work, 2017, <https://agra.org/where-we-work/ghana-4/>.

⁵¹⁶ BMZ, “The German Federal Ministry for Economic Cooperation and Development,” Federal Ministry for Economic Cooperation and Development, accessed October 8, 2019, https://www.bmz.de/en/service/error/404.php?redirect=/en;/bengo_Foerderrichtlinien-Private-Traeger-Englisch.pdf;%20https://terravivagrants.org/grant-makers/cross-cutting/german-federal-ministry-of-economic-cooperation-and-development/&.

⁵¹⁷ Danida Research Portal, “Climate Smart Cocoa Systems for Ghana (CLIMCOCOA).”

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

<ul style="list-style-type: none"> ○ Sustainable management of natural resources ○ Sustainable food production ○ Access to energy and water ○ Integrated approach to climate change 		<ul style="list-style-type: none"> ● Institutions of higher learning, mainly universities ● Civil servants and civil society organizations ● Innovative NGO in the support for HIV/AIDs 	<p>with Ghanaian poverty policies and strategies</p> <ul style="list-style-type: none"> ● Long term impacts are restricted to achievements from collaboration between Ghana’s individual efforts and that of other development partners
CANADIAN INTERNATIONAL DEVELOPMENT AGENCY (CIDA)⁵¹⁸			
<ul style="list-style-type: none"> ● Health ● Education ● Livelihood ● Democracy ● Youth ● Climate innovation 	<ul style="list-style-type: none"> ● Established in 1968 as an agency for foreign aid programs; merged in 2013 with Canadian foreign affairs department 	<ul style="list-style-type: none"> ● NGOs ● Governments ● Civil society organizations 	<ul style="list-style-type: none"> ● Country must be listed in the 20% to fulfil eligibility criteria
NORWEGIAN INVESTMENT FUND FOR DEVELOPING COUNTRIES (NORFUND)⁵¹⁹			
<ul style="list-style-type: none"> ● Investment in diverse sectors of the economy with opportunities for growth, profitability, and local development, including: <ul style="list-style-type: none"> ○ Clean energy ○ Financial institutions ○ Green infrastructure ○ Disaster management ● It offers equity and loans 	<ul style="list-style-type: none"> ● Norfund specifies amount to disburse over a certain period through an agreement 	<ul style="list-style-type: none"> ● Any country with a GDP under USD 5295 per capita 	<ul style="list-style-type: none"> ● Requires shareholders rights and nomination of one board member of the investee ● Follows Organization for Economic Co-operation and Development (OECD) guidelines on tax related issues
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)⁵²⁰			
<ul style="list-style-type: none"> ● Education ● Health ● Disaster management ● Governance ● Peace-building ● Social security ● Gender development ● Environmental management 	<ul style="list-style-type: none"> ● Interest rates and repayment periods of loans follow the OECD guideline 	<ul style="list-style-type: none"> ● Governments which need to work directly with NGOs 	<ul style="list-style-type: none"> ● A Japanese firm/company has to be the prime contractor or have a joint venture with a local company
ITALIAN GOVERNMENT GHANA PRIVATE SECTOR DEVELOPMENT FUND⁵²¹			

⁵¹⁸ Canadian International Development Agency, “About CIDA,” n.d., 2.

⁵¹⁹ Crossroads Global Hand, “Global Hand: Home,” accessed October 8, 2019, <https://www.globalhand.org/en/organisations/24631>; <https://www.norfund.no/how-we-work/investment/>.

⁵²⁰ fundsforNGOs, “Japan International Cooperation Agency (JICA),” October 11, 2008, <https://www.fundsforngos.org/bilateral-funds-for-ngos/japan-international-cooperation-agency-jica/>.

⁵²¹ “Italian Government Ghana Private Sector Investment Fund,” n.d., https://ambaccra.esteri.it/resource/2012/01/54373_f_amb61Guidelines1.doc.

ANNEX B: SITUATION ANALYSIS: POLICY AND PROGRAMMATIC CONTEXT FOR CSAIP IN GHANA

<ul style="list-style-type: none"> • Developing the private sector through: <ul style="list-style-type: none"> ○ Grants ○ Guarantees ○ Concessional Loans ○ Private Equity ○ Commercial Loans 	<ul style="list-style-type: none"> • Initial fund was disbursed in 2003 to promote development in private sector • Since 2007 the financial support has been continuous in two components (loan and grant) 	<ul style="list-style-type: none"> • Small and Medium Enterprises (SMEs) • 100% private ownership of enterprise • Startup companies • Activities should not be harmful to the environment or have any links to the military 	<ul style="list-style-type: none"> • Supply contracts for SME should not be <€25,000 and not > €550,000 • Commercial banks are intermediaries in lending credit to SMEs • Repayment of loans in not less than 5 years and not more than 8 years
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT⁵²²			
<ul style="list-style-type: none"> • Agriculture and Food Security • Democracy, human rights, and governance • Economic growth and trade • Education • Global health • Water 	<ul style="list-style-type: none"> • 10 years (2012–2022) 	<ul style="list-style-type: none"> • Bilateral agreements 	<ul style="list-style-type: none"> • Program evaluation and performance of a series of reports
GOVERNMENT OF GHANA			
<ul style="list-style-type: none"> • Sector plans 	<ul style="list-style-type: none"> • Annual budget 	<ul style="list-style-type: none"> • Government institution 	<ul style="list-style-type: none"> • Budget ceiling

⁵²² United States Department of Agriculture, “Ghana Exporter Guide,” Gain Report, 2012, <http://goo.gl/lmrBSz>.

ANNEX C: PRIORITIZING INTERVENTIONS: THE PROCESS FROM LONG-LISTS TO FINALISTS



This section summarizes the process used in prioritizing investments, with sections on:

- C-1. Producing a Long List of Investments
- C-2. Producing a Short List of Investments
- C-3. CSA Investment Practices, Location, Risks, and Institutions
- C-4. Participants at Prioritizing Workshop

C-1. Producing a Long List of Investments

Key strategic national documents (plan, strategy, policy) were reviewed by Ghanaian experts to develop the long list of CSA investments. A team of national experts was constituted to lead the process for the development of the CSAIP for Ghana. The CSAIP team, with representatives drawn from key stakeholders in the agriculture sector, such as the National Science-Policy Dialogue Platform in Ghana, Environmental Protection Agency (EPA), NGO/CSO, MESTI, Ministry of Finance (MoF), and academia, held a five-day stakeholder meeting from July 25 to 31, 2019 to take stock of CSA-related policies and activities in the country.

Many Ghanaian national policy documents were reviewed to identify CSA priority projects. Documents included the National Investment Plan for Agriculture (NAIP) and NDCs in addition to other projects and documents (for the full list, see Annex B). A draft document prepared for the World Bank Ghana Office called 'Development of Climate-Smart Agriculture (CSA) Investment Plan (CSAIP) For Ghana: Policy and Strategic Documents Review' was prepared by 13 experts from government institutions and research organizations prior to the workshop.

The prioritization process started with an inception workshop held at the World Bank country office in Accra on August 8–9 after the initial situational analysis. The CSA practices identified by the experts from the government institutions and research organizations in Ghana were presented to the audience in Accra to kickstart their discussions. Participants, grouped according to subject matter expertise (for example, crops-commercial, crops-food, livestock, forests), were asked to identify relevant CSA investments that apply to their area of work. Next, participants were regrouped based on AEZs and tasked to identify CSA practices relevant for specific AEZs. Each of the proposed CSA practices for different AEZs and crops were measured against their relevance to the national policy context, government priorities, and potential climate risks. The final step for this phase involved applying an evaluation criteria (low, medium and high) to score the CSA practices, based on CSA smartness (adaptation, mitigation and productivity), investment objectives (for example, growth potential in new sectors), and the potential of investments to boost the agricultural sector (value addition, infrastructure development, and so on).

CIAT provided technical support for the development of the long list through a multi-stakeholder

platform approach led by the MoFA and the World Bank Ghana country office. Key stakeholders included government ministries, institutions, research organizations, farmer groups, international development organizations. The long list of investments identified were grouped using AEZs, namely, northern savannah, transition, forest (deciduous and two types of evergreen), and coastal savannah (see Figure C-1).

Figure C-1: Ghana’s Agroeco Zones Used at the Prioritizing Workshop⁵²³



Criteria for investments were based on input from the CIAT team and in-country experts. Workshop participants then assessed the investments considering the following:

- **On-farm value:** economic, nutritional, and food security
- **CSA smartness:** productivity; adaptation/resilience; mitigation
- **Investment objective:** growth in a new sector; resilience in a crop/sector that is already important
- **Boosting agriculture:** agriculture value diversification; infrastructure and connectivity
- **Climate risks, climate mitigation, and productivity:** addresses key climate risks; increases agricultural productivity; provides adaptation and builds resilience to climate risks; reduces greenhouse gas emissions (either absolute emissions or emissions intensity)
- **Finance and private sector engagement:** improves access and affordability of finance for CSA; improves competitiveness of the agriculture sector through infrastructure, incentives, and other means; provides private sector investment and business opportunities (including PPPs); long-term sustainability of investment and adoption of interventions

⁵²³ FAO 2005 (modified), RESPTA 2008; The agroecological zones in Ghana

ANNEX C: PRIORITIZING INTERVENTIONS: THE PROCESS FROM LONG-LISTS TO FINALISTS

- **Policies and institutions:** aligns with national policies (for CSA); improves institutional capacities (economic, financial, natural resource management, and local government); engages and strengthens farmer networks/organizations; improves extension (public and/or private); improves research and development to support CSA
- **Social benefits and safety nets:** provides job creation opportunities; enhances gender equity and engages the youth; protects the poor and vulnerable through social safety nets; improves access to clean water and sanitation

Table C-1: Producing a Long List of Investments

Long List of Potential CSA Investments	CSA Investment Prioritization Criteria				Total
	Climate Risks, Climate Mitigation, and Productivity	Finance and Private Sector Engagement	Policies and Institutions	Social Benefits and Safety Nets	
TRANSITION ZONE					
Integrated cashew value chain development	20	20	18	19	77
Cereal productivity improvement	15	20	20	17	72
Poultry Productivity Improvement	18	20	19	16	73
Improved planting materials	18	20	20	12	70
Postharvest management	17	17	18	16	68
Small Ruminant Production	16	14	17	17	64
COASTAL SAVANNAH					
Cereal productivity improvement	14	16	16	14	60
Postharvest cereals management	15	17	16	16	64
Poultry Productivity Improvement	14	17	16	17	64
Enhanced Cattle Productivity	14	16	16	12	58
Aquaculture Development	14	16	16	17	63
FOREST					
Postharvest management of cereals	15	18	18	13	64
Improved planting materials	16	17	18	12	63
improved planting materials	16	17	18	12	63
Cereal productivity improvement	15	15	19	12	61
Investment in value addition of tubers	15	16	16	14	61
Poultry Productivity Improvement	15	16	16	13	60
Swine Production	12	16	16	12	56
NORTHERN SAVANNAH					
Integrated cashew value chain development	17	17	16	14	64
Cereal productivity improvement	17	14	13	13	57
Postharvest cereals management	16	16	14	10	56
Poultry Productivity Improvement	13	16	18	13	60

C-2. Producing a Short List of Priority Investments

The long list of potential investments was reduced by stakeholders through a process applying multiple filters and indicators to analyze investments. The higher-ranked investments were put through these

filters, and then discussed again to put the investments through a new round of prioritization. Discussions were focused on assessing a number of factors, including:

- **Time horizon:** both the time scale for implementation and for realizing results; priority given to investments for crops/sectors where climate impacts were already evident and action needed to begin now, even if results might come later (for example, new tree crop varieties)
- **Priority crops in each region:** recognizing that climate impacts and regional priorities vary, especially for food security
- **Type of different CSA interventions:** consideration was given to links between investment and each of the three CSA pillars (production, adaptation, mitigation)
- **Population and socioeconomic impact:** the impact of each investment on the economy as a whole and on smallholder farmers
- **Food security:** considering both Ghana’s current food-producing regions and which crops/areas will face severe food security issues due to climate change
- **Economic impact and well-being:** who will be affected by climate change; how will investments prevent losses, to what sector, and with what ripple/multiplier effects to the economy
- **Regional priorities:** ensure that different regions are represented

The identified short list of CSA investments from the first inception workshop was discussed with several stakeholders for further input. Based on inputs compiled from these discussions, a second workshop was organized on September 3, 2019, with subject matter and AEZ experts. Its purpose was to validate the initial short list of CSA investments. One regional workshop consultation will be included to incorporate regional perspective in the agreed CSA short list of investment packages. The priorities for each of the zones are shown in Table C-2.

Table C-2: Final Participant Project Recommendations

CSA Investment	CSA Investment Package	Commodities	AEZ
Cereal-legume integration	Improved crop varieties (heat and drought tolerant, disease resistant); soil fertility management	Maize, sorghum legume	Coastal savannah, savannah
Climate-smart cocoa production	Agroforestry to improve suitability of cocoa growing areas; improved planting materials (heat- and drought-tolerant, disease-resistant); replacement of old trees; cocoa spraying; soil fertility management	Cocoa	Forest, transitional
Poultry feed improvement and genetic resource enhancement	Poultry feed improvement and genetic resource enhancement	Chicken, guinea fowl	Transitional, savannah
Climate resilient ruminant production and genetic resource conservation	Water harvesting technologies; irrigation for growing feed; establishing grazing and watering pathway for livestock; establishing fodder banks; improved breed varieties (heat-stress and disease resistant)	Cattle, sheep and goats	Transitional, savannah, forest
Sustainable fisheries and aquaculture	Heat- and disease-resistant fish varieties; improved feed for aquaculture; culture based fisheries	Tilapia, catfish, shrimp, clams, and mussels	Coastal savannah, forest

CSA Investment	CSA Investment Package	Commodities	AEZ
Diversified tree crop production	Agroforestry, improved tree crop varieties (heat- and drought-tolerant, disease-resistant); soil fertility management	Cashew, oil palm	Forest, transitional
Roots and tubers-livestock integration	Improved crop varieties and livestock species (heat- and drought-tolerant, disease-resistant); soil fertility management	Roots and tubers (cassava and yam)	Coastal savannah, transitional, savannah
Knowledge system and advisory services	Evidence-based research, extension agents, ICT advisory services	All crop commodities, fish, and livestock	All AEZ
Water harvesting technologies and irrigation management	Irrigation facilities and water management for rice	All crop commodities, especially for rice	All AEZ

Participants undertook a ranking process and agreed on the first eight investments at the workshop. Expert knowledge and country discussion led to the addition of a final (ninth) investment in water harvesting technologies and irrigation management. The latter was considered critical due to climate risks posed by erratic rainfall patterns, dependence on natural rain, and limited harvesting technologies used by farmers in Ghana.

C-3. Investment CSA Practices, Location, Risks, and Institutions

Participants then considered each of the CSA investments to inform the development of the concept notes. They discussed leading institutions, the CSA practices that were needed, the necessary scope of the project, its proposed geographic reach, risks, and other relevant information. They also involved key actors to aid in fostering the adoption of CSA practices. For each actor, requisite changes in knowledge, skills, practices, and related activities were identified. This information was used to make more detailed project proposals and to articulate outcomes, activities, and other components of each investment or program. Workshop input, supplemented and developed where appropriate, was used to develop the project concepts found in Annex A. In addition, alignment of these investments with those proposed by the NDC partnership was considered (see Chapter 4 and each proposed investment in Annex A).

C-4. Participants at Prioritizing Workshop

The CSAIP development meeting for Ghana was on September 3, 2019. This meeting engaged multiple stakeholders, including of one or more representatives from the following organizations:

- Animal Production Directorate (APD)
- Civil Society Organization (CSO)
- Council for Scientific and Industrial Research (CSIR)
- Directorate of Crop Services (DCS)
- Environmental Protection Agency (EPA)
- Food and Agriculture Organization (FAO)
- Ghana Cocoa Board (COCOBOD)
- Government of Ghana (GoG)
- International Center for Tropical Agriculture (CIAT)
- Ministry of Environment, Science, Technology and Innovation (MESTI)

ANNEX C: PRIORITIZING INTERVENTIONS: THE PROCESS FROM LONG-LISTS TO FINALISTS

- Ministry of Finance (MoF)
- Ministry of Food and Agriculture (MoFA)
- Nongovernmental Organizations (NGOs)
- Savannah Agriculture Research Institute (SARI)
- University of Ghana (UG)
- Veterinary Services Directorate (VSD)
- World Bank (WB)

ANNEX D: METHODOLOGY FOR INTEGRATING CLIMATE CHANGE, CROP RESPONSE, AND ECONOMIC IMPACT

D-1. Climate Change Vulnerability and Economic Impacts in the Agricultural Sector

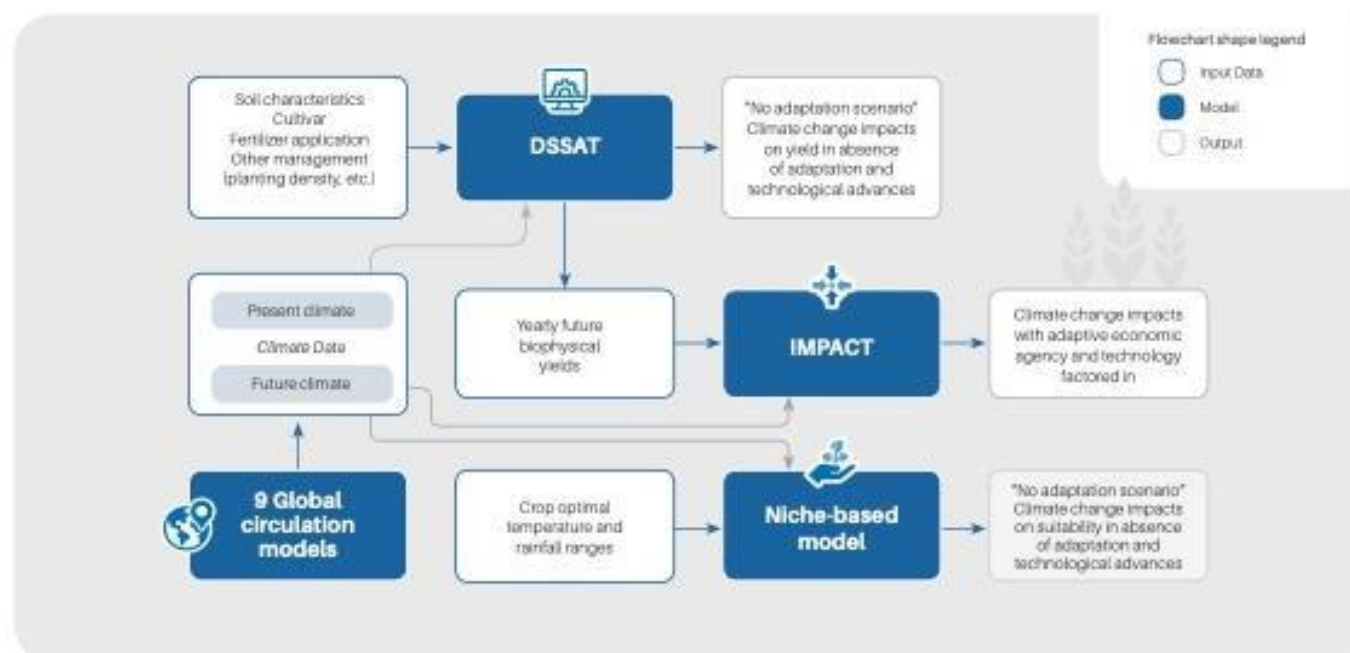
This modeling presents highly summarized, country-specific results distilled from a region-wide analysis of the potential impacts of climate change on the future yields, suitability, and economic performance of key crops. Yields were modeled using the Decision Support System for Agrotechnology Transfer (DSSAT v4.5). Specific, regionally relevant varieties were selected for each of these crops and their genetic coefficients were incorporated into the DSSAT modeling process. It is important to keep in mind that the impacts of climate change on yield and suitability are modeled without consideration of changes in management and technology (that is, these factors were held constant at current levels). DSSAT and niche-based results thus present a ‘no adaptation scenario’ which does not explicitly incorporate ongoing investments in yield-enhancing technologies or the adaptive agency of farmers who might switch to alternative land uses in response to economic incentives.

An additional economic impact assessment that explicitly incorporates changes in management and technology is also included. This economic assessment was conducted using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT).⁵²⁴ DSSAT, EcoCrop, and IMPACT require baseline (that is present) and future climate data as inputs. The baseline climate was drawn from the Watch Forcing Dataset,⁵²⁵ while the future climate is averaged from the output of nine global circulation models. A more detailed description of these modeling components is provided in the sections below. A visual schema of the overall modeling workflow is presented in Figure D-1.

⁵²⁴ For details, see Robinson et al. 2015a, b.

⁵²⁵ For details, see Weedon et al. 2011.

Figure D-1: Policy Brief Modeling Workflow



D-2. Present Climate Data and Future Climate Modeling

Historical weather conditions were reconstructed in growing areas across Ghana from 1971 to 2000 using the Watch Forcing Dataset (WFD). WFD is a global dataset of daily weather data derived via extensive calibration and bias correction of the European Center for Medium Range Weather Forecasts 40+ year Reanalysis (ERA-40).

For the future period from 2020 to 2049, daily general circulation model (GCM) output was used from nine models in the Climate Model Inter-Comparison Project 5 archive.⁵²⁶ All raw climate model output was downscaled to a 0.5° (about 50 km at the equator) resolution and bias-corrected with the historical WFD dataset. The nine selected GCMs (Table D-1) include one version per climate modeling institution and were selected as having the best performance for the region.⁵²⁷

⁵²⁶ CMIP5 2014. Coupled Model Inter-comparison Project Phase 5. [online] Available from <http://pcmdi9.llnl.gov/esgf-web-fe/http://faostat.fao.org/> [Accessed in April 2015].

⁵²⁷ For details on the assessment of GCM performance see Watterson, Bathols, and Heady 2014.

Table D-1. List of GCMs Used in the Modeling Simulations

GCM name	Institute	Country
BCC-CSM1	Beijing Climate Center, China Meteorological Administration	China
BNU_ESM	Beijing Normal University	China
CCCMA_CANESM2	Canadian Centre for Climate Modelling and Analysis	Canada
GFLD_ESM2G	NOAA Geophysical Fluid Dynamics Laboratory	United States
INM-CM4	Russian Institute for Numerical Mathematics	Russia
IPSL-CM5A-LR	Institut Pierre Simon Laplace	France
MIROC-MIROC5	University of Tokyo, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan
MPI-ESM-MR	Max Planck Institute for Meteorology	Germany
NCC-NORESM1-M	Norwegian Climate Centre	Norway

For the 30-year periods in the historical (WFD) and future models (GCMs), daily maximum and minimum temperatures, solar radiation, and precipitation were extracted for use in DSSAT. For EcoCrop, daily maximum and minimum temperatures and precipitation were aggregated to the monthly timescale for use in the analysis. In DSSAT, atmospheric CO₂ concentrations were fixed at 380 ppm for both the historical and future periods to disentangle the projected impacts of changes in climate variables from the more uncertain impacts of changes in CO₂.

Projected changes are considered by 3-month seasons for four relevant agricultural climate variables: precipitation, daily maximum and minimum temperatures, and solar radiation. These changes represent averages across the nine GCMs for the future period relative to the baseline climate data in the historical period.

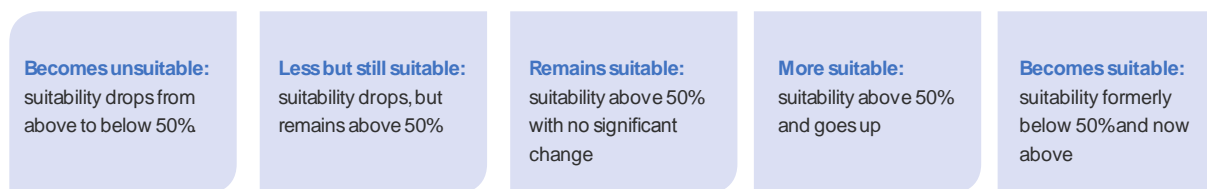
NICHE-BASED MODELING OF CLIMATE CHANGE IMPACTS ON SUITABILITY

Niche-based modeling was used to evaluate changes in suitable area of key crops. Most niche-based modeling was conducted using EcoCrop, a prediction model based on the FAO EcoCrop database.⁵²⁸ The EcoCrop model was originally developed by CIAT with support from Bioversity International and the International Potato Centre (CIP). Its basic model uses optimal ranges of temperature and precipitation (based on the literature and expert advice) as inputs to determine the main environmental niche of a crop. The precipitation and temperature at each pixel is compared with the optimal range of the crop. If the pixel is within the optimal range, the suitability is 100 percent. If not, then the conditions are compared with the minimum and maximum absolute temperature and precipitation at which the crop can grow, creating a linear decrease in the suitability index which is then expressed as a percentage. Like DSSAT, EcoCrop was run yearly for an historical period and a future period at a 0.5° spatial resolution in current and potential cultivation areas, excluding currently forested regions. A given pixel is said to be 'suitable' for a given crop if its suitability value for that crop is greater than a threshold of 50 percent.⁵²⁹ Five categories were defined to quantify changes in suitable area between current and future suitability (Figure D-2):

⁵²⁸ FAO, "EcoCrop," 2007, <http://ecocrop.fao.org/ecocrop/srv/en/home>.

⁵²⁹ This is done to ease interpretation and improve the usefulness of EcoCrop predictions. For similar approaches see Ramirez-Villegas and Thornton 2015; CGIAR 2015.

Figure D-2: Categories Quantifying Changes in Suitability



DSSAT MODELING OF CLIMATE CHANGE IMPACTS ON YIELD

DSSAT is a process-based crop model that simulates crop development, water/nutrient balances, and final yields at the field scale. DSSAT simulations require daily weather data, detailed information on soils, cultivars, planting dates and rules, applications of fertilizers and irrigation, and other agronomic information such as seeding density and row spacing. In this study, special care was taken to assign elevation- and daylight-adapted cultivars to pixels in a manner that reflects local variation across geography. DSSAT was run using a grid-based modeling framework at a 0.5° spatial resolution in current and potential cultivation areas, excluding currently forested regions.

To calculate climate impact on yields, the DSSAT models were run for a historical baseline period (1971–2000) and a future period (2021–2049). Due to interannual and decadal climate variability, a 30-year period is the standard unit to control for climate variability in each simulated period. Separate sets of DSSAT simulations were run for irrigated and rainfed production. Finally, a yield shock value was calculated for each, based on the relative difference in yields between the baseline and future periods

SIMULATION PROCESSING AND AGGREGATION

Yields and suitability values were estimated yearly for each of the 30-year periods in the historical and future analyses and for each GCM in the future period. This resulted in 300 simulations for each pixel and crop (and irrigated/rainfed combination with DSSAT), resulting in millions of simulations in total (the exact number depends on how extensively the crop is grown). Mean yield and suitability were then calculated across the baseline and future 30-year periods. Modeling results are presented at both the pixel level (each pixel roughly representing a 0.5° by 0.5° square of the Earth’s surface) and at the country level.

ECONOMIC IMPACT MODELING

Agricultural yields and production are not functions of climate and biophysical parameters alone, but also of economic incentives. Based on the biophysical DSSAT and EcoCrop analysis, it appears likely that the impacts of climate change on key commodity/food security crops will be heterogeneous. That is, impacts may drastically reduce yields and suitability across broad swaths of territory, but may also create pockets of increased yields and suitability. With regard to international trade, this amounts to a global rebalancing of comparative advantages in agriculture. The impacts of climate change anticipated by DSSAT and niche-based modeling do not account for this shifting landscape of economic incentives, nor for the individual farmer’s prerogative to take action in response to these changing incentives by adopting improved varieties and/or management practices, or by switching to other crops altogether. A natural question to ask, then, is what happens under climate change when the reality of economic agency is factored in? To what extent might the incentives created by international trade offset or exacerbate the (heterogeneous) worsening of biophysical suitability caused by climate change? The IMPACT model has been developed by the International Food Policy Research Institute to answer such questions.

IMPACT takes the yields generated by DSSAT as part of its input but modifies the data year upon year endogenously by market forces and ongoing yield-enhancing research. The extent of cultivated area dedicated to each crop is also endogenously modeled as a function of market incentives generated by global demand and supply, such that farmers are free to consider alternative land-use options in response to worsening biophysical suitability for their current crop(s) in any given year of the modeled period. Assumptions regarding future economic growth, population growth, and agricultural research trends are codified in a variety of ‘Shared Socioeconomic Pathways’ (SSPs). Likewise, assumptions regarding future GHG trajectories are codified in a set of ‘Representative Concentration Pathways’ (RCPs).

For the policy briefs, IMPACT was set to SSP2 and RCP 4.5, generally considered by the community of practice to represent a ‘business- as-usual’ trajectory in which agricultural research and GHG mitigation strategies continue at their current levels.

ANNEX E: METHODS FOR EX-ANTE FINANCIAL AND ECONOMIC PERFORMANCE

E-1. The Model

E-2. Data Sources

E-3. Data Analysis

E-1. The Model

The costs and benefits of investments were modeled using standard CBA and Monte Carlo simulations.

The model relies on an economic and financial analysis of expected inputs and outputs. A project's impact is monetized, discounted, and calculated annually considering the gradual adoption of interventions by the target beneficiaries, subject to the occurrence and influence of risks to implementation and benefits. The model assumes that benefits accrue for 20 years but investment costs are principally used in the first five years, with recurring costs equivalent to 10 percent of total investment each year thereafter.

A probabilistic approach was used to account for uncertainty in project costs and benefits subject to climate risks and barriers to adoption. Accurate estimates for parameters are a major challenge in ex ante impact assessments. The uncertainty inherent in these variables is modeled in the CBA using a probability distribution (typically a normal) representing our degree of confidence around the estimate and is then taken into account when calculating common indicators of CBA. The model applies the SIPMath standard developed by Probability Management Group.⁵³⁰ The critical piece here is that the SIPMath standard presents a way to preserve statistical relationships within scenarios when they are run. The model was specifically developed for implementation with the CSAIPs of Ghana and Burkina Faso. It is based on the same structure as was used for CSAIPs in Mali and Côte d'Ivoire.⁵³¹

In the following sections, we describe the development, parameterization, and running of the model.

The model has been coded using Microsoft Excel by World Agroforestry (ICRAF) and Probability Management Group. Source data for input values to parameterize the model are discussed below. The actual values used in the model are reported in their respective sections. All data and the MS Excel model will be available on ICRAF's Dataverse.⁵³²

E-2. Data Sources

The model requires six categories of data for each investment: (a) number of beneficiaries, (b) rates of adoption, (c) change of benefits with the project, (d) project costs, (e) risk frequency and severity, and (f) greenhouse gas impacts. Values for model parameters were defined based on a combination of expert knowledge and external data sources where available (Table E-1). Specific sources and approaches for each category are described below.

⁵³⁰ "Probability Management," n.d., <https://www.probabilitymanagement.org/s/SIP-Standard-Version-211.pdf>.

⁵³¹ Yet et al, 2020.

⁵³² "Dataverse," n.d.

Table E-1: Sources of Information for Model Parameters

Parameter	Expert Knowledge	External Data
Number beneficiaries		x
Adoption rates	X	
Change in benefits project		x
Project costs	X	
Risk frequency		x
Risk impact on project	X	

NUMBER OF BENEFICIARIES

We used census data⁵³³ and data from other surveys specific to the proposed project regions to estimate the potential number of beneficiaries (Table E-2). The number of beneficiaries includes both direct and indirect beneficiaries.

Table E-2. Number of Expected Beneficiaries for Each Investment in the Ghana CSAIP

Investment	Number of beneficiaries	Source of data
Cereal-legume	200,000	GLSS 2014
Cocoa	150,000	GLSS 2014
Poultry	160,000	GLSS 2014
Small ruminant	150,000	GLSS 2014
Aquaculture	70,000	Ghana Data Portal
Water harvesting and irrigation	140,000	GLSS 2014
Advisory services	500,000	Farmer's club, E-agriculture
Tuber-livestock	200,000	GLSS 2014
Tree crops	120,000	GLSS 2014

ADOPTION RATES

A project's scope is defined by the targeted total number of beneficiaries. A project's interventions are gradually adopted over the duration of the project, thus determining the accrual of benefits. The percentage of beneficiaries that adopt the project is modeled by the Bass model.⁵³⁴ The Bass model relies on two parameters: (a) rate of innovation, p , and (b) rate of imitation, q , to estimate the adoption rate (AR) over a specified time period t as shown below:

$$AR_t = \frac{1 - e^{-(p+q)t}}{1 + \left(\frac{q}{p}\right) e^{-(p+q)t}}$$

Broadly speaking, the rate of innovation can be thought of as the number of beneficiaries directly interacting with the project, and the rate of imitation can be considered the indirect beneficiaries. These parameters were then estimated using expert opinion based on a trajectory designed to map the likely and relative trajectory of implementation for each investment under the investment plan (Table E-3). The number of beneficiaries targeted was determined by assessment of agricultural census and secondary literature (see Table E-2). For both rates of innovation and adoption, higher numbers relate to more rapid adoption changing the functional form of the adoption curve.

⁵³³ Ghana Living Standards Survey Round 6, 2014.

⁵³⁴ Bass 1969.

Table E-3. Parameter Values Used for the Bass Model to Estimate Annual Adoption Rates

Rates of Innovation	Rates of Imitation (q)		
	0.4	0.5	0.6
0.05	Water harvesting and irrigation	Aquaculture	Cocoa, diversified tree crops
0.1	Small ruminant, tubers livestock	Poultry	Cereal-legume
0.15			Advisory services

IMPACTS WITH AND WITHOUT PROJECT

The impacts of each investment were modeled against the counterfactual of no project. Baselines of incomes before the project were generated from agricultural census data and standardized across the country to represent all farmers (US\$825). Returns over the project period without the project were adjusted for predicted climate impacts, based on estimated changes in agricultural productivity predicted with the IMPACT model respective to the relevant time period. Impacts with the projects were estimated based on change in income after project implementation generated from financial analysis of various management practices and technologies relevant for each investment (Table E-4). Data for the financial analysis were derived from ERA, a database of nearly 1,500 studies of farm-level management practices and technologies in Africa⁵³⁵ and supplemented with additional external sources as needed.

Table E-4: Financial Analysis

Technology	Average Percent Change with Project (SD)		
	Yield	Gross Returns	Costs
Cereal-Legume Integration			
Maize			
Improved Varieties	45.5 (9.2)	10.4 (10.7)	
Organic Fertilizer	105 (5.5)	81.8 (14.2)	101.8 (21.3)
Inorganic Fertilizer	82.5 (2.9)	84.2 (14.3)	57.0 (9.5)
Intercropping w/ Legumes	7.8 (3.9)	12.2 (17.1)	24.1 (19.0)
Rotation w/ Legumes	48.3 (6.0)		35.5 (20.4)
Mulching	34.9 (3.8)	62.7 (16.6)	13.4 (10.2)
Reduced Tillage	16.6 (3.3)	70.4 (24.4)	9.7 (11.9)
Sorghum			
Improved Varieties	32.2 (6.8)		
Organic Fertilizer	62.6 (5.7)		

⁵³⁵ Todd S Rosenstock et al., "The Scientific Basis of Climate-Smart Agriculture," Working Paper (Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security, 2015).

ANNEX E: METHODS FOR EX-ANTE FINANCIAL AND ECONOMIC PERFORMANCE

Inorganic Fertilizer	67.0 (6.7)	66.2 (16.6)	31.0 (-)
Intercropping w/ Legumes	0.4 (6.8)		
Rotation w/ Legumes	38.1 (12.0)		43.3 (-)
Mulching	23.5 (6.4)	36.3 (13.9)	63.2 (19.7)
Reduced Tillage	-3.3 (11.9)	-73.0 (46.2)	
Mean of all Technologies	40.0 (31)	51.3 (61.4)	47.2 (31.4)
Climate-Smart Cocoa			
Cocoa			
Improved Varieties	32 (25)		
Mean of all Technologies	32 (25)		
Poultry Improvement			
Chickens - Meat			
Improved Breeds	11.4 (2.5)		
Feed Supplementation	6.1 (2.5)	13.9 (9.4)	0.7 (0.6)
Feed Substitutions	1.2 (2.9)	0.9 (2.5)	-10.5 (3.3)
Addition of Poultry	89 (30)		
Mean of all Technologies	27.1 (20)		
Climate-Resilient Ruminants			
Cattle - Meat			
Improved Breeds	33.6 (6.4)		
Feed Supplementation	37.2 (5.8)	21.2 (1.1)	27.4 (12.6)
Feed Substitutions	6.0 (8.9)	12.4 (14.4)	-14.4 (8.4)
Improved Pasture	31.3 (2.6)		
Goats - Meat			
Improved Breeds	16.4 (6.0)		
Feed Supplementation	32.8 (9.1)	68.2 (5.1)	16.1 (48.6)
Feed Substitutions	9.6 (7.6)		1.0 (8.0)
Improved Pasture			
Sheep - Meat			
Improved Breeds	49.5 (3.8)		
Feed Supplementation	61.3 (19.1)	42.8 (12.5)	130 (46.1)
Feed Substitutions	7.1 (5.3)		-9.1 (1.4)

ANNEX E: METHODS FOR EX-ANTE FINANCIAL AND ECONOMIC PERFORMANCE

Improved Pasture	9.7 (11.4)		
Mean of all Technologies	26.8 (18.5)	36.1 (24.9)	
Diverse Tree Crop Systems			
Cashew			
Improved Varieties	21%		
Intercropping	-7.80%		
Soil Fertility Management			
Oil Palm			
Improved Varieties			
Agroforestry			
Soil Fertility Management			
Improved Management	73%		
Mean of all Technologies	29%		
Sustainable Aquaculture			
Fish			
Improved Breeds	11.6 (17.4)		
Feed Supplementation	49.5 (30.5)		
Feed Substitutions	-2.3 (4.1)		-15.1 (4.9)
Addition of Fishponds	80 (20)		
Mean of all Technologies	59.3 (30)		-12.8 (3.3)
Tuber-Livestock Integration			
Yam			
Inorganic Fertilizer	32.6 (8.4)		
Water Harvesting	28.4 (31.0)		
Cassava			
Improved Varieties	4.0 (11.2)		
Inorganic Fertilizer	36.5 (4.2)		
Organic Fertilizer	45.4 (13.0)		
Water Harvesting	28.7 (5.5)		
Cattle			
Improved Breeds	33.6 (6.4)		
Feed Supplementation	32.8 (9.1)		

Goats			
Improved Breeds	16.4 (6.0)		
Feed Supplementation	37.2 (5.8)		
Mean of all Technologies	27.2 (13.5)		
Advisory Services			
Use of Advisory for Planting	8.5 (6.8)		
Water Harvesting & Irrigation			
Rice			
SRI, AWD, Rice Management	46.8 (9.0)	49.2 (12.7)	2.6 (6.7)
Irrigation	45.9 (38.3)	46.2 (95.4)	
Water Harvesting	39.7 (2.5)		
Mean of all Technologies	44.1 (3.9)	47.7 (2.1)	

Note: Values are the percentage change with and without project. Values derived from the Compendium and other secondary sources.

PROJECT COSTS

Project costs were based on average costs per beneficiary following a typology of investments cost effectiveness derived by expert opinion. Investments are typically in the range US\$200–600 per beneficiary. Outside this range, the project is either unrealistically cost effective (if on the low end) or not cost efficient (if above the high end).

Each investment was then prescribed to one of three pathways: cost efficient, moderate, or très cher, with corresponding costs of US\$200, US\$400, and US\$600 per beneficiary. These values were then multiplied by the target number of beneficiaries based on census data in the regions identified in the investments (Table E-2). This provided an estimate of total costs. Annual costs were then distributed equally for years 1 through 5. Years 6–20 received 10 percent of annual budgets. The results are shown in Table E-5.

Table E-5. Budgets and Assumption for Cost/Beneficiary for each

Investment	Cost/Beneficiary (US\$)	Budget (US\$, thousands)
Cereal-legume	160	32,000
Cocoa	360	54,000
Poultry	200	32,000
CS ruminants	250	37,500
Aquaculture	500	35,000
Water-rice	500	70,000
Advisory services	100	50,000
Tuber-livestock	250	50,000
Tree crops	242	29,040
<i>Average</i>	<i>285</i>	<i>43,282</i>
Total		389,540

RISK FREQUENCY

Approach used to estimate the likelihood of occurrence and severity of impact on the project for each of the six modeled risks are described below.

GREENHOUSE GAS BALANCE

Estimates of changes in carbon stocks and GHGs were based on analysis using the EXACT model⁵³⁶ and published literature when figures were not available from EXACT. GHG balances are typically quantified in tons of carbon dioxide equivalent per ha (tCO₂e/ha). However, the economic analysis operates on beneficiaries (persons). Given the size and diversity of farms in Ghana, we assume that each beneficiary implements the interventions on 1 ha (1:1). When estimates were not available from EXACT, other data sources were found to provide an estimate of potential impacts. The results are shown in Table E-7.

Table E-7. Greenhouse Gas Balances Used in the Model

Investment	Midpoint GHG (tCO ₂ e/ha)	Assumptions	Source
Cereal-legume	2.2	Relies heavily on reduced tillage; crop rotation and crop residue retention	EXACT
Cocoa	6.1	Tree rejuvenation and good horticulture; biomass production	EXACT
Poultry	-1.5	Minor emissions source due to increase in amount of manure	Expert opinion
Ruminants	-8.3	Enteric emissions in crop-livestock systems dominate emissions	Expert opinion
Aquaculture	-1.8	Increased methane production due to pond management	Maritime
Water-rice	6.5	Relies on the systems of rice intensification	EXACT
Advisory services	0	Assumed these provide little benefit because they primarily induce persons to improve agronomy, planting in rows, and so on.	Expert opinion
Tuber-livestock	-5.1	Driven by livestock emissions in the system	Expert opinion
Tree crops	8	Significant biomass carbon accumulation	EXACT

The value of the change in emission and carbon stock was estimated based on the World Bank guidance note on the social cost of carbon. The World Bank's global social costs of carbon ranges between US\$40 and 80 per tCO₂e. We used a midpoint of US\$50 per ton and set the distribution such that 90 percent of selected values would be between US\$5 and 100 per ton. It should be noted that the most current assessment of the social cost of carbon differentiated for individual countries values carbon between US\$0.4 and 10.4 per tCO₂e for Ghana depending on the discount rate,⁵³⁷ much lower than the value used in this study.

⁵³⁶ FAO, unpublished.

⁵³⁷ Rick et al, 2018.

E-3. Data Analysis

Economic performance was measured using standard CBA indicators: NPV, IRR, ROI, and BCR. NPV measures the incremental flow of net benefits (net cash flow) generated by the investments over their life cycle period. The NPV indicates the amount of wealth accumulated due to the investment. The NPV is computed as follows:

$$NPV = \sum_{t=1}^n \frac{B_t - C_t}{(1+r)^t} \quad (1)$$

where B_t is the benefit of CSA practice (CSA package) at time t , C_t is the investment and recurrent cost of CSA practice (CSA package) at time t , t is the time horizon (life cycle), and r is the discount rate (prevailing commercial bank prime lending rates).

The IRR (Internal Rate of Return) is defined as the discount rate that makes the present value of the flow of future net benefits exactly equal to the initial investment, therefore setting the NVP to zero.⁵³⁸ Any CSA investment with an IRR exceeding the discount rate is viable.⁵³⁹ The IRR is computed as follows:

$$NPV = \sum_{t=1}^n \frac{B_t - C_t}{(1+r)^t} = 0, \text{ when } IRR > r \quad (2)$$

⁵³⁸ Juhász, 2011.

⁵³⁹ Mutenje et al., 2019.

BIBLIOGRAPHY

- 2017 Global ICT Development Index. “Ghana.” International Telecommunications Union, 2017. <https://www.itu.int/net4/ITU-D/idi/2017/index.html#idi2017economycard-tab&GHA>.
- Abbam, Tawia, Fiifi Amoako Johnson, Jadunandan Dash, and Sabu S. Padmadas. “Spatiotemporal Variations in Rainfall and Temperature in Ghana Over the Twentieth Century, 1900–2014,” 2018. <https://doi.org/10.1002/2017ea000327>.
- Abdulai, Issaka, Laurence Jassogne, Sophie Graefe, Richard Asare, Piet Van Asten, Peter Läderach, and Philippe Vaast. “Characterization of Cocoa Production, Income Diversification and Shade Tree Management along a Climate Gradient in Ghana.” *PLOS ONE* 13, no. 4 (April 16, 2018): e0195777. <https://doi.org/10.1371/journal.pone.0195777>.
- Abdul-Razak, Majeed, and Sylvia Kruse. “The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana.” *Climate Risk Management* 17 (2017): 104–22. <https://doi.org/10.1016/j.crm.2017.06.001>.
- Abou Zaki, Nizar, Ali Torabi Haghighi, Pekka M. Rossi, Stefanos Xenarios, and Bjørn Kløve. “An Index-Based Approach to Assess the Water Availability for Irrigated Agriculture in Sub-Saharan Africa.” *Water* 10, no. 7 (July 2018): 896. <https://doi.org/10.3390/w10070896>.
- ACDI/VOCA. “Ghana Poultry Project (GPP),” 2019. <https://www.acdivoca.org/projects/ghana-poultry-project-gpp/>.
- ACDI-VOCA and USDA. “Ghana Poultry Project.” ESRI ArcGIS, 2019. <https://www.arcgis.com/apps/Cascade/index.html?appid=2fc0e02e10d4477e969a5a5a5a751599>.
- Acheampong, Emmanuel Opoku, Colin J. Macgregor, Sean Sloan, and Jeffrey Sayer. “Deforestation Is Driven by Agricultural Expansion in Ghana’s Forest Reserves.” *Scientific African* 5 (September 1, 2019): e00146. <https://doi.org/10.1016/j.sciaf.2019.e00146>.
- Acheampong, George. “Financial Institution Ties and Survival of Small Commercial Poultry Farms (SCPFs) in Ghana.” *Journal of Entrepreneurship in Emerging Economies*, June 4, 2018. <https://doi.org/10.1108/JEEE-08-2017-0061>.
- Actualitix. “Analysis of 2011 World Bank Dataset,” 2011. <https://en.actualitix.com/country/wld/co2-emissions-per-capita.php>.
- Adaption Fund. “Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods.” Projects and Programmes, September 9, 2019. <https://www.adaptation-fund.org/project/increased-resilience-to-climate-change-in-northern-ghana-through-the-management-water-resources-and-diversification-of-livelihoods/>.
- Adjei-Nsiah, S., and Owuraku Sakyi-Dawson. “Promoting Cassava as an Industrial Crop in Ghana: Effects on Soil Fertility and Farming System Sustainability.” Research article. *Applied and Environmental Soil Science*, 2012. <https://doi.org/10.1155/2012/940954>.
- Adzawla et al, 2020.
- AFDB. “Ghana - Livestock Development Project.” Accessed October 19, 2019. <https://projectsportal.afdb.org/dataportal/VProject/show/P-GH-AA0-025>.
- Afr100. “Home.” African Forest Landscape Restoration Initiative, 2018. <https://afr100.org/>.
- African Development Bank. “About the ADF.” Text, April 2, 2019. <https://www.afdb.org/en/about-us/corporate-information/african-development-fund-adf/about-the-adf>.

BIBLIOGRAPHY

- African Union. "Agenda 2063: The Africa We Want." The African Union Commission, 2019. <https://au.int/en/agenda2063/overview>.
- Agbehadzi, R. K., J. A. Hamidu, K. Adomako, and R. Enu. "Economic Contribution of Local Hatchery Performance in the Poultry Value Chain in Ghana." *Poultry Science* 98, no. 6 (June 1, 2019): 2399–2404. <https://doi.org/10.3382/ps/pez020>.
- AGRA. "Ghana." Where We Work, 2017. <https://agra.org/where-we-work/ghana-4/>.
- AgricInGhana Media. "Ghana Launches a 10 Year Cashew Development Plan," 2019. <http://agricinghana.com/>.
- AgWater Solutions. "Mapping and Assessing the Potential for Investments in Agricultural Water Management." Brief. Country Investment. FAOWater. Accessed October 30, 2019. http://awm-solutions.iwmi.org/wp-content/uploads/sites/12/documents/Country_Docs/Ghana/ghana-country-investment-brief.pdf.
- Agyemang, Martin, Qinghua Zhu, Mary Adzanyo, Elena Antarciuc, and Senlin Zhao. "Evaluating Barriers to Green Supply Chain Redesign and Implementation of Related Practices in the West Africa Cashew Industry." *Resources, Conservation and Recycling* 136 (September 1, 2018): 209–22. <https://doi.org/10.1016/j.resconrec.2018.04.011>.
- Aheto, Denis Worlanyo, Esther Acheampong, and Justice Odoiquaye Odoi. "Are Small-Scale Freshwater Aquaculture Farms in Coastal Areas of Ghana Economically Profitable?" *Aquaculture International* 27, no. 3 (June 1, 2019): 785–805. <https://doi.org/10.1007/s10499-019-00363-9>.
- Ahmed, Abubakari, Eric Dompheh, and Alexandros Gasparatos. "Human Wellbeing Outcomes of Involvement in Industrial Crop Production: Evidence from Sugarcane, Oil Palm and Jatropha Sites in Ghana." *PLOS ONE* 14, no. 4 (April 25, 2019): e0215433. <https://doi.org/10.1371/journal.pone.0215433>.
- Akhtar-Schuster, M., R.J. Thomas, L. C. Stringer, P. Chasek, and M.K. Seely. "Improving the Enabling Environment to Combat Land Degradation: Institutional, Financial, Legal and Science-Policy Challenges and Solutions." *Land Degrad. Dev.*, no. 22 (2011): 299–312.
- Akudugu, M.A., and A.R. Alhassan. "The Climate Change Menace, Food Security, Livelihoods and Social Safety in Northern Ghana." *International Journal of Sustainable Development & World Policy* 1, no. 3 (2012): 80–95.
- Akuffobe-Essilfie, Mavis, Portia Adade Williams, Roland Asare, Sigrid Damman, and George Owusu Essegbey. "Promoting Rainwater Harvesting for Improving Water Security: Analysis of Drivers and Barriers in Ghana." *African Journal of Science, Technology, Innovation and Development* 0, no. 0 (April 17, 2019): 1–9. <https://doi.org/10.1080/20421338.2019.1586113>.
- Alidou, Salihou Mamadou. "Cross-Border Transhumance Corridors in West Africa." CapEx, February 2016.
- Alliance for Affordable Internet. "Affordability Index," 2019. <https://a4ai.org/affordability-report/data/>.
- Amenyogbe, Eric, Gang Chen, Zhongliang Wang, Mingde Lin, Xiaoying Lu, Denicia Atujona, and Emmanuel D Abarike. "A Review of Ghanas Aquaculture Industry." *Journal of Aquaculture Research & Development* 09, no. 08 (2018). <https://doi.org/10.4172/2155-9546.1000545>.
- Amewu, Sena. "Figure 3.1. Aquaculture Value Chain Map for Ghana." ResearchGate. Accessed October 30, 2019. https://www.researchgate.net/figure/Aquaculture-value-chain-map-for-Ghana_fig3_326069939.
- Anaadumba, P. "Analysis of Incentives and Disincentives for Yam in Ghana." Technical Note. MAFAP. Rome: FAO, 2013.
- Anang, Benjamin Tetteh, and Joseph A. Awuni. "Effect of Training on Small Scale Rice Production in Northern Ghana." *Applied Studies in Agribusiness and Commerce* 12, no. 3–4 (December 31, 2018): 13–20. <https://doi.org/10.22004/ag.econ.292388>.

BIBLIOGRAPHY

- Andres, Christian, Raphael Hoerler, Robert Home, Jonas Joerin, Henry K. Dzahini-Obiatey, George A. Ameyaw, Owusu Domfeh, et al. "Social Network to Inform and Prevent the Spread of Cocoa Swollen Shoot Virus Disease in Ghana." *Agronomy for Sustainable Development* 38, no. 5 (October 2, 2018): 53. <https://doi.org/10.1007/s13593-018-0538-y>.
- Ansah, K. O., C. Antwi, E. L. K. Osafo, S. Enning, and H. Adu-Dapaah. "Manure Characteristics of Small Ruminants Fed Agro By-Products in the Guinea Savannah Agro-Ecological Zone of Ghana." *Ghana Journal of Agricultural Science* 54, no. 1 (January 1, 2019): 67-76-76.
- Ansah, T., and A. C. Issaka. "Ruminant Livestock Feed Resources in the Kumbungu District of Ghana," 2018. <http://udsspace.uds.edu.gh:80/handle/123456789/1912>.
- Antwi-Agyei, Philip, and Andrew Dougill. "SRI Briefing Note Series No.13," no. 13 (n.d.): 8.
- Antwi-Agyei, Philip, Andrew Dougill, and Lindsay Stringer. "Assessing Coherence between Sector Policies and Climate Compatible Development: Opportunities for Triple Wins." *Sustainability* 9, no. 11 (November 18, 2017): 2130. <https://doi.org/10.3390/su9112130>.
- Apuri, Isaac, Kenneth Peprah, and Godwin Thomas Wedam Achana. "Climate Change Adaptation through Agroforestry: The Case of Kassena Nankana West District, Ghana." *Environmental Development* 28 (December 1, 2018): 32-41. <https://doi.org/10.1016/j.envdev.2018.09.002>.
- Aquastat. "Ghana." FAOSTAT, 2005. http://www.fao.org/fileadmin/user_upload/aquastat/pdf_files/GHA_tables.pdf.
- Ariga, Heffernan. "Ghana Fertilizer Assessment." African Fertilizer and Agribusiness Partnership. Alabama: IFDC, June 2012.
- Armah, E. K. "Productivity and Resource-Use-Efficiency of Cashew Production in Ghana." Thesis, University Of Ghana, 2018. <http://ugspace.ug.edu.gh/handle/123456789/29747>.
- Asante, Bright O., Renato A. Villano, Ian W. Patrick, and George E. Battese. "Determinants of Farm Diversification in Integrated Crop-Livestock Farming Systems in Ghana." *Renewable Agriculture and Food Systems* 33, no. 2 (April 2018): 131-49. <https://doi.org/10.1017/S1742170516000545>.
- Asante, Bright Owusu, Stella A. Ennin, Jonas Osei-Adu, Henry Asumadu, Anselme Adegbedi, Mama Saho, and Hamidou Nantoume. "Performance of Integrated Crop-Small Ruminant Production Systems in West Africa." *Agroforestry Systems* 93, no. 3 (June 1, 2019): 989-99. <https://doi.org/10.1007/s10457-018-0196-8>.
- Asante, Felix, and Franklin Amuakwa-Mensah. "Climate Change and Variability in Ghana: Stocktaking." *Climate* 3 (January 1, 2015): 78-99. <https://doi.org/10.3390/cli3010078>.
- Asante-Addo, Collins, and Daniela Weible. "Is There Hope for Domestically Produced Poultry Meat? A Choice Experiment of Consumers in Ghana." *Agribusiness*, August 30, 2019. <https://doi.org/10.1002/agr.21626>.
- Asare, Richard, Bo Markussen, Rebecca Ashley Asare, Gilbert Anim-Kwapong, and Anders Ræbild. "On-Farm Cocoa Yields Increase with Canopy Cover of Shade Trees in Two Agro-Ecological Zones in Ghana." *Climate and Development* 11, no. 5 (May 28, 2019): 435-45. <https://doi.org/10.1080/17565529.2018.1442805>.
- Ashu, Sarah Ntoh. "Ghana Agricultural Sector Investment Programme (GASIP)." Draft Supervision Report. Republic of Ghana: IFAD, November 23, 2016.
- Asiedu, Berchie, Dickson Malcolm, and Seidu Iddrisu. "Assessing the Economic Impact of Climate Change in the Small-Scale Aquaculture Industry of Ghana, West Africa." *AAS Open Research* 1 (November 1, 2018): 26. <https://doi.org/10.12688/aasopenres.12911.1>.
- Asubonteng, Kwabena, Karin Pfeffer, Mirjam Ros-Tonen, Jan Verbesselt, and Isa Baud. "Effects of Tree-Crop Farming on Land-Cover Transitions in a Mosaic Landscape in the Eastern Region of Ghana." *Environmental Management* 62, no. 3 (September 1, 2018): 529-47. <https://doi.org/10.1007/s00267-018-1060-3>.

BIBLIOGRAPHY

- Atindana, Sandra Akugpoka, Patrick Kwabena Ofori-Danson, and Sandra Brucet. "Modelling the Effects of Climate Change on Shellfish Production in Marine Artisanal Fisheries of Ghana." *AAS Open Research* 2 (May 22, 2019): 16. <https://doi.org/10.12688/aasopenres.12956.1>.
- AUDA-NEPAD. "Ghana." NEPAD Transforming Africa, 2019. <https://www.nepad.org/taxonomy/term/138>.
- . "The CAADP Country Process," 2019. <https://www.nepad.org/caadp/publication/caadp-country-process>.
- . "Tracking Progress: Ghana." NEPAD Transforming Africa, 2019. <https://www.nepad.org/caadp/countries/ghana>.
- Avorny, F.K., S. Salifu, E.K. Panyan, B.I. Al-Hassan, M. Ahiagbe, and F. Yeboah. "Characteristics of Guinea Fowl Production Systems in Northern Ghana. A Baseline Study of 20 Districts in Northern Ghana." Accessed October 2, 2019. <https://www.lrrd.cipav.org.co/lrrd28/8/avor28134.html>.
- Avorny, F.K., R. Zougmore, Samuel T. Partey, and K. Tengan. "Candidate Fodder Trees and Shrubs for Sustainable Ruminant Production in Northern Ghana." *Livestock Research for Rural Development* 30, no. 9 (2018).
- Baba, Sidik Sulemana. "Effectiveness of Knowledge Management Approaches on Agricultural Extension Services Delivery in Selected Districts of Northern Region." Thesis, University for Development Studies, 2018. <http://udspace.uds.edu.gh:80/handle/123456789/1933>.
- Balana, Bedru B., Jean-Claude Bizimana, James W. Richardson, Nicole Lefore, Zenebe Adimassu, and Brian K. Herbst. "Economic and Food Security Effects of Small-Scale Irrigation Technologies in Northern Ghana." *Water Resources and Economics*, March 21, 2019, 100141. <https://doi.org/10.1016/j.wre.2019.03.001>.
- Balma, Yakubu Issaka, and Nartey Yeboah Richard. "Socio-Economic Attributes of Guinea Fowl Production in Two Districts in Northern Ghana." *African Journal of Agricultural Research* 11, no. 14 (April 30, 2016): 1209–17. <https://doi.org/10.5897/AJAR2015.10258>.
- Barnett, I., S. Batchelor, L. Billings, B. Faith, D. Gilligan, J. Gordon, M. Hidrobo, et al. "External Evaluation of Mobile Phone Technology-Based Nutrition and Agriculture Advisory Services in Africa and South Asia." Mixed Methods Baseline Report. Ghana. Oxford Policy Management: Institute for Development Studies, February 1, 2019. https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/14321/Mixed_method_baseline_report_Ghana_FINAL_APPROVED.pdf?sequence=178&isAllowed=y.
- Bidzakin, John Kanburi, Simon C. Fialor, Dadson Awunyo-Vitor, and Iddrisu Yahaya. "Impact of Irrigation Ecology on Rice Production Efficiency in Ghana." *Advances in Agriculture* 2018 (June 12, 2018): 1–10. <https://doi.org/10.1155/2018/5287138>.
- Biratu, Gizachew Kebede, Eyasu Elias, Pheneas Ntawuruhunga, and Gudeta W. Sileshi. "Cassava Response to the Integrated Use of Manure and NPK Fertilizer in Zambia." *Heliyon* 4, no. 8 (August 1, 2018): e00759. <https://doi.org/10.1016/j.heliyon.2018.e00759>.
- Blaskovic, Teo. "At Least 28 Killed, 286 Homes Destroyed as Severe Flooding Hits Upper East Region, Ghana." Daily News Service. The Watchers, October 18, 2019. <https://watchers.news/2019/10/18/flood-upper-east-region-ghana-october-2019/>.
- Blum, Magdalena, and Judit Szonyi. "Investment Requirements in Extension to Achieve Zero Hunger and Adapt to Climate Change." FAO, 2012.
- Blummel, Michael, Melkamu Derseh, Aberra Adie, and Tunde Amole. "Feed the Future Innovation Lab on Small Scale Irrigation (ILSSI): Ethiopia, Ghana, and Tanzania." International Livestock Research Institute, 2018. https://cgispace.cgiar.org/bitstream/handle/10568/100485/smallscale_irrigated_fodder.pdf?sequence=1.

BIBLIOGRAPHY

- BMZ. "The German Federal Ministry for Economic Cooperation and Development." Federal Ministry for Economic Cooperation and Development. Accessed October 8, 2019.
https://www.bmz.de/en/service/error/404.php?redirect=/en;/bengo_Foederrichtlinien-Private-Traeger-Englisch.pdf;%20https://terravivagrants.org/grant-makers/cross-cutting/german-federal-ministry-of-economic-cooperation-and-development/&.
- Boafo, Hettie Arwoh, Siegfried Affedzie-Obresi, Dossou Séblodo Judes Charlemagne Gbemavo, Victor Attuquaye Clottey, Emmanuel Nkegbe, Gabriel Adu-Aboagye, and Marc Kenis. "Use of Termites by Farmers as Poultry Feed in Ghana." *Insects* 10, no. 3 (March 2019): 69.
<https://doi.org/10.3390/insects10030069>.
- Boafo, James. "Expanding Cashew Nut Exporting from Ghana's Breadbasket: A Political Ecology of Changing Land Access and Use, and Impacts for Local Food Systems." *The International Journal of Sociology of Agriculture and Food* 25, no. 2 (August 27, 2019): 152–72.
- Borgne, Ewen Le. "New Factories in Nigeria Transform Cassava Peels into Livestock Feed, Creating Jobs and Incomes for Women." *ILRI News* (blog), August 23, 2017.
<https://news.ilri.org/2017/08/23/ifad-cassava-processing-site-visit/>.
- Breisinger. edited by Diao, Xinshen, P. Hazell, S. Kolavalli, and D. Resnick., 2019.
- Brown, Michael Mensah, Benjamin Alenyorege, Gabriel Ayum Teye, and Regina Roessler. "Phenotypic Diversity, Major Genes and Production Potential of Local Chickens and Guinea Fowl in Tamale, Northern Ghana." *Asian-Australasian Journal of Animal Sciences* 30, no. 10 (October 2017): 1372–81. <https://doi.org/10.5713/ajas.17.0145>.
- Bunn, Christian. Climate Smart Cocoa in Ghana, September 30, 2019.
- Bunn, Christian, Pablo Fernandez-Kolb, Richard Asare, and Mark Lundy. "Climate Smart Cocoa in Ghana." Info Note. CCAFS & CIAT, September 2019.
- Bunn, Christian, Peter Läderach, Amos Quaye, Sander Muilerman, Martin R.A. Noponen, and Mark Lundy. "Recommendation Domains to Scale out Climate Change Adaptation in Cocoa Production in Ghana." *Climate Services*, September 2019, 100123.
<https://doi.org/10.1016/j.cliser.2019.100123>.
- Bunyeth, Ho, and T R Preston. "Growth Performance and Parasite Infestation of Goats given Cassava Leaves as a Supplement to Grazing in Lowland and Upland Regions of Cambodia." *Livestock Research for Rural Development* 18, no. 2 (2006): 8.
- Bush, Simon R., Ben Belton, David C. Little, and Md Saidul Islam. "Emerging Trends in Aquaculture Value Chain Research." *Aquaculture* 498 (January 1, 2019): 428–34.
<https://doi.org/10.1016/j.aquaculture.2018.08.077>.
- Canadian International Development Agency. "About CIDA," n.d., 2.
- Cárdenas, A Belén, Nicola Favretto, Philip Antwi-Agyei, Andrew J Dougill, and Lindsay C Stringer. "Policy Coherence for Climate-Sensitive Planning in Ghana," n.d., 7.
- Chakrabarti, Asit. "Sweet Potato: An Excellent Source of Livestock Feed." ResearchGate, March 4, 2014.
https://www.researchgate.net/publication/303856559_Sweet_Potato_-_An_Excellent_Source_of_Livestock_Feed/link/575853c208ae414b8e3f58da/download.
- Chamshama, S. A. O., G. C. Monela, K. E. A. Sekiete, and A. Persson. "Suitability of the Taungya System at North Kilimanjaro Forest Plantation, Tanzania." *Agroforestry Systems* 17, no. 1 (January 1, 1992): 1–11. <https://doi.org/10.1007/BF00122924>.
- Chandra, A., and A. Idrisova. "Convention on Biological Diversity: A Review of National Challenges and Opportunities for Implementation." *Biodiversity Conservation*, no. 20 (2011): 3295–3316.
- Chidiac, Sybil. "Achieving Impact at Scale Through ICT-Enabled Extension Services in Ghana." Final Joint Technical Narrative Report. Accra, Ghana: Grameen Foundation USA, March 30, 2018.
<https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57315/IDL-57315.pdf?sequence=2>.

BIBLIOGRAPHY

- Choudhary, Vikas, Garry Christienson, Stephan Paul D'Alessandro, and Henri Josserand. "Ghana Agricultural Sector Risk Assessment." Note. Agriculture Global Practice. Washington DC: World Bank Group, 2016. <http://documents.worldbank.org/curated/en/412431468198000868/Ghana-agricultural-sector-risk-assessment>.
- CIA. "Ghana." The World Fact Book, 2015. <https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html>.
- CIAT. "CSAIP Inception Report." Climate Smart Agriculture Investment Plan. Ghana. World Bank Group & CGIAR, September 19, 2019.
- Climate Investment Funds. "Engaging Local Communities in REDD+/Enhancement of Carbon Stocks," March 15, 2018. <https://www.climateinvestmentfunds.org/projects/engaging-local-communities-reddenhancement-carbon-stocks>.
- Climate Resilience Fund. "Climate Resilience Funding Guide." Accessed October 8, 2019. <https://www.climate-resiliencefund.org/%20http://www.mfpp.org/wp-content/uploads/2017/07/Climate-Resilience-Funding-Guide.pdf>.
- Climate Service Center. "Benin-Ghana-Togo." Climate Fact Sheet, 2015. http://www.climate-service-center.de/products_and_publications/fact_sheets/climate_fact_sheets/index.php.en.
- ClimateWatchData. "2020 NDC Tracker." ClimateWatch, September 23, 2019. https://www.climatewatchdata.org/ndcs-enhancements?mkt_tok=eyJpIjoiTXpkaE5EVXpNalkwWkdNeSIsInQiOiJCWZpZndURXBRY0VFZXhYN3pKM2hpQXBsQTh1bEF0T21NVnJHZjZ4ZWd4T0Nxd203bkNNb2lWMkFhcWNsbjhtNktrTk11NFFzSDZhNmJYa2hoazBvazFVZjUyaFdmV0VaTVARA1owVjZjbWtkQVpBSmJ1OFYzWUNCd0NZMnI2bCJ9&search=ghana.
- Cocoa Board. "Environmental Sustainability and Policy for Cocoa Production in Ghana (ESP I)." UNDP in Ghana, 2016. https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/environmental-sustainability-and-policy-for-cocoa-production-in-.html.
- . "Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II)." UNDP in Ghana, 2019. https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/ESP2.html.
- Convergence. "Conducting a Feasibility Study for a Financing Facility for Cocoa Smallholders in Ghana." Design Grant Summary. Rainforest Alliance & RaboBank, May 2018.
- Crossroads Global Hand. "Global Hand: Home." Accessed October 8, 2019. <https://www.globalhand.org/en/organisations/24631>; <https://www.norfund.no/how-we-work/investment/>.
- Danida Research Portal. "Climate Smart Cocoa Systems for Ghana (CLIMCOCOA)," June 2016. <http://drp.dfccentre.com/project/climate-smart-cocoa-systems-ghana-climcocoa>.
- Danso-Abbeam, Gideon, Dennis Sedem Ehiakpor, and Robert Aidoo. "Agricultural Extension and Its Effects on Farm Productivity and Income: Insight from Northern Ghana." *Agriculture & Food Security* 7, no. 1 (October 19, 2018): 74. <https://doi.org/10.1186/s40066-018-0225-x>.
- Darfour, Bernard, and Kurt Rosentrater. "Agriculture and Food Security in Ghana." Orlando FL: Iowa State University, 2016. <https://doi.org/10.13031/aim.20162460507>.
- "Dataverse," n.d.
- De Pinto, A., U. Demirag, A. Haruna, J. Koo, and M. Asamoah. "Ghana Strategy Support Program: Climate Change, Agriculture, and Foodcrop Production in Ghana." IFPRI, 2012. <http://www.ifpri.org/sites/default/files/publications/gssp3.pdf>.

BIBLIOGRAPHY

- Deans, Howard, Mirjam A. F. Ros-Tonen, and Mercy Derkyi. "Advanced Value Chain Collaboration in Ghana's Cocoa Sector: An Entry Point for Integrated Landscape Approaches?" *Environmental Management* 62, no. 1 (July 1, 2018): 143–56. <https://doi.org/10.1007/s00267-017-0863-y>.
- Diawuo, Francis, Enoch Akwasi Kosoe, and Dzigbodi A. Doke. "Participation of Women Farmers in Agroforestry Practices in the Jaman South Municipality, Ghana." *Ghana Journal of Development Studies* 16, no. 2 (January 1, 2019): 267-289–289. <https://doi.org/10.4314/gjds.v16i2.13>.
- Doku, Bortey Nketia Alabi, Sun Chen, Elliot Haruna Alhassan, Yusuf Abdullateef, and Mohammad Mizanur Rahman. "Fisheries Resources of Ghana: Present Status and Future Direction," n.d., 8. ECOWAS Commission. "Regional Agricultural Policy for West Africa," 2010. https://www.diplomatie.gouv.fr/IMG/pdf/01_ANG-ComCEDEAO.pdf.
- Emerta, Aragie, Artavia Marco, and Pauw Karl. *Strategic Public Spending: Scenarios and Lessons for Ghana*. Intl Food Policy Res Inst, n.d.
- Emmanuel, Amankwah, and Mensah Jackson Napoleon. "Rainwater Harvesting - A Potential Safety Net for Water Security in Ghana." *Asian Journal of Environment & Ecology*, September 25, 2019, 1–10. <https://doi.org/10.9734/ajee/2019/v10i230115>.
- Emmanuel, Bangmarigu, and Artan Qineti. "Cocoa Production and Export in Ghana." Nitra, Slovakia: Faculty of Economics and Management, Slovak University of Agriculture, 2018.
- Environmental Protection Agency. "Ghana's Fourth National Greenhouse Gas Inventory Report." United Nations Framework Convention on Climate Change, February 2019.
- EROS. "Land Use and Land Cover Trends in Ghana." United States Geological Service, 2013. <https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-ghana>.
- Estell, Richard E., Kris M. Havstad, Andres F. Cibils, Dean M. Anderson, and T. Scott Schrader. "The Changing Role of Shrubs in Rangeland-Based Livestock Production Systems: Can Shrubs Increase Our Forage Supply?" *Rangelands* 36, no. 2 (April 2014): 25–31. <https://doi.org/10.2111/RANGELANDS-D-13-00066.1>.
- Etwire, Prince Maxwell. "The Economic Impact of Climate Change on Farm Decisions and Food Consumption in Ghana." Thesis, University of Otago, 2018. <https://ourarchive.otago.ac.nz/handle/10523/8413>.
- Etwire, Prince Maxwell, Saaka Buah, Mathieu Ouédraogo, Robert Zougmore, Samuel Tetteh Partey, Edward Martey, Sidzabda Djibril Dayamba, and Jules Bayala. "An Assessment of Mobile Phone-Based Dissemination of Weather and Market Information in the Upper West Region of Ghana." *Agriculture & Food Security* 6, no. 1 (April 10, 2017): 8. <https://doi.org/10.1186/s40066-016-0088-y>.
- . "An Assessment of Mobile Phone-Based Dissemination of Weather and Market Information in the Upper West Region of Ghana." *Agriculture & Food Security* 6, no. 1 (April 10, 2017): 8. <https://doi.org/10.1186/s40066-016-0088-y>.
- Evans, Aincree. "Caught in The Net: An Investigation into NGO Development Interventions Targeting Coastal Fish-Smokers in Ghana." Leiden University, 2019. <https://openaccess.leidenuniv.nl/handle/1887/77129>.
- Evans, Ruth. "Cashew Cultivation, Access to Land and Food Security in Brong-Ahafo, Ghana: Preventing the Intergenerational Transmission of Poverty?" University of Reading. Accessed October 29, 2019. <https://www.reading.ac.uk/geographyandenvironmentalscience/Research/HER/ges-RE-Ghana.aspx>.
- Evans, Ruth, Simon Mariwah, and K. Barima Antwi. "Growing Cashew Nuts in Ghana." Briefing for policy and practice. Land Access, Food Security, and Poverty Alleviation. University of Reading: Walk Institute for Climate System Research, n.d.
- FAO. "EcoCrop," 2007. <http://ecocrop.fao.org/ecocrop/srv/en/home>.
- . "Fertilizer Use by Crop in Ghana," 2003. <http://www.fao.org/3/a0013e/a0013e09.htm>.

BIBLIOGRAPHY

- . “Strengthening Linkages between Small Actors and Buyers in the Roots and Tubers Sector in Africa.” Work Plan. Ghana, 2015. <http://www.fao.org/3/a-az554e.pdf>.
- “FAO EXACT,” n.d.
- FAOSTAT. “Ghana.” Food and Agriculture Organization of the United Nations, 2017. <http://www.fao.org/faostat/en/#country/81>.
- Farmerline LTD. “Farmerline Launches New CocoaLink Service: A Free Mobile App That Puts the Power of Mobile Technology in Farmers’ Hands,” May 24, 2018. <https://farmerline.co/2018/05/24/farmerline-launches-new-cocoalink-service-a-free-mobile-app-that-puts-the-power-of-mobile-technology-in-farmers-hands/>.
- Feder, Gershon, Sushma Ganguly, and Jock R. Anderson. *The Rise And Fall Of Training And Visit Extension*. Policy Research Working Papers. Agriculture and Rural Development Department: The World Bank, 2006. <https://doi.org/10.1596/1813-9450-3928>.
- Flood List. “Ghana--Accra Floods Again,” 2016. <http://floodlist.com/africa/ghana-accra-floods-june-2016>.
- Folitse, Benjamin Yao, Seth Awuku Manteaw, Lucy Payne Dzandu, Grace Obeng-Koranteng, and Stephen Bekoe. “The Determinants of Mobile-Phone Usage among Small-Scale Poultry Farmers in Ghana.” *Information Development* 35, no. 4 (September 1, 2019): 564–74. <https://doi.org/10.1177/0266666918772005>.
- . “The Determinants of Mobile-Phone Usage among Small-Scale Poultry Farmers in Ghana.” *Information Development* 35, no. 4 (September 1, 2019): 564–74. <https://doi.org/10.1177/0266666918772005>.
- Folitse, Benjamin Yao, Joel Sam, Lucy Payne Dzandu, and Simon Kwame Osei. “Poultry Farmers’ Information Needs and Sources in Selected Rural Communities in the Greater Accra Region, Ghana.” *International Information & Library Review* 50, no. 1 (October 9, 2017): 1–12. <https://doi.org/10.1080/10572317.2017.1351020>.
- Food and Agriculture Organization of the United Nations. *Climate-Smart Agriculture Sourcebook*, 2014. ———. *Climate-Smart Agriculture Sourcebook*, 2014.
- Frossard, Emmanuel, Beatrice A. Aighewi, Sévérin Aké, Dominique Barjolle, Philipp Baumann, Thomas Bernet, Daouda Dao, et al. “The Challenge of Improving Soil Fertility in Yam Cropping Systems of West Africa.” *Frontiers in Plant Science* 8 (November 21, 2017). <https://doi.org/10.3389/fpls.2017.01953>.
- FruitWorldMedia. “Production of Cashew in Ghana to Be Enhanced.” *The Clipper*, August 2, 2018. <https://theclippermag.com/index.php/nuts/cashews/production-of-cashew-in-ghana-to-be-enhanced/>.
- fundsforNGOs. “Japan International Cooperation Agency (JICA),” October 11, 2008. <https://www.fundsforngos.org/bilateral-funds-for-ngos/japan-international-cooperation-agency-jica/>.
- Gbedemah, S. F., F. O. Torgbor, and S. K. Kufogbe. “Adaptation Strategies of Poultry Farmers to Rising Temperature in the Greater Accra Region of Ghana.” *West African Journal of Applied Ecology* 26, no. 0 (January 1, 2018): 41-55–55.
- Geiger, Michael, Tomomi Tanaka, and Camille Nuamah. “Ghana’s Growth History: New Growth Momentum since the 1990s Helped Put Ghana at the Front of Poverty Reduction in Africa.” World Bank Blogs, December 10, 2018. <https://blogs.worldbank.org/africacan/ghanas-growth-history-new-growth-momentum-since-the-1990s-helped-put-ghana-at-the-front-of-poverty>.
- GFDRR. “Country Program Update: Ghana,” 2013. http://www.gfdr.org/sites/gfdr.org/files/Ghana_Country_Program_Updates_2013.pdf.

BIBLIOGRAPHY

- Ghana Business News. "Provide Livestock Corridors to Check Influx of Foreign Animals – Veterinary Officer," July 11, 2019. <https://www.ghanabusinessnews.com/2019/07/11/provide-livestock-corridors-to-check-influx-of-foreign-animals-veterinary-officer/>.
- Ghana Cocoa Forest REDD+ Programme. "Forest Carbon Partnership Facility (FCPF) Carbon Fund." Emission Reduction Programme Document. World Bank, April 21, 2017.
- Ghana FIP. "Enhancing Natural Forest and Agroforest Landscapes Project." Text/HTML. World Bank, February 27, 2015. <https://projects.worldbank.org/en/projects-operations/project-detail/P148183>.
- Ghana Ministry of Agriculture. "Food and Agriculture Sector Development Policy (FASDEP II)," 2009.
- Ghana Statistical Service. "Provisional 2017 Annual Gross Domestic Product," April 2018. http://www.statsghana.gov.gh/docfiles/GDP/GDP2018/2017%20Quarter%204%20and%20annual%202017%20GDP%20publications/Annual_2017_GDP_April%202018%20Edition.pdf.
- . "Rebased 2013-2018 Annual Gross Domestic Product," April 2019, 11. ghananewsagency.org. "Ghana Signs Deal to Cut Carbon Emissions and Reduce Deforestation." GhanaWeb, July 10, 2019. <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-signs-deal-to-cut-carbon-emissions-and-reduce-deforestation-762012>.
- Girvetz, Evan, Caitlin Corner-Dolloff, Christine Lamanna, and Todd Rosenstock. "'CSA-Plan': Strategies to Put Climate-Smart Agriculture (CSA) into Practice." *Agriculture for Development* 30 (2017): 5.
- giz. "CAADP: Supporting Agricultural Technical Vocational Education and Training (ATVET)," 2017. <https://www.giz.de/en/worldwide/15974.html>.
- . "Competitive Cashew Initiative (ComCashew)," 2019. <https://www.giz.de/en/worldwide/19011.html>.
- GiZ. "Strengthening Advisory Capacities for Land Governance in Africa," 2014. <https://www.giz.de/en/worldwide/38449.html>.
- giz. "Sustainable Smallholder Agribusiness in Western and Central Africa," 2014. <https://www.giz.de/en/worldwide/16002.html>.
- GiZ, ACA, TechnoServe, and Fairmatch Support. "A Value Chain Analysis of the Cashew Sector in Ghana." African Cashew Initiative. Ghana, February 2010.
- Global Commission on Adaptation. "Adapt Now: A Global Call for Leadership on Climate Resilience," September 13, 2019. https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf.
- . "Adapt Now: A Global Call for Leadership on Climate Resilience," September 13, 2019. https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf.
- Global Environment Facility. "Preparation of Ghana's Initial Biennial Update Report to UNFCCC," June 4, 2016. <https://www.thegef.org/project/preparation-ghanas-initial-biennial-update-report-unfccc>.
- . "Strengthening of the Enabling Environment, Ecosystem-Based Management and Governance to Support Implementation of the Strategic Action Programme of the Guinea Current Large Marine Ecosystem," October 31, 2017. <https://www.thegef.org/project/strengthening-enabling-environment-ecosystem-based-management-and-governance-support>.
- Government of Ghana. "Ghana's Intended Nationally Determined Contribution," 2015, 16.
- Groupe de la Banque Africaine de Developpement. "Ghana - Cashew Production Development Project," October 9, 2019. <https://projectsportal.afdb.org/dataportal/VProject/show/P-GH-AAA-001?lang=fr>.
- Healthline. "Nutrition Facts," 2019. <https://www.healthline.com/nutrition/cassava>.
- Heifer International. "Ghana," 2019. <https://www.heifer.org/about-us/where-we-work/ghana.html>.
- Hennessy, Maggie. "IITA Looks to Make Cassava a Major Source of Animal Feed." News. *FeedNavigator* (blog), February 10, 2014. <https://www.feednavigator.com/Article/2014/02/10/IITA-looks-to-make-cassava-a-major-source-of-animal-feed>.

BIBLIOGRAPHY

- Ibeagha-Awemu, Eveline M., Sunday O. Peters, Martha N. Bemji, Matthew A. Adeleke, and Duy N. Do. "Leveraging Available Resources and Stakeholder Involvement for Improved Productivity of African Livestock in the Era of Genomic Breeding." *Frontiers in Genetics* 10 (April 24, 2019). <https://doi.org/10.3389/fgene.2019.00357>.
- IEA. "Policies and Measures." Accessed October 8, 2019. <https://www.iea.org/policiesandmeasures/>.
- Index Mundi. "Ghana - Agricultural Irrigated Land," 2014. <https://www.indexmundi.com/facts/ghana/agricultural-irrigated-land>.
- . "Ghana - Agricultural Land," 2014. <https://www.indexmundi.com/facts/ghana/agricultural-land>.
- . "Ghana - Forest Area (Sq. Km)," 2015. <https://www.indexmundi.com/facts/ghana/indicator/AG.LND.FRST.K2>.
- Innovations for Poverty Action. "Evidence for Agriculture in Ghana." Accra, Ghana: IFPRI, USAID, and ESRC, 2015.
- Integrated Cassava Project. "Cassava in the Livestock Feed Industry." IITA & CGIAR. CassavaBiz, 2005. <http://www.cassavabiz.org/postharvest/lvstock.htm>.
- International Food Policy Research Institute (IFPRI). "Public Agricultural Spending and Growth in Ghana: Spending More, Smarter." Washington, DC: International Food Policy Research Institute, 2019. <https://doi.org/10.2499/p15738coll2.133333>.
- International Plant Nutrition Institute. "Oil Palm Best Management Practices in Ghana," 2018. <http://ssa.ipni.net/topic/oil-palm-best-management-practices>.
- International Telecommunication Union. "Global ICT Development Index." ITU, 2017. <https://www.itu.int/net4/ITU-D/idi/2017/index.html>.
- "Italian Government Ghana Private Sector Investment Fund," n.d. https://ambaccra.esteri.it/resource/2012/01/54373_f_amb61Guidelines1.doc.
- Jaffee, Siegel, and Andrews, 2008.
- Jansen, Johannes. "Transforming Agriculture for Economic Growth, Job Creation, and Food Security." Policy Note. Ghana Agriculture Sector. World Bank, June 2017.
- Johnson Gaither, Cassandra, Rita Yembilah, and Sparkler Brefo Samar. "Tree Registration to Counter Elite Capture of Forestry Benefits in Ghana's Ashanti and Brong Ahafo Regions." *Land Use Policy* 85 (June 1, 2019): 340–49. <https://doi.org/10.1016/j.landusepol.2019.04.006>.
- Juhász, 2011.
- Karanasios, Stan, and Mira Slavova. "How Do Development Actors Do 'ICT for Development'? A Strategy-as-practice Perspective on Emerging Practices in Ghanaian Agriculture." *Information Systems Journal* 29, no. 4 (July 1, 2019): 888–913. <https://doi.org/10.1111/isj.12214>.
- Karbo, Naaminong, George Essebey, Dilys Sefakor MacCarthy, Kingsely Amoako, Delali Nutsukpo, Vincent Ansah Botchway, Kingsely Odum Sam, et al. "Draft Report: Development of Climate-Smart Agriculture Investment Plan for Ghana: Review Of Policy, Strategic Documents, and Financial Mobilisation Mechanisms to Support Climate-Smart Agriculture." World Bank, 2019.
- Kermah, M., A.C. Franke, S. Adjei-Nsiah, B.D.K. Ahiabor, R.C. Abaidoo, and K.E. Giller. "N₂-Fixation and N Contribution by Grain Legumes under Different Soil Fertility Status and Cropping Systems in the Guinea Savanna of Northern Ghana." *Agriculture, Ecosystems & Environment* 261 (July 2018): 201–10. <https://doi.org/10.1016/j.agee.2017.08.028>.
- Kermah, Michael, Angelinus C. Franke, Samuel Adjei-Nsiah, Benjamin D.K. Ahiabor, Robert C. Abaidoo, and Ken E. Giller. "Maize-Grain Legume Intercropping for Enhanced Resource Use Efficiency and Crop Productivity in the Guinea Savanna of Northern Ghana." *Field Crops Research* 213 (November 2017): 38–50. <https://doi.org/10.1016/j.fcr.2017.07.008>.
- Kitchell, Erin, Matthew D. Turner, and John G. McPeak. "Mapping of Pastoral Corridors: Practices and Politics in Eastern Senegal." *Pastoralism* 4, no. 1 (October 8, 2014): 17. <https://doi.org/10.1186/s13570-014-0017-2>.

BIBLIOGRAPHY

- Kizito, Fred, Davie Kadyampakeni, Asamoah Larbi, Eliasu Salifu, and Abdul Rahman Nurudeen. "Water, Land and Soil Management Strategies to Intensify Cereal-Legume Farming Systems in Northern Ghana," n.d., 1.
- Kokutse, Francis. "Irrigation Earns Flood-Prone Farmers US\$4,344 a Hectare." *The Trust Project*. July 26, 2019. <http://www.scidev.net/index.cfm?originalUrl=/sub-saharan-africa/farming/news/irrigation-earns-flood-prone-farmers-hectare.html&>.
- Komarek, De Pinto, and Smith, 2020.
- Konlan, Solomon, Augustine Ayantunde, Weseh Addah, and Kwabla Dei. "Evaluation of Feed Resource Availability for Ruminant Production in Northern Ghana." *International Journal of Livestock Research* 6, no. 6 (2016): 39. <https://doi.org/10.5455/ijlr.20160613094759>.
- Koppen, Barbara C. M. van, Lesley Hope, and W. Colenbrander. "Gender Aspects of Smallholder Private Groundwater Irrigation in Ghana and Zambia." *Water International* 38, no. 6 (2013): 840–51.
- Kusi, Lawrence Yaw, Senyo Agbeblewu, Isaac Kwadwo Anim, and Kwamena Minta Nyarku. "The Challenges and Prospects of the Commercial Poultry Industry in Ghana: A Synthesis of Literature." *International Journal of Management Sciences* 5, no. 6 (2015): 14.
- Kwoyiga, Lydia, and Catalin Stefan. "Institutional Feasibility of Managed Aquifer Recharge in Northeast Ghana." *Sustainability* 11, no. 2 (January 2019): 379. <https://doi.org/10.3390/su11020379>.
- Laderach, P., A. Eitzinger, A. Martinez, and N. Castro. "Predicting the Impact of Climate Change on the Cocoa-Growing Regions in Ghana and Cote d'Ivoire." CCAFS & CIAT, 2011. http://www.eenews.net/assets/2011/10/03/document_cw_01.pdf.
- Laderach, Peter, A. Eitzinger, A. Martinez, and N. Castro. "Predicting the Impact of Climate Change on Cashew Growing Regions in Ghana and Cote d'Ivoire." Managua, Nicaragua: International Center for Tropical Agriculture (CIAT), September 2011. https://www.africacashewalliance.com/sites/default/files/documents/ghana_ivory_coast_climate_change_and_cashew.pdf.
- Land and Plant Nutrition Management Service. "Fertilizer Use by Crop in Ghana." Land and Water Development. Rome: FEO, 2005.
- Lemos, M.C., and B.J. Morehouse. "The Co-Production of Science and Policy in Integrated Climate Assessments." *Global Environmental Change* 15, no. 1 (2005): 57–68. <https://doi.org/10.1016/j.gloenvcha.2004.09.004>.
- Lipper, Leslie, Philip Thornton, Bruce M. Campbell, Tobias Baedeker, Ademola Braimoh, Martin Bwalya, Patrick Caron, et al. "Climate-Smart Agriculture for Food Security." *Nature Climate Change* 4, no. 12 (December 2014): 1068–72. <https://doi.org/10.1038/nclimate2437>.
- MacMillan, Susan. "USAID Supports the Commercial Potential of Cassava Peel for Livestock Feed in Nigeria." *ILRI Clippings* (blog), February 1, 2017. <https://clippings.ilri.org/2017/02/01/usaidsupports-the-commercial-potential-of-cassava-peel-for-livestock-feed-in-nigeria/>.
- Marinus, Wytze, and Esther Ronner. "What Role for Legumes in Sustainable Intensification? – Case Studies in Western Kenya and Northern Ghana for PROIntensAfrica," n.d., 64.
- Martin, Muchero. "Africa Agriculture Transformation Scorecard: Performance and Lessons for the Southern Africa Development Community-SADC," n.d., 10.
- Mavromichalis, Ioannis. "Using Cassava as a Global Livestock Feed Ingredient." *Feed Strategy*, April 18, 2017. <https://www.feedstrategy.com/animal-feed-manufacturing/using-cassava-as-a-global-livestock-feed-ingredient/>.
- McSweeney, C., M. New, and G. Lizcano. "Ghana." *Climate Change Country Profiles*. United Nations Development Programme, 2010. http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Ghana/Ghana.hires.report.pdf.
- Mensah, Henry Kofi, and Bachar Ibrahim. "Alternate Solutions Towards Sustainable Irrigated Agriculture in Ghana: Review of Literature," 2017.

BIBLIOGRAPHY

- Mensah-Bonsu, Akwasi, Nancy N. Lartey, and John K. M. Kuwornu. "Gender-Segregated Analysis of the Poultry Value Chain in Ghana." *Gender, Technology and Development* 0, no. 0 (September 26, 2019): 1–35. <https://doi.org/10.1080/09718524.2019.1661611>.
- Ministry of Food and Agriculture. "Investing for Food and Jobs: An Agenda for Transforming Ghana's Agriculture." Republic of Ghana, January 2018.
- . "West Africa Agricultural Transformation Program." Environmental and Social Management Framework. Republic of Ghana: World Bank, May 9, 2018. <http://documents.worldbank.org/curated/en/697441526656174464/pdf/WAATP-Ghana-ESMF-WAATP-MoFA-May-2018.pdf>.
- Ministry of Food and Agriculture, Republic of Ghana. "E-Agriculture Programme." Food and Agriculture Organization of the United Nations, March 15, 2017. <http://www.fao.org/e-agriculture/news/ghana-e-agriculture-programme-ministry-food-and-agriculture-republic-ghana>.
- Ministry of Foreign Affairs of the Netherlands. "Ghana Climate Change Profile." Reliefweb, April 2018.
- Munthali, Nyamwaya, Cees Leeuwis, Annemarie van Paassen, Rico Lie, Richard Asare, Ron van Lammeren, and Marc Schut. "Innovation Intermediation in a Digital Age: Comparing Public and Private New-ICT Platforms for Agricultural Extension in Ghana." *NJAS - Wageningen Journal of Life Sciences*, Diagnostics of case studies on environmental virtual observatories for connective action, 86–87 (November 1, 2018): 64–76. <https://doi.org/10.1016/j.njas.2018.05.001>.
- Murken, Lisa, Christoph Gornott, Paula Aschenbrenner, Abel Chemura, Fred Hattermann, Hagen Koch, Jascha Lehmann, et al. "Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ghana's Agriculture Sector." Potsdam Institute for Climate Impact Research & Deutsche Gesellschaft für Internationale Zusammenarbeit, May 2019.
- Mutenje et al., 2019.
- Naab, Francis Z., Zaid Abubakari, and Abubakari Ahmed. "The Role of Climate Services in Agricultural Productivity in Ghana: The Perspectives of Farmers and Institutions." *Climate Services* 13 (January 2019): 24–32. <https://doi.org/10.1016/j.cliser.2019.01.007>.
- NCD Support Programme. "Ghana." UNDP. Accessed September 15, 2019. http://www.gh.undp.org/content/ghana/en/home/projects/ndc_sp_gh.html.
- NDC Support Programme. "NDC Facts." UNDP. Ghana, 2018. <https://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/africa/ghana.html>.
- NewVision. "Converting Sweet Potato Garbage into High Quality Livestock Feed." October 26, 2017. http://www.newvision.co.ug/new_vision/news/1464515/converting-sweet-potato-garbage-quality-livestock-feed.
- Nowak et al., 2019.
- Nuddin, Andi, Muhammad Arsyad, Muhammad Ikbal Putera, Nuringsih Nuringsih, and Temesgen Tilahun Teshome. "Making the Case for Institutional Support on Designing Agroforestry Technology Models for Rehabilitating Critical Lands." *Forest and Society* 3, no. 1 (April 23, 2019): 49–63. <https://doi.org/10.24259/fs.v3i1.5975>.
- Nutsukpo, D.K., A. Jalloh, R. Zougmore, G.C. Nelson, and T.S. Thomas. "Chapter 6 – Ghana." In *West African Agriculture and Climate Change*. IFPRI & CGIAR, 2012. <http://www.ifpri.org/sites/default/files/publications/rr178ch06.pdf>.
- Nyantakyi-Frimpong, Hanson. "Combining Feminist Political Ecology and Participatory Diagramming to Study Climate Information Service Delivery and Knowledge Flows among Smallholder Farmers in Northern Ghana." *Applied Geography* 112 (November 1, 2019): 102079. <https://doi.org/10.1016/j.apgeog.2019.102079>.
- Obwanga, Benson, Eugene Rurangwa, Arie van Duijn, Katrine Soma, and Catherine Kilelu. "A Comparative Study of Aquaculture Sector Development in Egypt, Ghana and Nigeria:," n.d., 36.

BIBLIOGRAPHY

- Oduro, Kwame Antwi, Bas Arts, Boateng Kyereh, and Godefridus Mohren. "Farmers' Motivations to Plant and Manage On-Farm Trees in Ghana." *Small-Scale Forestry* 17, no. 3 (September 1, 2018): 393–410. <https://doi.org/10.1007/s11842-018-9394-5>.
- Olesen, J., N. Chirinda, and S. Adiku. "Climate Change Impacts on Crop Productivity and Possible Adaptations in Ghana." *Ghana Policy Journal Edition on Climate Change*, 2013. <http://dspace.africaportal.org/jspui/bitstream/123456789/34938/2/gpj-v5-n4.pdf?1>.
- Onumah, Edward Ebo, Justina Adwoa Onumah, and Gideon Edu Onumah. "Production Risk and Technical Efficiency of Fish Farms in Ghana." *Aquaculture* 495 (October 1, 2018): 55–61. <https://doi.org/10.1016/j.aquaculture.2018.05.033>.
- Oppong-Apene, Kwame. "Cassava as Animal Feed in Ghana: Past, Present and Future." Accra, Ghana: FAO, 2013.
- Organization for Economic Cooperation and Development. "A Comparative Analysis of Institutional Mechanisms to Promote Policy Coherence for Development." Paris, 2004.
- Osei, Richard, Stefan Zerbe, Volker Beckmann, and Aristotle Boaitey. "Socio-Economic Determinants of Smallholder Plantation Sizes in Ghana and Options to Encourage Reforestation." *Southern Forests: A Journal of Forest Science* 81, no. 1 (January 2, 2019): 49–56. <https://doi.org/10.2989/20702620.2018.1490992>.
- Owusu, Alex Barimah, Paul W. K. Yankson, and Stephen Frimpong. "Smallholder Farmers' Knowledge of Mobile Telephone Use: Gender Perspectives and Implications for Agricultural Market Development." *Progress in Development Studies* 18, no. 1 (January 2018): 36–51. <https://doi.org/10.1177/1464993417735389>.
- P. Udawatta, Ranjith, Lalith Rankoth, and Shibu Jose. "Agroforestry and Biodiversity." *Sustainability* 11, no. 10 (January 2019): 2879. <https://doi.org/10.3390/su11102879>.
- Palloni, G., J. Aker, D. Gilligan, M. Hidrobo, and N. Ledlie. "Paying for Digital Information: Assessing Farmers Willingness to Pay for a Digital Agriculture and Nutrition Service in Ghana." *AgEcon Search*, 2018. <https://doi.org/10.22004/ag.econ.277451>.
- Pandi, Janet. "Promoting Sweet Potato as Animal Feed." *The National* (blog), August 3, 2015. <https://www.thenational.com.pg/promoting-sweet-potato-as-animal-feed-2/>.
- Parish, Jane A. "Feeding Sweet Potatoes to Beef Cattle." Mississippi State University, n.d.
- Partey, Samuel T., Naresh V. Thevathasan, Robert B. Zougmore, and Richard F. Preziosi. "Improving Maize Production through Nitrogen Supply from Ten Rarely-Used Organic Resources in Ghana." *Agroforestry Systems* 92, no. 2 (April 1, 2018): 375–87. <https://doi.org/10.1007/s10457-016-0035-8>.
- Partey, Samuel T., Robert B. Zougmore, Mathieu Ouédraogo, and Bruce M. Campbell. "Developing Climate-Smart Agriculture to Face Climate Variability in West Africa: Challenges and Lessons Learnt." *Journal of Cleaner Production* 187 (June 2018): 285–95. <https://doi.org/10.1016/j.jclepro.2018.03.199>.
- Potsdam Institute for Climate Impact Research. "Climate Risk Analysis and Adaptation in Ghana's Agriculture Sector." Guidance note for policy makers. Deutsche Gesellschaft für Internationale Zusammenarbeit, April 2019.
- . "Climate Risk Profile: Ghana." Deutsche Gesellschaft für Internationale Zusammenarbeit & Federal Ministry for Economic Cooperation and Development, June 2019.
- Prensa Presidencia. "Climate Ambition Alliance: Nations Push to Upscale Action by 2020 and Achieve Net Zero CO2 Emissions by 2050." Gobierno de Chile, September 23, 2019. <http://prensa.presidencia.cl/comunicado.aspx?id=102021>.
- Priestly, Michael. "Ghana's Broiler Sector to Get Leg-up from Revitalization Project." The Poultry Site, July 16, 2014. <https://thepoultrysite.com/news/2014/07/ghanas-broiler-sector-to-get-legup-from-revitalization-project>.

BIBLIOGRAPHY

- “Probability Management,” n.d. <https://www.probabilitymanagement.org/s/SIP-Standard-Version-211.pdf>.
- Research Program on Roots, Tubers, and Bananas. “Cassava as Animal Feed in Africa: Taking Advantage of Expanding Cultivation.” CGIAR, October 24, 2013. <http://www.rtb.cgiar.org/blog/2013/10/24/cassava-as-animal-feed-in-africa-taking-advantage-of-expanding-cultivation/>.
- . “Roots, Tubers, and Bananas.” Proposal. CGIAR, July 2016. <http://www.rtb.cgiar.org/publication/view/rtb-proposal-2017-2022-volume-iii/>.
- Reuters. “Chocolate Gold: Ivory Coast and Ghana Set a Fixed Price for Cocoa.” Aljazeera, August 9, 2019. <https://www.aljazeera.com/ajimpact/chocolate-gold-ivory-coast-ghana-set-fixed-price-cocoa-190806221440295.html>.
- Rhebergen, Tiemen, Thomas Fairhurst, Anthony Whitbread, Ken E. Giller, and Shamie Zingore. “Yield Gap Analysis and Entry Points for Improving Productivity on Large Oil Palm Plantations and Smallholder Farms in Ghana.” *Agricultural Systems* 165 (September 1, 2018): 14–25. <https://doi.org/10.1016/j.agsy.2018.05.012>.
- Rhebergen, Tiemen, Thomas Fairhurst, Shamie Zingore, Myles Fisher, Thomas Oberthur, and Anthony Whitbread. “Climate, Soil and Land-Use Based Land Suitability Evaluation for Oil Palm Production in Ghana.” *European Journal of Agronomy* 81 (November 1, 2016): 1–14. <https://doi.org/10.1016/j.eja.2016.08.004>.
- . “Climate, Soil and Land-Use Based Land Suitability Evaluation for Oil Palm Production in Ghana.” *European Journal of Agronomy* 81 (November 1, 2016): 1–14. <https://doi.org/10.1016/j.eja.2016.08.004>.
- Rick et al, 2018.
- Rosenstock, Todd S, Christine Lamanna, Sabrina Chesterman, Patrick Bell, Aslihan Arslan, Meryl Richards, Janie Rioux, et al. “The Scientific Basis of Climate-Smart Agriculture.” Working Paper. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security, 2015.
- Ruml, Anette, and Matin Qaim. “Effects of Marketing Contracts and Resource-Providing Contracts in the African Small Farm Sector: Insights from Oil Palm Production in Ghana.” AgEcon Search, 2019. <https://doi.org/10.22004/ag.econ.289547>.
- Scott, G.J. “Roots, Tubers, Plantains and Bananas in Animal Feeding.” FAO, 1989. <http://www.fao.org/3/T0554E/T0554E13.htm>.
- Segoe, R. “Climate Change and Root Crop Production in Ghana.” EPA, 2006. http://www.nlcap.net/fileadmin/NCAP/Countries/Ghana/ROOT_TUBERS_DRAFT_FINAL_REPORT.pdf.
- Sejian, V., M. Bagath, G. Krishnan, V. P. Rashamol, P. Pragna, C. Devaraj, and R. Bhatta. “Genes for Resilience to Heat Stress in Small Ruminants: A Review.” *Small Ruminant Research* 173 (April 1, 2019): 42–53. <https://doi.org/10.1016/j.smallrumres.2019.02.009>.
- Sekyi-Annan, Ephraim, Bernhard Tischbein, Bernd Diekkrüger, and Asia Khamzina. “Performance Evaluation of Reservoir-Based Irrigation Schemes in the Upper East Region of Ghana.” *Agricultural Water Management* 202 (April 1, 2018): 134–45. <https://doi.org/10.1016/j.agwat.2018.02.023>.
- Signs, Mia, and Matthew McCartney. “Fish in Irrigation Systems: An Ancient Practice May Be the Way of the Future!” CGIAR Water, Land and Ecosystems. *Thrive* (blog), September 2, 2019. <https://wle.cgiar.org/thrive/2019/09/02/fish-irrigation-systems-ancient-practice-may-be-way-future>.
- Slavova, Mira, and Stan Karanasios. “When Institutional Logics Meet Information and Communication Technologies: Examining Hybrid Information Practices in Ghana’s Agriculture.” *Journal of the*

BIBLIOGRAPHY

- Association for Information Systems* 19, no. 9 (September 30, 2018).
<https://aisel.aisnet.org/jais/vol19/iss9/4>.
- SNV. "Cocoa Eco-Project," 2019. <http://www.snv.org/project/cocoa-eco-project>.
- Statistics, Research, and Information Directorate. "Agriculture in Ghana." Facts and Figures. Ministry of Food and Agriculture, October 2016. https://www.agrofood-westafrica.com/fileadmin/user_upload/messen/agrofood-WestAfrica/Brochure/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf.
- Sumberg, James, Martha Awo, and George T.-M. Kwadzo. "Poultry and Policy in Ghana: Lessons from the Periphery of an Agricultural Policy System." *Development Policy Review* 35, no. 3 (2017): 419–38. <https://doi.org/10.1111/dpr.12223>.
- Tanaka, Tomomi, Camille Nuamah, and Michael Geiger. "Ghana's Challenges: Widening Regional Inequality and Natural Resource Depreciation." World Bank Blogs, December 14, 2018. <http://blogs.worldbank.org/africacan/ghanas-challenges-widening-regional-inequality-and-natural-resource-depreciation>.
- The Hershey Company. "Three-Year Study Concludes That CocoaLink 'Significantly Improved the Livelihoods' of Ghanaian Cocoa Farmers." *Business Wire*. March 18, 2014. <https://www.businesswire.com/news/home/20140318005928/en/Three-Year-Study-Concludes-CocoaLink-%E2%80%9CSignificantly-Improved-Livelihoods%E2%80%9D>.
- The World Bank. "Ghana - Commercial Agriculture Project." The World Bank, May 8, 2018. <http://documents.worldbank.org/curated/en/520451527996621206/Ghana-Commercial-Agriculture-Project>.
- . "Ghana - Fourth Agriculture Development Policy Operation Project." The World Bank, September 28, 2015. <http://documents.worldbank.org/curated/en/863071467987836148/Ghana-Fourth-Agriculture-Development-Policy-Operation-Project>.
- . "Ghana - Greater Accra Resilient and Integrated Development Project." The World Bank, May 9, 2019. <http://documents.worldbank.org/curated/en/675901559440929710/Ghana-Greater-Accra-Resilient-and-Integrated-Development-Project>.
- . "Ghana - West Africa Regional Fisheries Program (GEF)." Projects and Operations, August 25, 2019. <http://www.projects.worldbank.org/P124812/ghana-west-africa-regional-fisheries-program-gef?lang=en>.
- . "Ghana: Second Additional Financing for Sustainable Land and Water Management Project." Projects and Operations, May 20, 2016. <http://www.projects.worldbank.org/P157595?lang=en>.
- The World Bank Group. "Agriculture Observatory." April 2019.
- . "Ghana." Data, 2019. <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=GH&view=chart>.
- Torbaghan, Mehran Eskandari, and Michael Burrow. "Small Town Water Supply Infrastructure Costs," April 2019. <https://opendocs.ids.ac.uk/opendocs/handle/123456789/14487>.
- UN Communications Groups. "The Sustainable Development Goals in Ghana." United Nations Development Programme, November 2017.
- UNDESA. "World Population Prospects: The 2017 Revision, Key Findings and Advance Tables." Working Paper, 2017. https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.
- UNDP. "Strengthening Resilience of Rural Women through Dry Season Farming in Ghana." Accessed October 19, 2019. <https://www.gh.undp.org/content/ghana/en/home/presscenter/articles/2019/strengthening-resilience-of-rural-women-through-dry-season-farmi.html>.
- United Nations. "Digital Agriculture: Feeding the Future." Project Breakthrough, 2019. <http://breakthrough.unglobalcompact.org/disruptive-technologies/digital-agriculture/>.

BIBLIOGRAPHY

- United Nations Development Programme. "Human Development Index," 2017. <http://hdr.undp.org/en/composite/HDI>.
- United States Department of Agriculture. "Ghana Exporter Guide." Gain Report, 2012. <http://goo.gl/lmrBSz>.
- . "Ghana Exporter Guide." Gain Report, 2012. <http://goo.gl/lmrBSz>.
- USAID. "Ghana." Climate Change Risk Profile, 2017. <https://www.climatelinks.org/resources/climate-change-risk-profile-ghana>.
- . "Sustainable Fisheries Management Project (SFMP)." USAID Biodiversity Conservation Gateway, October 2014. <https://rportal.net/biodiversityconservation-gateway/legality-sustainability/fisheries-development/project-search/add-a-project-activity/usaid-ghana-sustainable-fisheries-management-project-sfmp>.
- Villano, Renato, Bright Owusu Asante, and Boris Bravo-Ureta. "Farming Systems and Productivity Gaps: Opportunities for Improving Smallholder Performance in the Forest-Savannah Transition Zone of Ghana." *Land Use Policy* 82 (March 1, 2019): 220–27. <https://doi.org/10.1016/j.landusepol.2018.12.010>.
- Voorhies, Rodger. "OPINION: How to Stop Climate Change Robbing African Farmers of a Brighter Future." *Property Rights*, n.d., 20.
- West Africa Agricultural Productivity Program. "Who We Are," 2015. <http://www.waapp-paao.org/en/content/who-we-are>.
- Weyori, Alirah Emmanuel, Mulubrhan Amare, Hildegard Garming, and Hermann Waibel. "Agricultural Innovation Systems and Farm Technology Adoption: Findings from a Study of the Ghanaian Plantain Sector." *The Journal of Agricultural Education and Extension* 24, no. 1 (January 1, 2018): 65–87. <https://doi.org/10.1080/1389224X.2017.1386115>.
- WHO, and UNFCCC. "Climate and Health Profile: Ghana," 2015. http://apps.who.int/iris/bitstream/10665/208862/1/WHO_FWC_PHE_EPE_15.08_eng.pdf?ua=1.
- World Bank. "Enhancing Financial Inclusion." Economic Update. Ghana, June 2019. <https://www.worldbank.org/en/country/ghana/publication/ghana-economic-update-enhancing-financial-inclusion>.
- . "Fertilizer Consumption (Kilograms per Hectare of Arable Land)." Data, 2016. https://data.worldbank.org/indicator/AG.CON.FERT.ZS?locations=ZG&most_recent_value_desc=true&view=chart.
- . "Ghana Climate Innovation Center." Text/HTML, February 2016. <https://projects.worldbank.org/en/projects-operations/project-detail/P145765>.
- . "Ghana Dashboard." Climate Change Knowledge Portal, 2017. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=GHA&ThisTab=ImpactsVulnerabilities.
- . "Ghana Dashboard." Climate Change Knowledge Portal, 2017. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=GHA&ThisTab=ImpactsVulnerabilities.
- . "Transforming Agriculture for Economic Growth, Job Creation and Food Security." Agriculture Sector Policy Note, June 2017. <http://documents.worldbank.org/curated/en/336541505459269020/text/119753-PN-P133833-PUBLIC-Ghana-Policy-Note-Ag-Sector-Review.txt>.
- World Economic Forum. "Networked Readiness Index." Global Information Technology Report 2016, 2016. <http://wef.ch/29cCKbU>.
- World Resources Institute. "CAIT Climate Data Explorer," 2017. <http://cait2.wri.org/>.
- . "CAIT Climate Data Explorer," 2017. <http://cait2.wri.org/>.

BIBLIOGRAPHY

- . “RELEASE: At UN Summit, New Commitments of Over \$790 Million to Support Climate Adaptation for Over 300 Million Small-Scale Food Producers,” September 23, 2019. <https://www.wri.org/news/2019/09/release-un-summit-new-commitments-over-790-million-support-climate-adaptation-over-300>.
- World Vision. “Food Security & Livelihoods.” Fact Sheet. Agriculture and Food Security, March 21, 2016. <https://www.wvi.org/sudan/publication/food-security-livelihoods-fact-sheet>.
- Worqlul, Abeyou W., Yihun T. Dile, Jaehak Jeong, Zenebe Adimassu, Nicole Lefore, Thomas Gerik, Raghavan Srinivasan, and Neville Clarke. “Effect of Climate Change on Land Suitability for Surface Irrigation and Irrigation Potential of the Shallow Groundwater in Ghana.” *Computers and Electronics in Agriculture* 157 (February 1, 2019): 110–25. <https://doi.org/10.1016/j.compag.2018.12.040>.
- Yaro, J.A. “Building Resilience and Reducing Vulnerability to Climate Change: Implications for Food Security in Ghana.” Friedrich Ebert Stiftung, 2013. <http://library.fes.de/pdf-files/bueros/ghana/10517.pdf>.
- Yet et al, 2020.