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India's Experience with Climate Smart Agriculture

Opportunities for Triangular Cooperation in the Indo-Pacific

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Foreword

India and the U.S. share a common vision for a free and open Indo-Pacific region. India's long-standing engagement in the region makes it a strong development partner and leader. The Asia Foundation through its India- U.S. Triangular Development Partnership (TriDeP), a program funded by USAID, is working toward realizing this vision and strengthening India's and the U.S.'s development cooperation footprint in the Indo-Pacific region and beyond. The program builds on the U.S. government's commitment to strengthen triangular partnership programs with India in the Indo-Pacific region and is informed by the U.S. government's Indo-Pacific Strategy and its Pacific Islands Strategy.

TriDeP seeks to support the Government of India's development assistance in the Indo- Pacific region by identifying countries keen to expand their development partnership with India in sectors defined by their country needs, and by supporting programming based on such identification. Disaster Risk Reduction, Climate Smart Agriculture and Renewable Energy are sectors where India demonstrates policy leadership and technical skills, and thus can provide sustainable solutions. This report presents a diagnostic study that maps India's capabilities in climate smart agriculture, as well as identifying opportunities for India and the developing countries in the Pacific Islands, Southeast Asia, and South Asia to partner for promising solutions.

Over the years, India has enhanced its capabilities to make its agricultural sector more climate resilient and sustainable. Several innovative agricultural practices, technological solutions, inclusive policies, and programs have been introduced by the government and the private sector to help the sector adapt to climate change and its impact on food security and nutrition. Improved financing mechanisms, climate and weather advisory services, ecologically sensitive techniques to respond to the variable geographical and climatic conditions in the country, strengthening farmer producer groups and integrating the needs of women farmers are examples of such efforts.

This research, undertaken by Global AgriSystem Private Limited, presents a diagnostic of the agricultural sector in India and its shift towards climate smart approaches, institutions that have been working towards creating climate resilient solutions, policy and programmatic paradigm shifts, and examples of good practices emerging across the country. The report also includes an analysis of the needs and current gaps in adopting and transitioning to climate smart agriculture practices in the Indo-Pacific region. It identifies opportunities for establishing development cooperation partnerships with countries in the Indo-Pacific in this sector. The study has also identified Indian centers of excellence that can provide context-specific and inclusive solutions to help the proposed partner countries adopt promising, replicable, and scalable solutions that can make their agricultural systems climate resilient which can ultimately enhance food security.

I would like to thank Global AgriSystem Private Limited for undertaking this study led by the Chairman, Gokul Patnaik, IAS (Retd.), and the key research team members, Vijay Sakhuja, Consultant; Suryamani Roul, Director; and Amisha Sharma, Assistant Manager.

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I hope the findings from this report will pave the way for strengthening India's and U.S.'s approach to triangular partnerships in the Indo-Pacific region.

Nandita Baruah
Country Representative – India
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Abbreviations and acronyms

ADB	Asian Development Bank
ADS	Area Development Strategy
PJTSAU, AgHub	Professor Jayashankar Telangana State Agricultural University, AgHub
AI	Artificial Intelligence
AICRPDA	All India Coordinated Research Projects on Dryland Agriculture
APCNF	Andhra Pradesh Community Managed Natural Farming
AIPA	Apex Committee for Implementation of Paris Agreement
APMAS	Mahila Abhivruddhi Society, Andhra Pradesh
APRACA	Asia Pacific Rural and Agricultural Credit Association APRACA
ATMA	State Extension Programmes for Extension Reforms
AWD	Alternate Wetting Drying
BBF	Broad Bed and Furrow
BISA	Borlaug Institute for South Asia
CAFRI	Climate Adaptation and Finance in Rural India
CBOs	Community-based Organizations
CCAFS	Climate Change, Agriculture and Food Security
CCPI	Climate Change Performance Index
CGIAR	Consultative Group on International Agricultural Research
CHCs	Custom Hiring Centres
CIAT	The International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIWA	ICAR Centre for Women in Agriculture
CoE	Center of Excellence
CRI	Climate Risk Index
CRIDA	Central Research Institute for Dryland Agriculture
CRVs	Climate Resilient Villages
CSA	Climate Smart Agriculture
CSOS	Civil Society Organizations
CSV	Climate Smart Village
DAC & FW	Department of Agriculture and Cooperation and Farmers' Welfare
DCAS	Digital Climate Advisory Services
DSR	Direct Seeded Rice
DST-ICRISAT	Department of Science and Technology- International Crops Research Institute for the Semi-Arid Tropics
EEZ	Exclusive Economic Zone
EU	European Union
FAO	Food and Agriculture Organization
FIRB	Furrow Irrigated Raised Bed
FPO	Farmer Producer Organization
FTF	Feed the Future
GDP	Gross Domestic Product

GESI	Gender Equity and Social Inclusion
GHG	Greenhouse Gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
GoI	Government of India
GP	Gram Panchayat
GAPL	Global AgriSystem Private Limited
GPI	Global Partnership Initiative
GRAVIS	Gramin Vikas Vigyan Samiti
IAAS	Integrated Agro-meteorological Advisory Service
ICAR	Indian Council of Agricultural Research
ICAR-NRRI	Indian Council of Agricultural Research-National Rice Research Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communications Technology
IDPA	India Development Partnership Activity
IFC	International Finance Corporation
IFPRI	The International Food Policy Research Institute
IFS	Integrated Farming Systems
IIFM	The Indian Institute of Forest Management
IIMR	Indian Institute of Millets Research
ILRI	International Livestock Research Institute
IoT	Internet of Things
IREDA	Indian Renewable Energy Development Agency
IRMA	Institute of Rural Management Anand
IRRI	International Rice Research Institute
ITEC	Indian Technical and Economic Cooperation
IWM	Integrating Weed Management
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
KVKs	Krishi Vigyan Kendras
M&E	Monitoring and Evaluation
MANAGE	National Institute of Agricultural Extension Management
MARD	Vietnamese Ministry of Agriculture and Rural Development
MGC	Mekong–-Ganga Cooperation
ML	Machine Learning
MoEFCC	Ministry of Environment, Forest and Climate Change
MoRD	Ministry of Rural Development
MUSP	Mekong–-US Partnership
NAARM	National Academy of Agricultural Research Management
NABARD	National Bank for Agriculture and Rural Development
NAFCC	National Adaptation Fund for Climate Change
NAPCC	National Action Plan on Climate Change
NCDC	National Cooperative Development Corporation
NDRI	National Dairy Research Institute
NFSM	National Food Security Mission
NGOs	Non-Governmental Organizations

NGRCA	The National Gender Resource Centre in Agriculture
NICRA	National Initiative on Climate Resilient Agriculture
NIRD & PR	National Institute of Rural Development and Panchayati Raj
NMAET	National Mission on Agriculture Extension and Technology
NMMI	National Mission on Micro-Irrigation
NMSA	National Mission for Sustainable Agriculture
NPTR	Non Puddled Transplanting Rice
NRLM	National Rural Livelihoods Mission
NSDP	National Strategic Development Plan
OUAT	Odisha University of Agriculture and Technology
PDR	Lao People's Democratic Republic
PJTSAU	Professor Jayashankar Telangana State Agricultural University
PMFBY	Pradhan Mantri Fasal Bima Yojana
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PNG	Papua New Guinea
PRAGATI	Prabhakar Adhikari and Luna Panda
PRIs-SHGs	Panchayati Raj Institutions-Self Help Groups
QIP	Quick Impact Projects
RCM	Rice Crop Manager
RKVY	Rashtriya Krishi Vikas Yojana
SAPCC	State Action Plan on Climate Change
SDG	Sustainable Development Goal
SDSS	Spatial Decision Support System
SEWA	Self-Employed Women's Association
SFAC	Small Farmers Agribusiness Consortium
SHGs	Self Help Groups
SMEs	Small & Medium Agro-Entrepreneurs
SPCR	Strategic Program for Climate Resilience
SPEM	State Poverty Eradication Mission
SPIS	Solar Powered Irrigation System
SRLM	State Rural Livelihoods Mission
SSNM	Site-specific Nutrient Management
SSP	Swayam Shikshan Prayog
TERI	The Energy Research Institute
TrC	Triangular Cooperation
TriDeP	Triangular Development Partnership
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WCRF	Women-led Climate Resilient Farming' Model
WEAI	Women's Empowerment in Agriculture Index
WHR	Warehouse Receipt
WWW	Women's Weather Watch
ZBNF	Zero Budget Natural Farming

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Introduction

Overview of the program

The U.S. and India's geostrategic interests, and a vision for a free and open Indo–Pacific, are balanced by India's commitment to South-South cooperation. India's strong development expertise and experience have benefited third countries in the Indo–Pacific region, contributed to strengthening U.S.–India partnership and fostering regional and global prosperity. Under TriDeP, three sectors are identified to expand India's development cooperation footprint in the Indo–Pacific region. These include climate-smart agriculture (CSA), disaster risk reduction, and renewable energy. The program aims to promote the exchange of ideas and knowledge, technologies, and strengthen cooperation among interested countries, and India, with support from the U.S.

TriDeP intends to establish partnerships with government, civil society, business corporations, think tanks, and academic institutions in countries across the region. Through Indian centers of excellence (CoEs), training institutes, and private sector activities, TriDeP aims to build capacities, forge collaborations, and develop triangular cooperation (TrC) projects to provide targeted assistance. In doing so, TriDeP aims to promote India's strong development expertise, expand joint U.S.–India development cooperation, and foster greater regional prosperity.

In this context, TriDeP draws on The Asia Foundation's six-decade-long experience operating in the Indo–Pacific, its operational infrastructure, and relationships in 18 countries in the region to transfer Indian innovations for addressing climate-related challenges in agriculture. This diagnostic study was undertaken to explore, expand, and establish sustainable TrC and partnerships for CSA.

Defining climate smart agriculture

The Food and Agricultural Organization of the United Nations [1] defines CSA as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gas (GHG) mitigation where possible, and enhances achievement of national food security and development goals." Climate-Smart Agriculture is based on three key pillars (i) Productivity; (ii) Mitigation; and (iii) Resilience and Adaptation. These three pillars are described in Annexure 1. As part of the Sustainable Development Agenda, CSA is directly linked to SDG1 (No Poverty), SDG2 (Zero Hunger), and SDG13 (Climate Action). At the same time, SDG5 is also relevant to CSA as it addresses gender equality. Women are increasingly being seen as more vulnerable than men to the effects of climate change and therefore need special attention. Appropriate systems to reach women farmers need to be put in place, especially considering their time, responsibilities, and social constraints.

CSA and sustainable agriculture

Climate-Smart Agriculture is not distinct from sustainable agriculture; rather, it combines various sustainable methods to tackle the specific climate challenges of a specific farming community [2]. Finding the right combination to manage a farm's climate challenges and building resilience to the future impacts makes CSA "smart."

About 16 Sustainable Agricultural Practices and Systems (SAPSs) use agroecology as an investigative lens. These include [3]: Organic farming, natural farming, agroforestry, system of

Photo Credit: CR Shelare
A farmer inspecting his crop as part of his integrated pest management practice, in an onion field in Maharashtra, India.

rice intensification, precision farming, conservation agriculture, crop rotation and intercropping, cover crops and mulching, integrated pest management, vermicomposting, biodynamic farming, contour farming, integrated farming systems, rainwater harvesting (artificial recharge of groundwater), floating farming, and permaculture.

Even though it is of utmost importance, CSA still faces challenges in disseminating climate smart technologies, tools, and practices. For this reason, CSA requires a full value chain approach that includes tools and technologies and focuses on [4] post-harvest, credit, insurance, market access, supply chain inefficiencies, and climate proofing the value chain.

Through agricultural extension services, climate-specific knowledge, technologies, and practices can be widely shared with farmers, researchers and extension workers [5]. Extension and advisory services play a crucial role in disseminating new information and tools among farming communities, so that they can effectively adopt innovative agricultural practices suitable for their needs. There needs to be greater emphasis on improving adaptation to climate smart agricultural practices among women farmers. Apart from their limitations of time, responsibilities, and social constraints, many of the value chain's requirements are out of their reach, such as the lack of land ownership, credit, access to information about markets and infrastructure and knowledge of agricultural technology.

Study objectives

The main objective of the study is to identify Indian expertise and relevant institutions working on CSA and explore the need for implementing CSA interventions in potential countries in the Indo-Pacific. The study offers a broad understanding of India's CSA landscape and capabilities to expand support to potential countries in the Indo-Pacific through viable TrC project designs.

The CSA supply analysis presents the paradigm shift in Indian agriculture, the impact of COVID-19, prevailing political-economic factors, trends in agricultural technology, technological solutions, institutional architecture of CSA and extension services, gender integration (concepts, practices, interventions, results) in CSA-based responses, relevant institutions, and their competency—both in CSA, and as centers of excellence (CoEs) in third countries. The demand analysis presents the potential partner country's needs, interest in receiving support through development cooperation, current policies, resources, and existing capacities and gaps in CSA. Both the supply and demand analyses have informed key recommendations and viability of CSA partnerships through TrC, identifying any immediate, medium- and long-term challenges and opportunities.

Study methodology

The study includes four main elements: literature review, supply analysis, demand analysis, and an analysis of potential TrC partnerships in the Indo-Pacific. The study has been informed by a mixed methodology approach that includes virtual and personal interviews, and literature review of existing documents, reports, and academic/grey literature. The data sources provided relevant information, evidence, and practices on CSA where support has been offered to countries in the past, as well as identifying opportunities for future triangular partnerships. The report embeds a gender equity and social inclusion lens, offers innovative solutions through AgTech and private sector initiatives on CSA, and maps non-governmental organizations (NGO) programs and collaborative efforts between state governments and development agencies.

The study used both primary and secondary research methods. The primary research was conducted through in-person and virtual interviews with members of different organizations such as MANAGE, NIRD, NAARM, CRIDA, TERI, IIMR, Centre for Sustainable Agriculture, APMAS, AgHub, ICRISAT, NIAM, ICAR-NRM, Digital Green, CropIn, APRACA, Excel Geomatics, GRAVIS, Tanager, IFPRI, JEEViKA, GIZ, among others. The sources for secondary desk research were:

- Academic and research publications
- Government of India (GoI) publications
- Case studies and briefs by organizations implementing CSA approaches and practices

The literature review was based on a search criteria and specific keywords such as climate change indices and Sustainable Development Goals (SDGs), CSA and sustainable agriculture, CSA and weather forecast, policies and programs of CSA, climate smart technologies, institutional systems, gender integration, climate financing, business model for CSA, AgTech in India, CSA and the private sector, and triangular partnerships between India and other countries.

Additionally, two convenings were held, one on the supply side and the other on the demand side, to discuss the findings of the study with CSA experts from the public and private sector, and academia, along with representatives from the United States Agency for International Development (USAID) and GoI. Both the convenings were widely attended, and the participants provided valuable inputs that enriched the study. The study was undertaken from July until December 2021.

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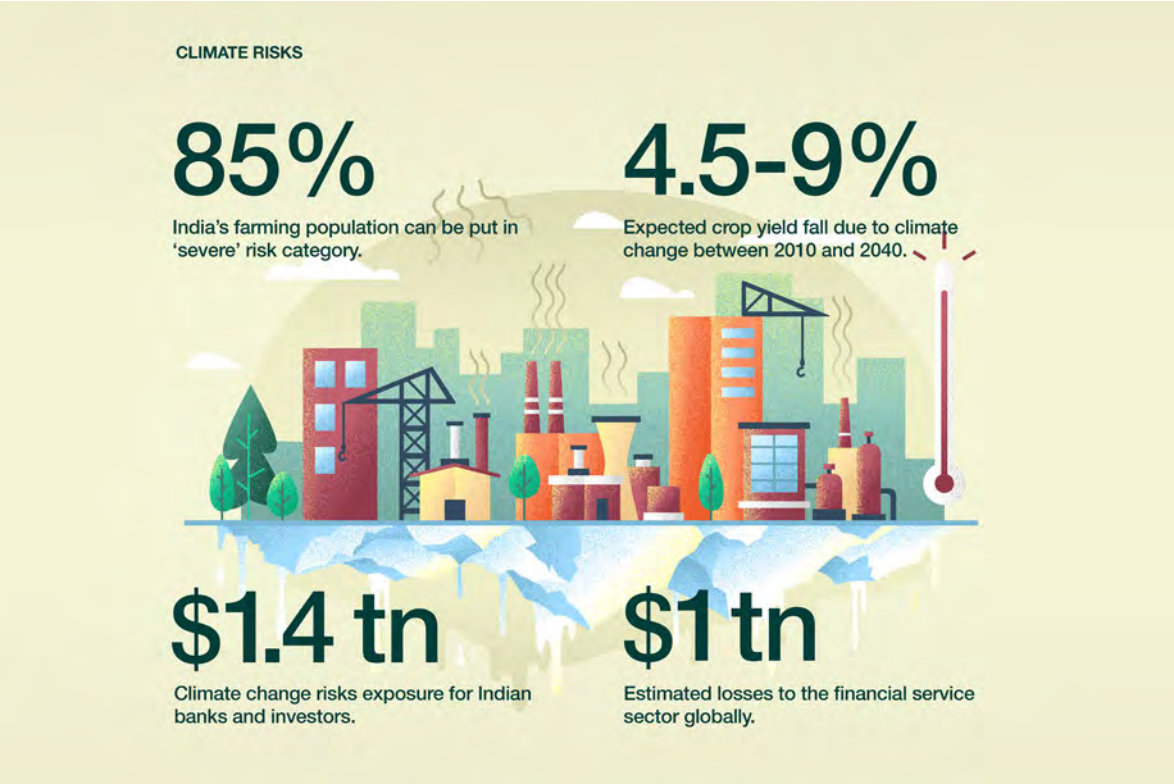
India's experience in climate smart agriculture

India's agriculture landscape and the impact of climate change

The agriculture sector in India has witnessed a series of reforms and transformative measures over the last five years with the mandate to double farmers' incomes [6]. In 2020, India's agriculture sector witnessed a rapid growth. The Economic Survey Report 2020–21 states that India's agricultural sector has become more resilient amid the adversities of COVID-19-induced lockdowns, recording a growth of 3.4 percent at constant prices during 2020–2021 (first advance estimate) [7]. Agriculture cushioned the shock of the Covid-19 pandemic, resulting in an increase in its share in India's GDP to 19.9 per cent in 2020-21 from 17.8 per cent in 2019-20.

The share of agriculture in GDP has reached almost 20 percent for the first time in the last 17 years, making it the only bright spot in GDP performance during 2020–2021. Regarding the need for agriculture reforms, the Economic Survey report notes the paradigm shift in how agriculture is viewed, "from a rural livelihood sector to a modern business enterprise." It questions where women fit in the vision of a "modern business enterprise" that agriculture is ostensibly moving toward. The Economic Survey highlights the challenges faced by women farmers in India, and the strategies needed to empower them.

Climate change disproportionately impacts the lives and livelihoods of smallholder farmers and women farmers in India. According to Census 2011, 65 percent of all female workers and 80 percent of rural female workers depend on agriculture, contributing 55 to 66 percent to total agricultural production. A recent study by McKinsey Global Institute [9]



Source: CAFRI-NABARD Project Brochure [8]

reported that the increasing adversities of climate change may cost Indian GDP US$200 billion by 2030. The report categorizes India as vulnerable to climate change. The challenges of climate change are multidimensional, and it is an important determinant of crop productivity in India, where around two-thirds of the cultivated area is rainfed. A recently published report by the Center for Climate Change Research shows that there is clear evidence of human-induced changes in climate over the Indian region on account of anthropogenic greenhouse gases and aerosol forcing, and changes in land use and land cover, which have contributed to an increase in the climatic extremes. [10]. A report by the Indian Council of Agricultural Research (ICAR) states that crops, plantations, and even livestock in 151 districts (about 20 percent of the total districts in India) are susceptible to the impact of climate change [11]. The Economic Survey 2018 estimated that the adverse effects of climate change led to an annual loss of US$9 to 10 billion. Another report by the ICAR under the National Initiative on Climate Resilient Agriculture (NICRA) states that problems caused by climate change could reduce agricultural yields by up to 9 percent in the medium term (2010–2039). Farmers are especially vulnerable to the effects of climate change and natural disasters like droughts and floods, including loss of crops, livestock, infrastructure, reduced production. and loss of income. According to India's Parliamentary Standing Committee on Agriculture, losses due to the climate crisis are 4 to 9 percent of the agricultural economy each year, which represents an overall GDP loss of 1.5 percent [12]. The Inter-Governmental Panel on Climate Change report provides a grim picture of the looming climate change crisis worldwide. It points out that fossil fuel-based production will contribute to a rising global temperatures at the rate of 1.4 to 1.5 degrees Celsius within the next two decades, leading to an unprecedented increase in catastrophic natural disasters. Women are likely to be the worst affected in this scenario.

India's response to climate risks and creation of policy paradigms

India ranked 7th in the global Climate Risk Index (CRI) in 2021, with a CRI score of 16.67 [13]. Globally, India has a long-standing commitment to combating climate change, being a party to the United Nations Framework Convention on Climate Change (UNFCCC), its Kyoto Protocol, and the Paris Agreement on Climate Change. Independent studies rate India's efforts as compliant with the requirements under the Paris Agreement. According to Burck et al., India ranked 10th in the Climate Change Performance Index (CCPI) in 2021 [14]. The CCPI is an independent monitoring tool to track the climate protection performance of 57 countries and the European Union. Experts say that India's policy frameworks contributed to its high ratings.

The GoI is committed to combating climate change through its many programs and schemes, including the National Action Plan on Climate Change (NAPCC) that was launched in 2008 by the Prime Minister's Council on Climate Change. It comprises missions in the areas of solar energy, energy efficiency, water, agriculture, Himalayan ecosystem, sustainable habitat, green India, and strategic knowledge on climate change. It recognizes the importance of integrating gender in climate change action, which is central to most of the focus areas of the national missions. It acknowledges that adaptive capacities and vulnerabilities to climate change are different for men and women, and India's policies must be gender responsive. The government supports women through various schemes, which generally receive a 30 percent allocation of funds from the total union budget for women's programs. Government initiatives to promote women's participation could provide a blueprint for women-centered activities to counter climate change. Mainstreaming gender equality and social inclusion (GESI) is necessary for planning and designing inclusive and improved

habitats, preserving and creating gender-responsive environments, waste management, and increasing women's participation as key stakeholders.

The foregoing discussion shows that India has taken measures at the policy and planning levels to coordinate efforts toward climate change. In addition, the GoI has initiated a number of programs, such as funding the Climate Vulnerability Atlas under the National Innovations in Climate Resilient Agriculture, to address the impact of climate change and make agriculture more resilient. Moreover, 33 states and union territories have prepared their independent State Action Plans on Climate Change (SAPCC) in line with NAPCC. These SAPCCs outline sector-specific and cross-sectoral priority actions, including climate adaptation. The development of state-level plans presented an opportunity to integrate gender into India's approach to tackling climate change. Many states have made efforts for integrating GESI, which could provide insights on mainstreaming women into climate change programs in agriculture and associated sectors.

Odisha climate change action plan

Concerned about its climatic vulnerability, the government of the Indian state of Odisha drew up a Climate Change Action Plan in 2010, making it one of the first states in the country to have done so. The Plan identified 11 critical sectors for intervention: agriculture, coasts and disasters, energy, fisheries and animal resources, forestry, health, industry, mining, transport, urban planning, and water resources. It highlighted various vulnerabilities faced by women because of climate change. The Plan emphasized the role of women's self-help groups (SHGs) in augmenting social capital and making the community more resilient. It also highlighted the high risk that heat poses to vulnerable groups such as infants, elderly, pregnant women, disabled, farm laborers, etc. [15].

Recognizing the importance of climate change and agriculture, the GoI constituted an inter-ministerial Apex Committee for Implementation of the Paris Agreement (AIPA) in December 2020 for a coordinated response from various ministries involved in policymaking, regulation, and research and development on matters pertaining to climate change with the goal of supporting India's obligations under the Paris Agreement. The concerned ministries and agencies of AIPA include the Ministry of Environment, Forest, and Climate Change as the nodal ministry, along with the Ministries of Science and Technology; Earth Sciences; Power; New and Renewable Energy; Agriculture and Farmers' Welfare; Rural Development; Jal Shakti; Housing and Urban Affairs; Health and Family Welfare; Women and Child Development; Finance; Commerce and Industry; External Affairs; and the public policy think tank NITI Aayog.

Transformative climate adaptation in the Indian context

Climate change is adversely impacting India's agriculture system. Farmers across all agro-climatic zones face serious challenges like erratic weather conditions and extreme temperatures. To cope with such challenges, farmers in India are adopting new options, information, and technology that are helping them transform their farming practices to survive in a changing climate. Various systems like enhanced climate services are being developed to provide climate information to farmers, helping them become resilient and make more climate-informed decisions. Introducing such transformative technologies in agriculture has ensured that crop and livestock production remain viable [16]. It is also widely acknowledged that women farmers are at the center of the climate change crisis as they are impacted differently and more severely than men. Women's farm productivity is lower than men's as they are faced with several limitations, to begin with: less access to information, services, mobility,

markets, decision-making, technology, etc., which, if addressed, could make adaptation to climate change easier for them. Analyzing the gender gap to identify specific gender differences would help design gender-responsive strategies to deal with food insecurity and malnutrition, declining incomes, disaster preparedness, and resilience building, among other ways to cope with climate change impacts.

India's CSA policies and initiatives

India's priority in meeting the challenges posed by climate change on agriculture is focused on the development of adaptation and mitigation strategies. In 2015, the GoI set up the National Adaptation Fund for Climate Change (NAFCC) and identified agriculture as the key area among eight national missions. The NAFCC is a central sector scheme established in August 2015 to meet the cost of adaptation to climate change for the particularly vulnerable states and union territories, and it continues to do so. The projects under the NAFCC prioritize building climate resilience in the areas identified under the SAPCC and the relevant missions under the NAPCC.

The National Bank for Agriculture and Rural Development (NABARD) has been designated as the National Implementing Entity to implement the adaptation projects under the NAFCC by the GoI. Thus, NABARD facilitates the identification of project ideas/concepts from the SAPCC, project formulation, appraisal and sanction, disbursement of funds, monitoring and evaluation, and capacity building of stakeholders, including state governments.

National Initiative on Climate Resilient Agriculture (NICRA)

Launched in 2011 under the ICAR, NICRA is a network project which has strategic cross-disciplinary research components on adaptation and mitigation (covering crops, livestock, fisheries, and natural resource management), providing demonstrations of technologies on farmers' fields while also creating awareness among farmers and other stakeholders on how to minimize the impacts of climate change on agriculture. Eleven sponsored projects and 20 competitive grant projects are also funded as part of this initiative to complement transdisciplinary research. The technology demonstration component of NICRA has been implemented in approximately 151 vulnerable districts to address issues related to climate vulnerabilities such as drought, floods, salinity, frost, cyclone, heat, and cold waves. The National Agricultural Research System has developed location-specific technologies suited to the needs of different agro-climatic conditions, which can help build resilience against climate vulnerability. These technologies like seed treating drums, pedal-operated pumps, drip irrigation methods, transplanters, and many others have been showcased to farmers through participatory mechanisms in the most vulnerable districts of the country through Krishi Vigyan Kendras (KVKs) and several centers of the All India Coordinated Research Projects on Dryland Agriculture (AICRPDA).

Climate smart village (CSV)

Climate smart village (CSV) is a community approach for sustainable agricultural development where farmers, researchers, local partners, and policymakers collaborate to select the most appropriate technological and institutional interventions based on global knowledge and local conditions to increase productivity and incomes, achieve climate resilience, and enable climate mitigation. The Consultative Group on International Agricultural Research (CGIAR) is the leading organization working on the development of CSVs through its research program on Climate Change, Agriculture and Food Security (CCAFS). As a comprehensive approach to sustainable agricultural development, CCAF'S CSVs focus on climate change hotspots in India (along with Africa, Asia, and Latin America) with critical climate smart interventions in key areas to encourage the CSVs to adopt weather-smart activities, water-smart practices, carbon-smart practices, nitrogen-smart practices, energy-smart technologies and practices, and knowledge-smart activities (for more details, see Annexure I).

Livestock and animal husbandry

Livestock contributes significantly to the climate smart food supply system. Several CSA practices in India to manage organic matter and nutrients have already been implemented, directly and indirectly. These practices include fodder management, pasture management, zero grazing, grassland restoration and management, manure management, and crop-livestock integration. Promising interventions by some organizations, which are closely connected with CSA practices, can be considered as good practices for customized technology transfer. These organizations include the National Dairy Research Institute (NDRI); the National Dairy Development Board (NDDB); the Indian Grassland and Fodder Research Institute, Jhansi; Abbott Nutrition in partnership with Prabhat Dairy; Pune's Maval Dairy

Climate smart villages in Andhra Pradesh

APMAS, a Hyderabad-based resource organization, has conceptualized and is engaged in implementing a program on CSVs called the 'Towards Climate Smart Villages'. The program promotes affordable and replicable adaptation and mitigation practices to enhance livelihoods and support people's organizations in vulnerable communities of Ananthapur district in Andhra Pradesh. It is implemented in Muthukuru, Mandhalapalli, and Konkallu gram panchayats (GPs) in Gudibanda Mandal (200 families in each of the three GPs), and Gopipalli and Patabattalapali GPs in Nallamada Mandal (100 families in each of the two GPs) of Ananthapur district. The target communities include 800 beneficiaries and 1,500 indirect beneficiaries comprising small landholders, women-headed households, and vulnerable families.

The major focus areas of the project are:
Climate Smart Institutions: Strengthening peoples' institutions—GPs, FPOs, SHGs, and Federations.
Climate Smart Knowledge: MIS and communication, capacity building, weather, crop and livestock, and advisory services.
Climate Smart Agriculture: Tank silt application. efficient manure management, dung- based inoculants, water management, crop diversification, agroforestry, promoting bio-pesticides, livestock management.
Climate Smart Nutrition: Millet promotion, kitchen gardens.
Climate Smart Energy: Biogas plant, solar pump sets, solar/LED lamps, and energy efficient biomass cooking stoves.

(Source: APMAS document 'Towards Climate Smart Villages')

Photo Credit: Hari Gaddigopula
Farmer in the field at Eluru, Andhra Pradesh, India.

(owned and run by women and set up on the lines of a community dairy model, it is supported by Tata Power); Suguna Poultry; The Goat Trust (based in Lucknow, which promotes small livestock-based livelihoods such as rearing of goat/sheep/backyard birds by demystifying production technology); and the Pashu Sakhi model of JEEViKA, an alternative livestock extension approach implemented by the Aga Khan Foundation in Bihar.

Fisheries and aquaculture

India has vast and varied inland open waters like lakes, reservoirs, wetlands, rivers, and estuaries—the traditional sources of fisheries—that support many landless and poor fishing communities. The impact of climate change is already perceptible in these inland aquatic ecosystems and on fisheries, increasing pressure on livelihoods and food supplies.

Several organizations, including the FAO, World Fish, World Bank, and Asian Development Bank (ADB) advocate minimizing the impacts of climate change on fisheries and aquaculture. Climate smart strategies in fisheries and aquaculture include the dissemination of locally suitable practices and context-specific technologies (for example, promoting integrated crop–fisheries systems), as well as the creation of a supportive enabling environment for change through sound policies, robust institutions, and secure financing: for instance, mainstreaming CSA/fisheries into national agricultural investments.

The Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, has five regional centers across the country that are engaged in research and extension programs in freshwater aquaculture. The institute acts as a leading center of carp farming in India under the Network of Aquaculture Centres in Asia–Pacific.

Forestry and CSA

Climate-smart agriculture in the forest sector entails designing adaptation strategies targeted at the most vulnerable communities of the population (e.g., indigenous population, women, youth, elderly) and forest systems (e.g., drylands, mountain, coastal forests). India's intended nationally determined contributions for climate action emphasize the creation of an additional carbon sink of 2.5 to 3 billion tonnes by 2030 by increasing the country's green cover.

The GoI is implementing policies and programs such as the National Mission on Green India, the National Afforestation Programme, compensatory afforestation, and plantation drives across states to support afforestation and reforestation. In the Union Budget 2020–2021, the overall allocation for the Ministry of Environment, Forest and Climate Change (MoEFCC) increased to ₹3,1000 million for 2020–2021 from ₹2,6579.4 million, with additional support to 27 states for their afforestation efforts under the Compensatory Afforestation Fund Management and Planning Authority.

India is now ranked third globally for an annual net gain in terms of forest area. Several institutions can serve as centers of excellence and can develop effective products in agro-forestry/carbon sequestration mitigation. Examples of such institutes include the Indian Institute of Forest Management (IIFM); Centre for Ecological Sciences; Indian Council of Forestry Research and Education, Dehradun; Environment Protection, Training and Research Institute (EPTRI—an autonomous institute of the Government of Telangana working toward environmental protection and management through research, training, and consultancy); IIPM; IPIRTI; World Agroforestry (ICRAF); International Food Policy Research Institute (IFPRI); and Institute of Wood Science and Technology.

Government programs linked to promotion of CSA

A few government policies and programs that have a direct link with the development of CSA are presented in the chart below [44].

Government policy/program	Water smart	Energy smart	Nitrogen smart	Crop smart	Knowledge smart	Weather smart
Pradhan Mantri Agriculture Irrigation Plan (Pradhan Mantri Krishi Sinchayee Yojana)	Micro irrigation (drip and sprinkler)				Capacity building	
	Water conservation and harvesting					
	Irrigation infrastructure through MGNREGA)					
National Mission for Micro Irrigation	Micro irrigation (2005–2006 to 2013–2014)					
National Mission for Sustainable Agriculture	On-farm water management 2014–2015 Rainfed area development		Soil health card and management			
Rashtriya Krishi Vikas Yojna	Micro irrigation		Integrated nutrient management	Crop diversification and development		
	Natural resource management					
National Food Security Mission	Conservation Agriculture	Resource conservation machines	Integrated nutrient management		Farmers' training	
	Micro irrigation					
National Mission for Horticulture	Micro irrigation			Area rejuvenation		

Government policy/program	Water smart	Energy smart	Nitrogen smart	Crop smart	Knowledge smart	Weather smart
Renewable Power Program		Solar pump sets				
National Mission on Agriculture Extension and Technology		Farm mechanization			Training on improved agronomic practices	
Agriculture Insurance						Pradhan Mantri Fasal Bima Yojana
Weather Advisory						Agro metrology


3

Indian perspective on gender equity and social inclusion in CSA

Around the world, women's leadership in agriculture is increasingly being recognized as key to tackling climate change, with women playing a strong role in adapting to new technology, disseminating information, and urging climate action. In 2020, India ranked 112 out of 153 countries in the World Economic Forum's Global Gender Gap Index. Further, India has one of the lowest economic participation levels and opportunities for women, ranking 149 out of 153 countries [17]. Such gender inequalities, coupled with regressive social norms, stigma, limited mobility, low literacy rate, lack of financial resources, restricted rights, and a muted voice in shaping decisions, make women highly vulnerable to climate change, which is likely to magnify existing patterns of gender disadvantage. However, India also has examples of women's participation in a few exemplary programs:

a) National Mission for Sustainable Agriculture (NMSA) under the NAPCC and the SAPCC of Odisha, Kerala, and Gujarat. The NMSA gauges the level of gender mainstreaming in these state policies. A study conducted by IFPRI in 2015 found that women were more likely to notice impacts of climate change than men on reduced water availability (18 percent versus 9 percent), agricultural productivity (87 percent versus 72 percent), and livestock problems (17 percent versus 8 percent) [18].

b) Women-led Climate Resilient Farming Model (WCRF) [19]—the Swayam Shikshan Prayog (SSP), an NGO based in Pune, has worked extensively on this model. The model uses a preparedness pathway involving women in addressing drought situations, like depletion of groundwater, low crop productivity, uncertain cash flows, and an increase in climate risks. The WCRF is a community-based approach that focuses on building overall resilience among women farmers through knowledge sharing and facilitating access to government schemes in an array of farming and allied livelihoods, including water and water infrastructure.

c) In the deserts of Rajasthan [20], women farmers are adopting farming that can combat the impact of climate change in the drylands. The Gramin Vikas Vigyan Samiti (GRAVIS), along with scientific expertise from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), has worked closely with the local community on these practices. Experiences of the women's self-help group (SHG) model from Kerala, Andhra Pradesh, Bihar, Odisha, and Madhya Pradesh are promising examples of women engaged in climate resilient agriculture practices.

ICAR Centre for Women in Agriculture (CIWA): an example of institutional approach to integrating GESI

The ICAR Women's Centre undertakes research on several issues including gender issues in farming systems, technical assessment, drudgery reduction, policy issues and research methodologies. The Center also provides services (training, extension services, demos, PPP models, gender knowledge center).

The Centre has developed a research model on gender gaps to double farm incomes. They have also developed technology and tools for women; improved goat and poultry rearing; undertaken

research on aquaculture, fisheries, dairying, seeds, and seed production for women; and analyzed rice-based cropping systems, etc.

CIWA's mission is to generate and disseminate knowledge and promote gender-responsive decision-making to enhance women's efficiency and effectiveness in agriculture. As a premier Indian institute promoting GESI in agriculture, the Center can provide expertise on integrating gender in CSA practices as a potential partner in third countries.

Government of India's support to women farmers

The GoI is taking various measures to increase the participation of women farmers in the agriculture sector. The guidelines of the various beneficiary-oriented schemes of the Department of Agriculture and Cooperation and Farmers' Welfare (DAC & FW), Ministry of Agriculture and Farmers' Welfare, provide for states and other implementing agencies to incur at least 30 percent expenditure on women farmers [21]. This includes providing them additional support and assistance under

Photo Credit: Amol Sonar
Women farmers in Hingoli, Maharashtra, India.

separate initiatives: supporting women's food security groups; undertaking macro- and micro-level studies in critical areas related to women in agriculture; delivering gender sensitization modules in training programs at the national, regional, and state levels; compilation and documentation of gender-friendly tools/technologies; farm-women friendly handbook; compilation of good practices/success stories of women farmers, etc.

Some of the programs under which the schemes are included are listed below. These provide an overview of the kind of schemes that have been designed to benefit women farmers, covering many aspects that impact their lives:

- Support to State Extension Programmes for Extension Reforms
- National Food Security Mission
- National Mission on Oilseed and Oil Palm
- National Mission on Sustainable Agriculture
- Sub-Mission for Seed and Planting Material
- Sub-Mission on Agricultural Mechanization
- Mission for Integrated Development of Horticulture under the Deendayal Antyodaya Yojana—National Rural Livelihoods Mission (DAY-NRLM) (Department of Rural Development, Ministry of Rural Development)
- Mahila Kisan Sashaktikaran Pariyojana (MKSP), implemented as a sub-component of DAY-NRLM. This scheme began in 2011 with the objective of empowering women by making systematic investments to enhance their participation and productivity and create sustainable livelihoods for rural women. The program is implemented in project mode through the State Rural Livelihoods Mission (SRLM).

Women farmers are being trained under various schemes of the Department of Agriculture and Farmers' Welfare (DA & FW) and DAY-NRLM to familiarize them with the latest techniques in agriculture and allied sectors. These include:

- Support to State Extension Programs for Extension Reforms under the sub-mission on agriculture extension. This includes the dissemination of technological solutions through an Agricultural Technology Management Agency (ATMA) at the district level for operationalizing extension reforms.
- Skill training courses in agriculture and allied areas (minimum 200 hours duration) for farmers, including women farmers, through national training institutes, State Agricultural Management and Extension Training, KVKs, and State Agricultural Universities across the country.
- Under DAY-NRLM, trainings on agro-ecological practices are provided by community resource persons.

Other organizations focusing on gender and social inclusion in agriculture

Self-Employed Women's Association (SEWA): The SEWA movement originated in Ahmedabad, Gujarat. In order to safeguard farmers, both women and men, against climate and market shocks, SEWA initiated an integrated farm planning and management package that includes technological interventions at multiple stages—such as but not limited to, providing access to technical trainings and agri-advisory inputs, establishing a tool and equipment library, spot and future prices, offering customized rainfall insurance products, affordable access to farm-top renewable energy, access to finance and credit, market support, etc., incorporating digitization, and generating smart secondary source of employment to supplement traditional livelihoods.

SEWA runs an agriculture campaign with a three-pronged framework: agriculture, water, and energy. There are four major pillars of the campaign: (1) organizing, capacity building, and access to technical services; (2) access to agriculture inputs; (3) financial services; and (4) market linkages. Climate resilient

practices have been gradually interwoven in this model over the past few decades. This helps its members make structural transformations to become fully self-sustainable and profitable. These four pillars helped SEWA etch out a working model of agriculture development that emphasizes developing the farm as an enterprise, shifting the focus from mere subsistence to viability and profitability.

SEWA has successfully linked over 60 percent of its small farmer members in 14 districts of Gujarat to the government's Khedut Mitra App.

Kudumbashree: This is the poverty eradication and women's empowerment program implemented by the State Poverty Eradication Mission (SPEM) of the state Government of Kerala. Under the leadership of Kudumbashree, smart agri-villages have been established across the state. The program was launched to improve the livelihoods and food security of landless women through land leasing. The Kudumbashree intervention under the project involved the setting up of women's federations at the village, block, and district levels. Currently, the Kudumbashree initiative supports women farmers as a project implementation agency of the MKSP as a sub-component of the NRLM to improve the present status of women in agriculture and to enhance opportunities for their empowerment. In addition, the Samruthi campaign has also been taken up to strengthen Kudumbashree's farm livelihood sector by including more farmers and bringing more area under cultivation. Under this scheme, launched in 2018–2019, 38,865 farmers have brought 2,742.4 hectares under cultivation.

Photo Credit: Ashish
Women farmers working their wheat fields during harvest season, winnowing wheat grains from chaff in Gujarat, India.

4

New ideas and emerging CSA solutions from India

Given the challenges of climate change, the concept of CSA is gaining traction in the Indian context to cope with and address the issues. There is no definite stage by which the goal of achieving CSA can be said to have been fully realized. It is rather a journey and direction in which various climate smart agricultural practices and technologies are adopted. These practices and technologies strengthen and contribute to the path leading to climate smartness in agriculture. Thus, CSA requires both adaptation to climate change and as well as strategies to mitigate it. For instance, strategies like sustainable agriculture and zero budget natural farming (ZBNF), private sector engagement in CSA, farmer producer organizations (FPOs) as platforms for CSA popularization, weather index-based crop insurance, new financial products supporting adoption of climate smart agriculture technologies, DCAS, use of renewable energy for agriculture, etc., are proven strategies that can be applied in the Indian context.

India has developed new technologies and practices to address climate change. Some that have been successfully implemented are:

Zero budget natural farming (ZBNF): This is a form of chemical-free farming where the total cost of growing and harvesting plants works out to zero (the costs incurred by the farmers are recovered through intercropping). It is an effective cross-sectoral strategy for achieving SDG targets (14 out of the 17 SDGs), including the status of natural resources, the health of communities, access to secure nutrition, and empowerment of women.

It has spread across several states and proven successful in south India, especially in Karnataka, where it first evolved. The movement in Karnataka was born out of a collaboration between Subhash Palekar, who put together the ZBNF practices, and the State Farmers' Association Karnataka Rajya Raitha Sangha (KRRS), a member of La Via Campesina[1] (LVC).

In Andhra Pradesh, ZBNF was launched in September 2015 under the GoI's Rashtriya Krishi Vikas Yojana. Fifty villages across 13 districts were selected for the pilot project. A few districts like Anantapur, Kadapa, Kurnool, and Chittoor are traditionally drought-prone, and there are many villages that witness dry spells for a month. In these areas, the scheme has helped boost agricultural land productivity [22].

Private sector engagement and CSA: While India has made significant strides in climate change mitigation, the International Finance Corporation (IFC) believes that demonstrating the business side of emerging climate smart practices and technologies will allow the private sector to scale up adaptation and build resilience faster. The agriculture cooperatives, FPOs, and community-based organizations (CBOs) also help promote CSA technologies in many locations. The examples of DCM Shriram Ltd., Golchha Organization, Hindustan Coca-Cola Beverages Pvt. Ltd., Jain Irrigation Systems Ltd., JK Paper Ltd., Mountain Hazelnut Venture India Pvt. Ltd. ("Mountain Hazelnuts"), Bigbasket.com, Olam International Ltd., and Supreme Seed Company Ltd. could be considered examples of CSA technology models. Many others like ITC Ltd., PepsiCo, Solvay,

1 A global organization and farmers' movement formed in 1993 in Belgium. It coordinates peasant organizations of small- and middle-sized producers, agricultural workers, rural women, and indigenous communities from Asia, Africa, Europe, and America.

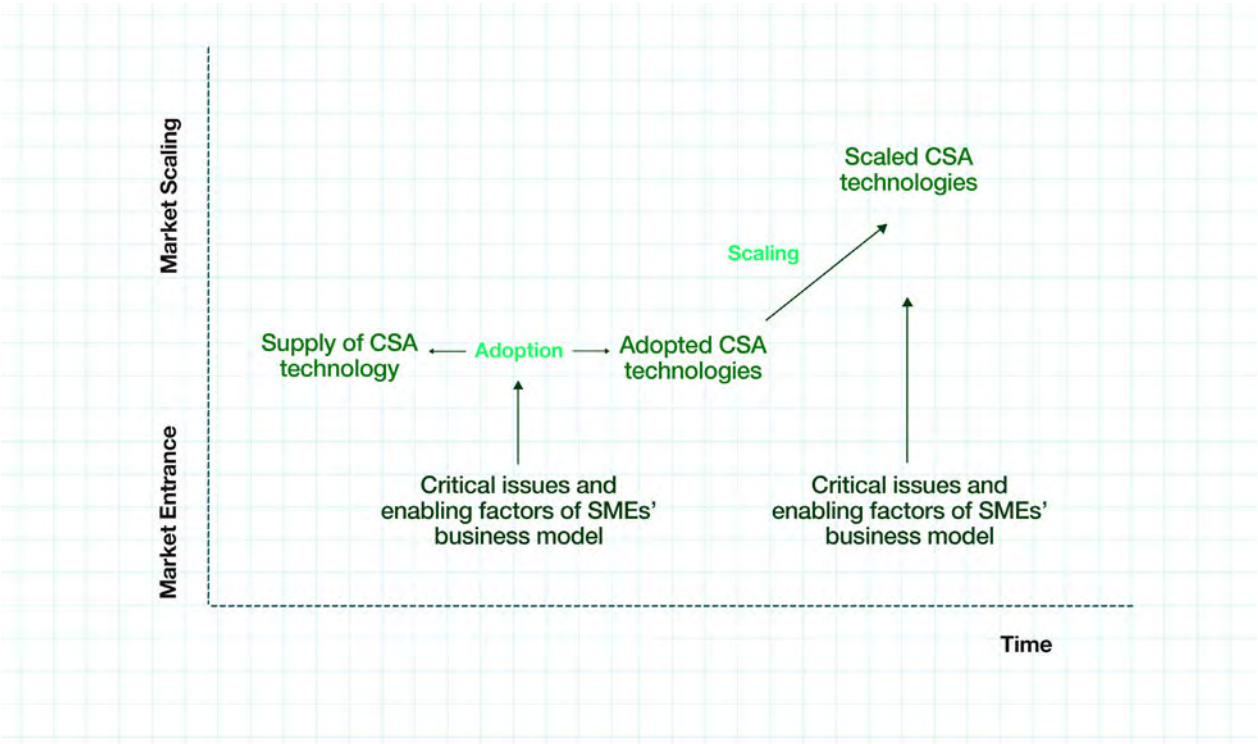
L'Oréal, Cargill Pvt. Ltd., Pioneer Seeds, Mars India, and Kellogg's actively promote CSA through the farmers associated with them for sourcing produce.

Farmer producer organizations as instruments and platforms for CSA: An FPO is an organization in which farmers themselves are members. "Farmers, who are the producers of their agricultural products, can form the groups and register themselves, under the Indian Companies Act [23]." According to recent GoI guidelines, each FPO, barring those in hilly areas and the north-eastern states, should have a minimum of 300 farmer members, and 50 percent of them should be small, marginal, and landless tenant farmers with the maximum possible representation of women farmers. An FPO's major operations include the supply of seed, fertilizer, and machinery, market linkages, training and networking, and financial and technical advice. Many FPOs in India (7,374 in various stages of growth as per a study undertaken by Azim Premji University in 2020) are engaged in procuring agricultural produce from member farmers, undertaking aggregation and storage, value addition and packaging, input services, extension and training, custom hiring centers, etc [24].
The new guidelines issued in 2020 by the Ministry of Agriculture for the formation of FPOs through three apex central agencies—NABARD, Small Farmers Agribusiness Consortium (SFAC), and National Cooperative Development Corporation (NCDC), along with the respective state-implementing agencies and the National Agricultural Cooperative Marketing Federation of India—is a big step forward to benefit many farmers.

Weather index-based crop insurance: Crop insurance programs like Pradhan Mantri Fasal Bima Yojana (PMFBY) and Integrated Agro-meteorological Advisory Service (IAAS) have helped farmers maximize income from crop production by assisting them in coping with current, short-term climate-induced risk.

Business models, transfer of CSA technology, and financing: NABARD, the apex national bank in the agriculture and rural development sector, has a

Figure 1: Conceptual framework to identify critical issues and enabling factors in the adoption and scale-up of CSA



major role, and international organizations like the World Bank, ADB, Japan International Cooperation Agency (JICA), GIZ, United Nations Development Programme, and International Fund for Agricultural Development (IFAD) make a point of including CSA in any investment decisions. Agriculture in India is largely reliant on subsistence farming, organic farming, and industrial/commercial/ intensive farming, therefore making CSA an important approach to farming. However, the commercialization of CSA technologies and their transfer will rely on the business model depicted in Figure 1 [25].

A study in Punjab shows that the business models of small and medium agro entrepreneurs (SMEs) are successful in scaling CSA technologies. This is enabled by the mix of drivers, including scientific and practical evidence of CSA technologies, a good partnership between SMEs and researchers, excellent customer relationships, and effective channels through farmers' field trials and demonstrations in CSVs. Research institutes such as the International Maize and Wheat Improvement Centre (CIMMYT) and the Borlaug Institute for South Asia (BISA) are working closely with farmer cooperatives and service providers in CSVs. Participatory field trials have generated knowledge on the agricultural and socioeconomic effects of CSA technologies, which is necessary to assess the viability of the business model. There are 1,609 farmer cooperatives in Punjab, of which 1,308 were viable during 2015–2016. There are 719,460 members in cooperatives. Cooperatives cover 88.18 percent of a total of 6,687 villages in Punjab. According to the director of BISA, there are approximately 13,000 service providers in the business of selling CSA technologies to farmers [26].

Digital climate advisory services (DCAS): These services are climate related advisories and services delivered via digital tools and platforms. They include online portals, mobile applications, and more traditional digitally enabled formats like radio and interactive voice response systems. Digital technology solutions for farmers, including DCAS, have significantly risen in India over the last decade (see Annexure IV). Key supply side drivers have ensured that a wide range of farmer advisory and service applications are available. The rich offerings, mainly through means of bundling, have also increased the demand for advisory services. Networks have played a role in the faster adoption of DCAS among farmers in India.

5

CSA technologies and cropping systems

In their overview of CSA technologies around the world, the International Center for Tropical Agriculture (CIAT)/CCAFS and the World Bank [27] have identified 44 CSA technology clusters and assessed more than 1,700 combinations of CSA technologies and cropping systems. They found that just five technology groups account for 50 percent of all technologies considered climate-smart. These technologies are also in alignment with the FAO's *Climate-Smart Agriculture Sourcebook*.

Successful CSA technologies and cropping systems in India

Some of the successful climate resilient practices and technologies that have the potential for scaling out through various schemes under the National Action Plan for Climate Change, particularly under the¬ NMSA, are [28]:

- **Land shaping:** This technology has been developed by ICAR-CSSRI (Central Soil Salinity Research Institute). Through the excavation of lowland fields and the use of the dugout pond for rainwater harvesting and dugout soil to raise the adjacent field area, a model for rainwater harvesting in kharif (monsoon season), vegetable cultivation during rabi (winter season), and fresh-water fish culture has been developed in the coastal region of West Bengal, which is ecologically vulnerable to climatic variability such as cyclones and floods that wreak havoc on agriculture and the livelihoods of farmers [29].

- **Paddy nursery:** Under NICRA, this local strategy of staggered community paddy nurseries has been successfully adapted by farmers in Affaur village of Saran district (Bihar) to combat the problem of deficit rainfall in lowlands [30].

- **Direct seeding rice:** This is an alternative to transplanted rice and has emerged as an efficient resource conservation technology. It became popular in rainfed rice-growing states like Chhattisgarh, Odisha, Andhra Pradesh, and now in Punjab and Uttar Pradesh [31].

- **Drum seeding technique:** The technique involves sowing pre-germinated seeds in a well-puddled and leveled land through drums arranged in a row for dispensing seeds. This technique has been demonstrated under NICRA in Aurangabad, Jehanabad, Saran (Bihar), Gonda, Sonbhadra (Uttar Pradesh), Khammam, Nalgonda (Telangana), West Godavari, Anantapur, Kurnool, Srikakulam (Andhra Pradesh), and Alappuzha (Kerala), and has shown an average yield increase of 9 to 29 percent [32].

- **Drought-tolerant paddy varieties:** Under NICRA, drought-tolerant paddy varieties were demonstrated on 185 ha, covering 463 farmers in Buxar, Jehanabad, Saran, Aurangabad, Supaul in Bihar; Koderma, Gumla, Chatra, East Singhbhum and Palamu in Jharkhand; Jharsuguda, Sonepur and Ganjam in Odisha; Bilaspur in Chhattisgarh; East Sikkim; and Port Blair [33].

- **Crop diversification (intercropping):** Several World Bank-led joint programs such as the program on climate resilient agriculture (PoCRA), Odisha Integrated Irrigation Project for Climate Resilient Agriculture (OIIPCRA), and diversified agriculture programs could be mined as there are sufficient knowledge capsules for public system integration (water, soil conservation, Water and Land Management Institute [WALMI], etc.) dealing in this subject. Intercropping was demonstrated over 2,654 ha, covering 2,033 farmers in Kathua (Jammu & Kashmir); Hamirpur, Chamba (Himachal Pradesh); Ropar (Punjab); Saran, Jehanabad, Supaul (Bihar);

Photo Credit: CR Shelare
Aerial view of farmers working in a drought tolerant agricultural field.

Sonitpur, Dhubri (Assam); Sonepur, Kendrapara (Odisha); Dantewada, Bilaspur (Chhattisgarh); Gondia, Amravati, Aurangabad (Maharashtra); Kushinagar, Chitrakoot (Uttar Pradesh); Kutch, Valsad (Gujarat); Satna, Datia (Madhya Pradesh); Nalgonda, Anantapur (Andhra Pradesh); Davangere (Karnataka), and Nammakal (Tamil Nadu), with a yield advantage ranging from 10.5 to 85.2 percent [34] [35].

- **Integrated farming systems (IFS):** It is the system that supports the integration of agriculture with related subsidiary enterprises like livestock, poultry, piggery, fish, and duck rearing and has been experimented in NICRA villages. The system has helped in maximizing production and increasing total household income. It has been successfully demonstrated in places like Jodhpur, Bikaner (Rajasthan); Haryana, Punjab, and north-eastern states [36].

- **Custom hiring centers (CHCs):** Established in NICRA villages for farm machinery (such as rotavator, rainwater drill, drum seeder, multi-crop planter, power weedier, and chaff cutter), CHCs (also known as farm equipment centers) have helped mechanization of small farms in Andhra Pradesh, Assam, Gujarat, Punjab, Himachal Pradesh, Meghalaya, Madhya Pradesh, Tripura, and Jammu & Kashmir [37].

- **Improved planting methods (broad bed and furrow [BBF]and furrow irrigated raised bed [FIRB]):** The BBF method was developed mainly at ICRISAT [38], whereas FIRB planting was promoted for the cultivation of different crops in Uttar Pradesh, West Bengal, Punjab, Maharashtra, Karnataka, Rajasthan, and Tamil Nadu [39].

- **Zero-till sowing of wheat:** It is gaining popularity in NICRA villages as farmers are convinced of its performance and benefits. It is more efficient as

Successful CSA technologies and cropping systems	Primarily climate smart	Productivity enhancement/ farm management contributing to climate resilience	Both
Land shaping	●		
Drought-tolerant paddy varieties	●		
Rainwater harvesting	●		
Paddy nursery		●	
Direct seeding rice		●	
Drum seeding technique		●	
Broad bed and furrow		●	
Zero-till sowing of wheat		●	
Rotavator		●	
Crop diversification (intercropping)			●
Integrated farming systems			●
Custom hiring centers			●
Furrow irrigated raised bed			

the crop can be sown in large areas with limited moisture availability and also improves crop yield, soil structure, and fertility [40].

- **Rotavator:** Introduced in NICRA villages, this technology is used to change the practice of burning crop residues which aggravates GHG emissions and air pollution, besides depriving the land of biomass needed for precious soil organic carbon. It helps in improving soil health and crop productivity [41].

- **Rainwater harvesting:** This can be done using check dams, water catch ponds/pits (jalkund), individual/community tanks/ponds/tankha, etc. It is increasingly being used in NICRA villages to cope with climatic vulnerability. Tamil Nadu is the first state to make rainwater harvesting mandatory [42].

Mainstreaming CSA technology and practices in India

Based on successful outcomes of the Sustainable Livelihoods and Adaptation to Climate Change (SLACC), a World Bank-supported project implemented in Bihar and Madhya Pradesh, the National Institute of Rural Development and Panchayati Raj (NIRD & PR) proposed an innovative idea of creating a cadre of over 200 certified smart community resource persons and prepared a manual on "Sustainable Livelihoods and Adaptation to Climate Change" in June 2019. It involved putting together 23 CSA technologies prioritized through farm-level activities for climate resilience to reduce the cost of cultivation, improve yield, profitability, empower women, and generate employment. These technologies are Climate change adaptation planning tool; zero-tillage practices; soil health management; seed and planting material in crop production; system of rice intensification; dynamic spectrum refarming; machine transplantation; organic farming; integrated nutrient management; integrated pest management; IFS; fodder crop production and management; farm pond; micro irrigation system; livestock and poultry farming; smallholder dairy farming; small ruminant rearing; backyard poultry; water-based agro-advisories; custom hiring center; agro-insurance and credit; program convergence with other schemes.

Further, rural technologies located on their campus are promoted through the Rural Technology Park under NIRD & PR, particularly on waste management, organic farming technologies, agri entrepreneurship start-ups, energy solutions like solar dehydration, eco hatchery, and backyard aquaculture systems. Similarly, several good practices focused on climate smart solutions have emerged from Odisha. These efforts have been undertaken by the International Rice Research Institute (IRRI) in collaboration with the Department of Agriculture & Farmers' Empowerment of GoI; Indian Council of Agricultural Research–National Rice Research Institute (ICAR-NRRI); Odisha University of Agriculture and Technology (OUAT); and CIMMYT under the aegis of CGIAR research program, CCAFS. Examples of those promising innovations have been presented in Annexure II. These include practices such as sowing flood-resilient crops, integrated weed management, improved practices for maize production, and utilizing solar energy to minimize climate risks, among other successful practices.

India also has experience in scaling up resilient weather smart agricultural practices, technologies, and services in vulnerable areas through CSV approaches that include both men and women. These are: using institutional models involving local organizations, FPOs, CBOs, NGOs, SHGs, agriculture departments, and the private sector (input suppliers, insurance, information and communication technology [ICT] companies, and agribusiness entrepreneurs).

In addition, reference should be made to successful CSA technologies in India, prioritization of Indian CSA technologies, and exploration of demand-

led opportunities for TrC. AgTech companies like CropIn, DeHaat, Digital Green, Crofarm, etc., play a major role in integrating the agriculture sector with information and technology. Widespread adoption of technology through digital platforms, analytics, artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) is critical for transforming India's agriculture. Women entrepreneurs, such as NEERX Technovation Private Limited, also provide "SHOOL: Smart Sensor for Hydrology and Land Application," which gives accurate and real-time farm microclimate information using dielectric technology.

Photo Credit: CR Shelare
Woman harvesting strawberry in a farm using drip irrigation and tissue culture in Maharashtra, India.


6

Climate finance models in the Agriculture Sector in India

Small farmers are largely unaware of the terms for loans, finance schemes, procedures for repayments, payouts, and subsidies awarded to them. Inefficient processes require several long-distance trips to the bank to avail a loan. Adding climate change-related risks to the mix further worsens access to suitable finance. Accessing finance is doubly difficult for women. As a response to these factors, innovative financial products have been introduced by organizations in public and private sectors (for details, see Annexure IV).

Weather-based Insurance Products: In Bihar, the Indian Farmers Fertilizer Cooperative and Tokio General Insurance have offered a weather index-based crop insurance scheme. To achieve widespread implementation of this scheme, India has made massive investments in weather station infrastructure with the installation of 10,000 to 15,000 additional stations [43].

Warehouse Receipts (WHR): This external financing mechanism encourages scientific storage of post-harvest crops in a warehouse that serves as collateral to provide immediate financing to farmers. The Warehousing (Development and Regulation) Act enacted by the GoI in 2007 introduced negotiable warehouse receipts (NWRs) and laid down procedures for the development and regulation of warehouses, negotiability of warehouse receipts, and obtaining loans from banks. As the apex bank in the country, NABARD has several lending and investment instruments. Many projects supported by NABARD can be classified under climate finance. To facilitate attempts to address the impacts of climate change, especially fostering sustainable development, the Climate Change Fund was created out of the profits of NABARD in 2016–2017. NABARD contributes to the corpus of the fund annually from its profits. The Umbrella Programme for Natural Resource Management implemented by NABARD and GIZ intersects climate smart agri-horti-forestry and financing smallholder farmers.

Climate Adaptation and Finance in Rural India (CAFRI): The overarching goal of CAFRI is to contribute to policies and practices that reduce rural poverty by analyzing and disseminating knowledge on how collective action and property rights influence efficiency, equity, and sustainability of natural resource use. This project is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) with the lead executing agencies—MoEFCC and NABARD. It has partnered with the Department of Environment, Science and Technology, Government of Himachal Pradesh; Directorate of Environment, Government of Uttar Pradesh; and Bankers Institute of Rural Development (BIRD), Lucknow.

Providing FPOs access to financial solutions and market linkages: Samunnati is an agri value chain solutions provider enabling growth across the agricultural ecosystem. It provides support to farmers by enabling agri enterprises to scale through customized financial and non-financial solutions. Samunnati announced the launch of India's first Open Agri Network, FPOnEXT, an exclusive network of entities working with the FPO ecosystem via an affiliation program offering unique benefits to the members. The network aims to enable FPOs and the ecosystem to reach the next level by providing access to financial solutions, market linkages, value-added services, technology interventions, and other on-tap services. The members of the network are primarily FPOs and federations of FPOs, but Samunnati also endeavors to bring in other players like resource institutions, POPIs, training, and

Photo Credit: Niks Ads
Farmer using online climate finance model on his mobile phone, in Haryana, India.

capacity-building institutions, and other ecosystem players committed to FPOs and smallholder farmers. In line with Samunnati's vision to enable agri value chains to operate at higher equilibriums and make markets work for smallholder farmers, it aims to foster FPO engagement to the next level through this network, hence the name FPOnEXT.

Arya.ag, India's Grain OS: The organization connects the widest range of agriculture stakeholders, providing secure access to a digitally exponentially growing base of grain to fulfill their financing and commerce needs. Arya has reimagined the Indian agriculture ecosystem through its innovative tech-powered agri-service model, agchain, and its digital platform.

Arya provides storage solutions that help the organic storage of food grains without any chemical interventions. They work with CBOs and their value chains in climate-stressed geographies to help smallholder farmers bridge losses emanating from climate challenges. Ninety percent of Arya's presence is in the near farm, primary, and secondary markets, thus reducing the need to transport commodities over large distances and minimizing emission footprint.

Carbon Finance: India is leading in smallholder carbon (intersection of agri-forestry-horticulture) financing (Boomitra, ITC–Sunehra Kal) and carbon farming (mangrove financing–Sundarbans) initiatives. Climate finance is a diverse concept and is often integrated with related and overlapping concepts of green finance, sustainable finance, or low-carbon finance.

7

Leading Indian institutes and centers of excellence in CSA

The role of institutions in improving CSA in India has been expanding, starting with the farmers at community-level institutions to policymaking bodies, as already described. These institutions and stakeholders—such as farmer field schools, SHGs, FPOs—are critical and essential to creating and transferring useful information and guiding the farming community in their implementation. Since farmers have limited means to access credit and markets and are unable to invest and adapt to these new techniques for the success of CSA, a robust institutional mechanism can maintain and balance such transfers of technology efficiently [45].

In this endeavor, some of the organizations which have been active in CSA-related program design and implementation and technology transfer and are willing to extend their support[2] in upscaling and transferring Indian CSA expertise are described below:

Public Institutions (Government and Quasi-Government)

National Initiative in Climate Resilient Agriculture (NICRA), New Delhi

NICRA was launched to utilize strategic research, technology demonstration and capacity development to improve India's agriculture sector's resilience against climate change and vulnerability. The Central Research Institute for Dryland Agriculture (CRIDA) under the ICAR is the lead institute and the national nodal point for NICRA, which is being implemented at many research institutes of the ICAR, state agricultural universities, and several KVKs across the country. The Institute undertakes national/international collaborations and consultancy projects.

NICRA has a well-established climate change research infrastructure at multiple locations in India. Training programs and exposure visits for experts from other countries can facilitate knowledge and technology transfer. Some examples of the research infrastructure are:

- High Throughput Plant Phenomics
- Free Air Temperature Treatment
- Indian Grassland and Fodder Research Institute
- Emission reduction plantation techniques for rice at the National Rice Research Institute in Cuttack, Odisha.

National Institute of Rural Development and Panchayati Raj (NIRD & PR), Hyderabad

NIRD & PR is an autonomous organization under the MoRD. It has a separate Centre for Gender Studies and Development (CGSD) and follows multi-sectoral approaches to enhance gender-responsive governance. As an apex institution for rural development, it is the knowledge leader in the process. Its role is to train the trainers and create key knowledge products to consolidate and scale up gender-responsive governance across the country.

2 All the organizations reached out during the study and have expressed their willingness and keenness on the transfer of CSA technologies to neighboring countries under the TrC.

NIRD builds the capacities of rural development functionaries, elected representatives of Panchayati Raj Institutions (PRIs), bankers, NGOs, and other stakeholders through interrelated activities of training, research, and consultancy. The key objectives of the organization are (1) organizing training programs, conferences, seminars, and workshops; and (2) analyzing and offering solutions to problems in the planning and implementation of programs for rural development. There are several relevant studies and projects undertaken by NIRD, including two research projects titled "Study of the Impact of Climate Change on the Natural Resources and Rural Livelihoods to Develop Spatial Decision Support System [SDSS] Using Geo-informatics Technology" and "Achieving Sustainable Development Goals [SDGs] Through Panchayats: A Study on PRIs-SHGs Convergence'; and a proposed project titled "Estimating Carbon Sequestration Potential for Gram Panchayat: A Methodological Approach." NIRD has experience in organizing bilateral programs, particularly in African countries. NIRD organizes two categories of international training programs. The first category is sponsored by the Ministry of External Affairs, GoI, under the fellowship scheme Indian Technical and Economic Cooperation (ITEC)/Special Commonwealth African Assistance Plan (SCAAP). The programs are meant for Africa and the Pacific. The second category is organized in collaboration with the Centre for Integrated Rural Development in Asia and the Pacific (CIRDAP) and customized for participants in Asia and the Pacific.

National Institute of Agricultural Extension Management (MANAGE), Hyderabad

MANAGE is an autonomous institute of the Ministry of Agriculture and Farmers' Welfare. MANAGE offers professional services across five streams: management; training; research and information services. It has several programs on CSA and has already facilitated bilateral and TrC programs under the Feed the Future (FTF) initiative and India–Africa exchange. It has trained more than 1,400 extension officials from Africa (Uganda, Ghana, Malawi, Kenya) and Asia (Mongolia, Afghanistan, among others). It has dedicated faculty, complete infrastructure, course curricula, and a coordinated system with all ICAR institutions facilitating TrC programs.

The National Gender Resource Centre in Agriculture (NGRCA), New Delhi

The activities of NGRCA include a gender dimension in agriculture policies, programs, and advocacy/advisory services to the states/union territories to embed gender-specific interventions in policies/programs of the agriculture sector. It is mandated to ensure that its policies and programs in agriculture are fully gender inclusive and reflect India's national commitment to the empowerment of women. Besides undertaking and supporting training, research, and advocacy for mainstreaming gender issues in agriculture and natural resource management, NGRCA aims to forge effective functional linkages with other related departments, agencies, and institutions.

National Academy of Agricultural Research Management (NAARM), Hyderabad

ICAR–NAARM was established by the ICAR. The mandates include: (1) enhancing individual and institutional competencies in managing innovation through capacity development, research, and policy advocacy; and (2) serving as a think tank for the National Agricultural Research and Education System and facilitating strategic management of human capital.

Indian Institute of Millets Research (IIMR), Hyderabad

The IIMR conducts research on sorghum and other millets under the ICAR. Its mandates are: (1) primary and strategic research to increase the productivity of millets and utilize sorghum and millets in diversified ways to enhance profitability; (2) coordination and development of improved crop production and protection technologies of millets; (3) training and consultancy on millet production and utilization; and (4) dissemination of technologies and capacity building.

Institute of Rural Management Anand (IRMA), Gujarat

IRMA offers management programs focusing on understanding real management problems and socioeconomic realities of under-served communities through intensive fieldwork.

Private Institutions (NGOs, for-profit companies, incubation centres etc.)

The Energy and Resources Institute (TERI), New Delhi

TERI is an independent, multidimensional organization that runs several academic programs, with expertise in research, policy, gender mainstreaming, consultancy, and implementation. On CSA, TERI is well equipped with advanced programs on climate modelling, nano water solutions, and energy solutions.

Photo Credit: B Dayakar Rao
Centre of Excellence for Sorghum Research in Hyderabad, Telangana, India.

CropIn, Bengaluru

CropIn delivers innovative farming solutions. It has developed tools to strengthen the sustainability of agribusinesses. It has been running pilot programs in Vietnam and Cambodia on agriculture advisory.

Digital Green, New Delhi

Digital Green works with smallholder farmers by utilizing technology and grassroots-level partnerships. It is an independent NGO that focuses on training farmers to make and screen short videos recording their problems, sharing solutions, and highlighting success stories. Digital Green works across seven states in India and other countries, including Vietnam and Cambodia.

Centre for Sustainable Agriculture, Secunderabad

The Centre for Sustainable Agriculture works with small and marginal farmers across the country to bring about economic and ecological sustainability in farming. It has supported the Government of Chhattisgarh in incorporating CSA education in schools and colleges. It has an academy running online programs for FPOs and their functionaries and is associated with several international universities on sustainable agriculture.

M. S. Swaminathan Research Foundation (MSSRF), Chennai

The MSSRF, established in 1988, is a non-profit trust. It aims to accelerate the use of modern science for sustainable agricultural and rural development. It focuses specifically on tribal and rural communities with a pro-poor, pro-women, and pro-nature approach. In 2012, "Gender and Grassroots Institutions" was institutionally recognized as a cross-cutting theme. The main objectives were to mainstream and integrate gender issues across programs and evolve specific research studies on gender and institutions.

BAIF Development Research Foundation, Pune

BAIF Development Research Foundation is a voluntary organization established in 1967 in Maharashtra. It provides sustainable livelihoods to the rural poor through climate resilient agriculture, management of natural resources, livestock development, watershed development, and agri-horti-forestry as major income-generation activities. BAIF has developed innovative watershed models and promotes micro-enterprises to ensure inclusive development through dairy husbandry, goat production, agri-horti-forestry, and sustainable agricultural production for food security and poverty alleviation. Formation of producers' groups, empowerment of women, and environmental sustainability cut across all these programs.

Professor Jayashankar Telangana State Agricultural University (AgHub, PJTSAU), Hyderabad

AgHub, Agri Innovation Hub, a first-of-its-kind innovation Hub of PJTSAU Hyderabad, aims to promote food and Agritech start-ups, and its rural innovation seeks to promote rural entrepreneurship

among rural youth, women, and FPOs. Currently, AgHub is working on 15+ Agritech start-ups through incubation programs (Agritech enterprise-building track) and Agritech innovation pilots (immersion/ piloting platform for the Agritech start-ups).

With the range of diverse organizations working on CSA, the farmers and communities at large benefit at different levels. Similarly, agriculture cooperatives, FPOs and CBOs also help promote CSA practices and technology in many locations [46]. Moreover, with the increasing digitalization in India, there are now several technology-based applications to address most of the challenges that farmers face: from issues concerning soil, climate, irrigation, to supply chain gaps to weather forecasts, waste reduction, etc. The transformation from agriculture to AgTech is intensified based on 10 global megatrends, which include: (1) rise in population; (2) societal and demographic shifts; (3) increasing urbanization; (4) climate change; (5) CSA technologies; (6) biotechnology; (7) servicization around core products; (8) increasing value chain integration; (9) globalized trade; and (10) changing global regulations. Farmers can now use something as simple as their smartphones to receive timely updates and relevant information to monitor their crops. More farmers are beginning to understand how the latest technologies such as AI, ML and Cloud can help them acquire greater climate resilience, higher crop yield, and better price control. Widespread adoption of technology through these digital platforms is critical to transform India's agriculture. According to NITI Aayog, AI in agriculture is expected to grow at a rate of 22.5 percent compound annual growth rate and is likely to be valued at $2.6 billion by 2025.

Over the years, through various legislation, policies, schemes, and implementation models (public, private, and nongovernmental), India has made significant progress in CSA. Multiple institutions in the country have developed specialized capacities and potential to offer CSA expertise to the countries in the Indo–Pacific and beyond. Based on the supply analysis and expert consultations, the demand for Indian technical expertise in CSA has been established.

8

Exploring demand for climate smart agriculture in the Indo–Pacific

Most countries in the Indo–Pacific region are witnessing climate-induced changes, such as varying rainfall patterns, severe flooding, frequent droughts, and altered growing seasons. These near-calamitous phenomena are adversely impacting agriculture. At another level, the Earth is warming, glaciers are melting faster, and unpredictable water flows in streams and rivers are new dimensions to the discourse on sustainable agriculture. Consequently, there are fears of reduced outputs and declining returns from agriculture, and these can potentially lead to greater social–economic tensions, including loss of livelihoods and jobs.

Furthermore, the differential and greater impact of climate change on women is well documented. They face greater food insecurity, malnutrition, violence, and displacement, among other adverse impacts. It is important that adaptation and mitigation strategies are shared regionally, and women benefit equally from all efforts in this direction.

In these nature–human weather and climate-created conditions, CSA strategies have reached a critical juncture necessitating focused governance, proactive policy frameworks, and robust national capacities for response in the hope that CSA practices will enable food security while help combating climate change.

India and the U.S. are "credible responders" to climate change affecting agriculture in the Indo–Pacific region by building capacity in CSA. The U.S. has longstanding partnerships with countries in the Indo–Pacific, and its vision is to help the region by sharing skills and solving critical challenges arising from climate change, environmental degradation, ecological damages, etc. [47] Similarly, India is a pivotal state in the Indo–Pacific and its engagements in the region through the Indo–Pacific Ocean's Initiative, announced in November 2019, has been labeled the "bread-and-butter expression of our [Indian] political, economic, connectivity, travel and societal interests [48]."

The "Vision and Principles for India–U.S. Comprehensive Global Strategic Partnership" emphasizes the "importance of advancing education, economic empowerment and entrepreneurship of women and girls." This assertion is in line with the U.S.'s "Women's Global Development and Prosperity (W-GDP) Initiative, which, among others, focuses on developing and demonstrating women's empowerment in agriculture supply chains by providing women with technical and leadership skills and income generation opportunities [49]. Similarly, India's "Mahila Kisan Sashaktikaran Pariyojna (MKSP)" under the National Rural Livelihood Mission (NRLM) strives to improve women's status in agriculture and enhance opportunities for empowerment [50].

Scoping triangular cooperation (TrC)

The Socialist Republic of Vietnam, the Kingdom of Cambodia, Lao People's Democratic Republic (PDR) in Southeast Asia, and Republic of Fiji and Papua New Guinea (PNG) in the Oceania region, have been identified because the terrain of Southeast Asian countries matches Indian terrain in many ways, and the two Pacific Island countries are large enough for a substantive intervention that could be emulated by other island countries. Moreover, a study of the political economy of these countries reveals at least four reasons for TrC in CSA capacity building.

First, CSA is a high priority for the governments of these countries, and this is evident in their policies and plans. However, these countries are constrained by inadequate technical, technological, and fiscal resources. India has been an active participant in the Pacific Island Forum since 2002, and the U.S. is an active partner in the region and considers their security and prosperity as shared futures. The U.S. and India are suitably poised to deliver high-quality activities in CSA. This has been demonstrated through TrC to address food security challenges in Africa through technological and innovative solutions [51] that included women's participation and programs aimed at women's empowerment.

Second, these countries are willing to accept CSA assistance from foreign countries, several of whom, along with multilateral institutions/groupings, NGOs/civil society organizations (CSOs), are engaged in CSA activities in these countries. Based on its domestic CSA, India is in an advantageous position to provide technical expertise and share best practices, as explained in earlier sections.

Third, India–U.S. Strategic Partnership identifies issues of common interest such as climate change, energy, environment, education, science and technology, agriculture, space, and oceans, and these are intrinsically linked to CSA [52].

Photo Credit: Doan Tuan
Rice terrace cultivation in Chế Cu Nha commune, Vietnam.

Fourth, there is a convergence between the Mekong–U.S. Partnership (MUSP) [53] involving the U.S., Vietnam, Cambodia, Laos, Thailand, and Myanmar, and the Mekong–Ganga Cooperation (MGC) comprising India, Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam [54]. India is also an Observer in the Friends of the Mekong Initiative.

The table below presents key indicators for the five countries, and India, to understand the demographic and socio-economic context of these countries. Additionally, indicators associated with agriculture have also been included to provide a snapshot of the country's reliance on the agricultural sector.

Indicators	India	Vietnam	Cambodia	Lao PDR	Fiji	Papua New Guinea
Population	1.38 billion	98 million	16 million	7.1 million	0.9 million	9 million
Sex ratio	108.18 males per 100 females	99.71 males per 100 females	95.39 males per 100 females	100.774 males per 100 females	102.620 males per 100 females	104.319 males per 100 females
% Urban population	35%	37%	24%	36%	57%	13%
Proportion of population dependent on agriculture (%)	70%	42%	54.20%	70%	18%	80%
Contribution of agriculture to GDP	20%	14.85%	22.84%	44%	10%	25%
Per hectare/acre yield of major crops	Rice: 2.4 tonnes per hectare, Wheat: 3.15 tonnes per hectare	Rice: 5.6 tonnes per hectare, Maize: 3.5 tonnes per hectare, Sugarcane: 12 tonnes per hectare	Rice: 0.95 tonnes of unmilled rice per hectare	Rice: 3.5 tonnes per hectare	Rice: 2.95 tonnes per hectare, Sugarcane: 4 million tonnes on just under 100,000 hectare	Cereal: 4.65 tonnes per hectare

Note: The data sources used in this table have been taken from several sources, including data from the UN World Population Prospects, Statista, World Bank, country-level data from government sources and Index Mundi.

Agriculture landscape in the Socialist Republic of Vietnam

Vietnam is a mid-sized country and is spread over an area of 331,210 square kilometers (128,565 square miles). It is the world's 66th largest country (in terms of landmass) and the topography is marked by tropical lowlands, hills, and densely forested highlands. The weather is predominantly tropical in the south and monsoonal in the north.

Its 94 million people make it the 15th largest populous country in the world, with two-thirds living in rural areas [55]. Nearly 70 percent of Vietnam's current population is under 35 years of age, and there is an emerging middle class that accounts for 13 percent of the population; this is expected to reach 26 percent by 2026 [56].

In 1986, Vietnam launched Doi Moi to transform into a socialist-oriented market economy. The reforms catapulted Vietnam from being one of the poorest nations of the world into a lower-middle-income country. There has been remarkable economic growth in recent years and the current leadership aims to make Vietnam a developed country by the middle of the 21st century, albeit with a "socialist orientation" [57].

Vietnam is vulnerable to climate change and has resulted in a reduction of agricultural land, increased drought and pests, and has put enormous pressure on the development of the cultivation process [58]. Agricultural production is "responsible for 30 percent of the greenhouse gas (GHG) emissions of the country, and half of it is produced by paddy rice fields" [59]. In 2019, after global forecasting of El Niño, the government issued several directives, including "adjusting rice planting to avoid salinity intrusion" [60].

Evolution, policy, and practice

Vietnam is predominantly an agrarian country, with 42 percent of the population employed in agriculture; 69 percent of the farmers are smallholders [61]. Vietnam's agricultural production has more than tripled in volume since 1990 which is attributed to the significant structural changes led by Doi Moi. It resulted in a "shift away from collectivization to individual land ownership" [62]. Further, it triggered agricultural market liberalization and raised agricultural output. In particular, rice exports from Vietnam witnessed a phenomenal increase by 4.2 percent in 2019, totaling 6.4 million tonnes [63].

Agriculture contributes as much as 15 percent to the GDP (2019). It employs nearly 40 percent of the labor force corresponding to over 18.8 million people [64]. While the share of the agriculture sector in GDP has been decreasing in recent years due to the shift towards a service economy, its GDP value is growing steadily.

The Vietnamese Ministry of Agriculture and Rural Development's (MARD) project to "Promote the Export of Agricultural, Forestry and Fishery Products through 2030" aims to increase the export value of agricultural, forestry, and fishery products to US$ 50–51 billion by 2025, and to US$ 60–62 billion by 2030 [65].

Closely associated with this is the "National Strategy on Green Growth for the Period 2011–2020 with Vision to 2050" (VGGS) which aims to "stem environmental degradation, while still achieving relatively high economic growth" [66].

Vietnam's "Master Plan on Agricultural Production Development to 2020, Vision to 2030" emphasizes that "agricultural production must be based on innovation thinking, marketing, combining

rapid application of scientific and technology achievements, efficient use of land resources, water, trained human resource and adaptation to climate change, protecting the ecological environment to effectively exploit advantages and natural conditions of each region, each locality" [67]. Besides this, issues concerning drainage of rivers and effective management of irrigation systems are a priority.

Vietnam's national strategies also focus on agriculture finance across value chains. The new lending programs offer higher financial resources, which involve policy innovations concerning financing products such as "new form of collateral, lending without collateral and financial incentives to high-tech application and agri-business linkages" [68]. Meanwhile, the National Agriculture Insurance Pilot Programme (NAIPP) has covered over 300,000 households in 20 provinces focusing on rice, livestock, and aquaculture insurance [69].

As far as high-tech applications in agriculture are concerned, most Vietnamese farmers still rely on traditional agro-technology, cultivation practices, and experiences [70]. In spite of this, industry 4.0 technologies are beginning to take off [71]. In the coffee sector, for instance, IoT solutions have improved water saving by 30 percent and reduced electricity and labor costs by 20 percent [72].

Also, the Department of Crop Production (DCP) under MARD, along with the CGIAR's Research Program CCAFS, have developed Climate Smart Maps and Adaptation Plans [73].

Actors and active projects

International donors and development agencies are encouraged to support Vietnam's Agriculture Climate Change National Action Plan in the belief that their contribution can "ensure national food security and reduce the effect of climate change on the Vietnamese economy" [74].

Japan's "10-year Socio-Economic Development Strategy (2011–2020) of Vietnam" prioritizes the development of CSA. JICA has several ongoing CSA-related projects in Vietnam [75]. During the recent Vietnam–Japan Public-Private Cooperation Forum on Agriculture, there was agreement on "improvement of agricultural infrastructure; support environmental protection and response to climate change; promote private investment and application of advanced technology" [76].

The Republic of Korea has engaged in CSA-related capacity building. The Vietnam Korea Rural Development Administration Association Alumni network, supported by the Rural Development Administration of Korea, has promoted sustainable agricultural and rural development by transferring advanced agricultural technologies, implementing small projects, human resource training, organizing short training courses, and setting up databases on technologies in the form of digitalized "Knowledge Banks" disseminated through the internet [77]. The recent MoU, "Building a Vision for Medium and Long-term Cooperation for the Agricultural Sector between Vietnam and Korea for the Period of 2021–2025," envisages "practical agricultural cooperation through technical assistance and technology transfer, investment such as public-private partnerships, joint ventures and value chain linkages, as also encouraging and attracting investment in agriculture" [78].

The International Fund for Agricultural Development (IFAD), whose focus is on green and climate resilient agriculture, is working on South-South cooperation and TrC. Vietnam, Cambodia, China, and Laos are "benefiting from a grant to help identify and develop climate resilient value chains between farmers groups, processing units and enterprises in the context of the IFAD-supported projects in these countries" [79].

The 2017 Australia–Vietnam "Agriculture Strategy" focuses on "improving knowledge and decisions on

climate resilient investments and livelihoods in the Mekong Delta [80].

The Vietnamese government supports CSA initiatives by CSOs and NGOs. There are nearly 1,000 such organizations engaged in Vietnam and are associated with issues such as "environment, risk reduction and climate change response," and have contributed to designing the National Action Plan policy on climate change [81].

Gender equity and social inclusion

Gender equality is an important component of Vietnam's national plans for climate change adaptation, sustainable development, and CSA. The government recognizes the importance of the equal involvement of both women and men in tackling climate change and other environmental challenges. Feminization in agriculture has evolved over the years and is currently an important policy issue.

The government acknowledges the potential of rural women to play a key role in the sector, and "MARD's Action Program in Response to Climate Change of the Agriculture and Rural Development (ARD) Sector During 2011–2015 and Vision to 2050" gives primacy to gender equality and empowerment.

The Law on Gender Equality and the Gender Equality Action Plan for the agriculture sector for the period 2016–2020 is another commitment to the feminization of CSA, given that approximately 60 percent of the 57 percent of the workforce in the agriculture sector comprises women [82].

In accordance with the Paris Agreement, the Vietnamese government updated the Nationally Determined Contribution in 2020 to incorporate gender equality and social inclusion. This reflects its commitment to gender-responsive climate action [83]. The State of Gender Equality in Climate Change in Vietnam (2021) [84] states that gender equality is included as a guiding principle and objective in both the National Target Program to Respond to Climate Change (2008) as well as the National Strategy on Climate Change (2011).

Agriculture experts in Vietnam note that CSVs "promote inclusion of youth, women and ethnic minorities" and the model can be replicated in other locations in Vietnam and Southeast Asia [85]. It is important to mention that CSVs are models of climate resilient communities and function as field labs for gender-sensitive CSA technologies and approaches—for example, agro-climate information services for women and ethnic minority farmers in My Loi, Vietnam [86]. Women also participate in roving workshops. Community smart villages empower local communities and women farmers who have become more resilient to climate change. The strategies adopted also impact policy and investments for climate change, adaptation, and mitigation at the community level.

Projects supported by the ADB have "helped nearly 1.6 million women and girls be better prepared and become more resilient towards external shocks such as COVID-19, climate change, and natural disasters" [87].

COVID-19 pandemic

The COVID-19 pandemic and climate change, according to MARD, can be turned into opportunities to transform the agriculture sector through "restructuring, utilizing technology in the industry 4.0 era, while taking advantage of foreign direct investment." The pandemic has unlocked an unprecedented opportunity for "economic and social benefits, trigger green agriculture employment by introducing green stimulation policy support packages as part of the MARD's Climate Change Strategy and Action Plan" [88].

TrC viability

Modernization of agriculture is a priority for Vietnam and the government aims to enhance the agricultural value chain and competitiveness among both men

and women. Also, women's inclusion in climate change adaptation and mitigation will further contribute to increased agricultural production and enhanced food security.

Agriculture landscape in Cambodia

The Kingdom of Cambodia covers an area of 181,040 square kilometers and is largely flat with low-lying plains that are drained by the Tonle Sap (Lake), the Mekong River (500 kilometers), and the Bassac River (190 kilometers). It is a hot and humid country with two distinct dry and rainy seasons with average annual rainfall between 50 and 75 inches. Nearly 80 percent of the population is rural, and 65 percent rely on agriculture, fisheries, and forestry for livelihood. Ninety percent of the cultivable land is devoted to rice.

Cambodia is an open economy with good economic performance. Over the last decade and a half, its average GDP growth rate has been over 7 percent annually. Government policies are robust and ensure strong macroeconomic stability [89]. The Vision 2050 document and the National Strategic Development Plan (NSDP) 2019–2023 of the Cambodian government aim to "enable progression to Upper Middle-Income and then High-Income Country status on the basis of socioeconomic inclusion and environmental sustainability [90]."

Evolution, policy, and practice

Climate change could severely impact Cambodia's economic growth. Climate change could reduce Cambodia's average GDP growth to 6.6 percent and absolute GDP by 0.4 percent in 2020; 2.5 percent in 2030; and 9.8 percent in 2050, as against an average of 6.9 percent per year from 2017 to 2050 under "no climate change" impacts [91]. The phenomenon can reduce "productivity in agriculture, fisheries and forests and reduce labor productivity across most sectors." Further, "rising sea levels will cause flooding and storm damage in coastal areas, affecting urban areas and natural resources" [92].

The Cambodian government's Climate Change Strategic Plan 2014-2023 endorses national "commitment and readiness for reducing climate change impacts on national development, and contributing, with the international community, to global efforts for mitigating GHG emissions under the UNFCCC" [93]. On its part, the Cambodian government acknowledges that "agriculture-based livelihoods and overall food security in Cambodia are being affected by increased frequency and severity of floods, dry spells and drought events" [94].

Consequently, CSA is a priority for the government and can be discerned from the Rectangular Strategy (Growth, Employment, Equity and Efficiency); NSDP 2019–2023; and Zero Hunger Action Plan, 2016–2025, to ensure the sector is competitive, inclusive, and resilient for sustainable agriculture [95]. These can potentially "build resilience in the Cambodian agricultural sector" supported by the private sector [96].

Active projects and actors

The Agriculture Services Programme for Innovation, Resilience and Extension 2015–2022 is the first national program that provides smallholder farmers access to quality information services, including supporting climate resilient agriculture [97].

Cambodia has also made significant progress in developing and implementing monitoring and evaluation (M&E) frameworks, including for climate finance. The country has produced regular climate public expenditure reviews and has improved tracking of climate finance in its Official Development Assistance database. The National

Photo Credit: Boudewijn Huysmans
Stress tolerant rice growing in a paddy field in Fish Island, Kampot, Cambodia.

M&E Framework for Climate Change Response has also been developed, and it is anticipated that future adaptation and mitigation efforts will be supported by international donors and multilateral funds, as well as by national contributions.

The Cambodia Community Based Adaptation Programme promotes innovative partnerships between government, civil society, academia, and the private sector to reduce vulnerability and increase the adaptive capacity of the targeted communities to manage the additional risks of climate change. It also aims to "enhance the capacity of vulnerable communities in building resilience, mainstreaming climate change in commune development planning, and documenting good practices of climate change adaptation" [98].

Cambodia seeks international cooperation and investments in "rural infrastructure, agricultural research and extension services, and technology development and plant and livestock gene banks" [99]. At the multilateral level, Cambodia signed the Regional Comprehensive Economic Partnership (RCEP) [100].

The recent Cambodia–China Free Trade Agreement, the first bilateral trade agreement covering 300 agriculture products, could "increase Cambodia's exports to China by 23 percent" [101]. The agreement also places agro processing and manufacturing sectors in a stronger position to export to the Chinese market.

The ADB supports CSA in Cambodia through technical and institutional capacity building [102].

The United Cambodia Agri, a private agriculture consultancy company, and USAID have worked on Helping Address Rural Vulnerabilities and Ecosystem Stability to disseminate CSA practices among farmers [103].

The IRRI (a part of the CGIAR global network), in partnership with the Japanese government, have agreed to a collaboration to support Cambodia's agricultural sector [104].

Similarly, the Ministry of Agriculture, Forestry and Fisheries and the South Korean government signed an MoU for implementing the "Smart Farm Project" to set up a technical training center for officers and farmers, as also for research on potential crops for production and marketing [105].

Australia's Cambodia Agricultural Value Chain Programme involves building irrigation schemes and improving farming practices. Australia plans to invest Aus$ 50 million to boost "agricultural productivity, diversify crops and target new markets" [106].

Gender equity and social inclusion

The Rectangular Strategy for Growth, Employment, Equity and Efficiency Phase III (2014– 2018) acknowledges "gender equality as a key component of national development, capacity building, and human resources development" to "further improve the status of women, who are the backbone of Cambodian society and economy" [107].

Since 2015, the Cambodian government has embedded gender in agricultural policies and initiatives; the National Champion Woman Farmer Forum, a space to discuss issues affecting women in rural areas, is noteworthy [108].

Nearly 75 percent of Cambodian women are active in the agriculture sector. However, "Cambodian women still face many difficulties in terms of access to land, extension services, financial services, markets, and technology which result [in] a huge gap of gender in accessing to [sic] agriculture resource and service" [109]. The researcher profile at Cambodia's two largest agricultural R&D agencies is highly skewed, with 70 percent male and 30 percent female [110].

In 2015, Cambodia identified Rohal Suong, a commune in Battambang province, as its first CSV for climate change adaptation and mitigation [111]. A good example of women's engagement in CSA in Cambodia is the story of Saveth, a female farmer who is involved in CSA activities in Rohal Suong CSV. She is instrumental in helping "pilot implementation of CSA practices such as the plant clinic, water harvesting and use of stress-tolerant rice varieties" [112].

Cambodia has also experienced a rise in migration, both within and outside the country. "Cambodian women migrate largely to Thailand and Malaysia, primarily to work in low paying manufacturing, hospitality, domestic work and agriculture sectors and most likely to work without documents" [113].

COVID-19 Pandemic Challenges

COVID-19 has hit the Cambodian economy. Border closures and lockdowns affected the movement of labor, causing a drop in output profits for farmers. Similarly, some companies in the supply chains had to lay off employees and some even shut down, leaving thousands of people jobless. The Cambodian economy is now recovering and is projected to grow at 4 percent in 2021 after contracting to 3.1 percent in 2020 [114].

TrC Viability

While CSA is evident in the Cambodian government's policies and plans, the country is constrained in implementing CSA due to inadequate technical, technological, and fiscal resources.

The India–U.S. Strategic Partnership identifies issues of common interest, such as climate change, energy,

environment, education, science and technology, agriculture, space, and oceans [115], all of which are intrinsically related to CSA, including a digital gender divide. Also, convergences between MUSP and the MGC can potentially trigger a robust TrC [116] [117].

Agriculture landscape in Lao People's Democratic Republic

Lao PDR is a mountainous land-locked country with a total area of 236,800 square kilometers. It lies in the lower Mekong River Basin and has a tropical climate with an average temperature of 20°C. There are two distinct seasons (dry and rainy) and it experiences high humidity. Nearly 70 percent of its annual rainfall is from the southeast monsoon. The country is exposed and vulnerable to climate change and some of the observable impacts are changes in the rainy season, flash floods, extended dry seasons, and drought.

Its climate risk level is ranked 69th out of 191 countries; 6th in exposure to flooding; 47th in exposure to tropical cyclones and their associated hazards; but has a low drought exposure at 115. These climate risks and disasters are altering the landscape, vegetation, flora–fauna, and affecting productive land, agricultural harvests, and infrastructure. Eighty percent of Laotian (estimated population of 6.8 million) livelihoods are associated with some form of agricultural activity and are particularly vulnerable to climate change [118].

Evolution, Policy, and Practice

Agriculture constitutes 16.2 percent of Laotian GDP and some of the important government initiatives for the sector are: Agriculture Development Strategy (ADS) till 2025 and Vision to 2030; the 8th Five-Year Development Plan (2016–2020); and the Forestry Strategy to the Year 2020.

The ADS aims to "ensure national food security through clean, safe and sustainable agriculture and build an agricultural production potential that contributes significantly to the nations' economy, according to its objectives of industrialization and modernisation" [119]. The Five-Year Agriculture and Forestry Sector Development Plan focuses on food production, commercial agriculture, forestry, and nutrition" [120].

In 2017, the government enacted a law on water management related to "monitoring, management and planning of the country's vast rivers." Several new provisions have been added to ensure effective utilization of water resources in the country for agriculture, such as "water rights and use, including waste-water discharge permits, wetlands and water-resources protection, groundwater management, and river-basin management" [121].

Although "Lao has the highest level of renewable water resources available per unit of agricultural land in Asia, but irrigation coverage is low." It is primarily due to operational and maintenance challenges such as poor-quality irrigation structures [122].

Actors and active Projects

Around 80 percent of the rural population of Lao is still "subsistence farmers, depending heavily on rice-based agriculture, raising livestock and collection of food from the wild, including Non-Timber Forest Products, to meet food and nutritional needs" [123].

According to a study by Global Health Action, food insecurity and undernutrition are prevalent among remote communities living in mountainous areas [124]. However, the country has drawn up national policies and laws concerning CSA, such as the Disaster Risk Management and Climate Change, National Policy for Meteorology and Hydrology,

and regulations to control mismanagement of land use, including the 2012 moratorium on issuing land concessions for certain types of investment [125].

However, these are "not tailored to specific agro ecological regions" and there are no policies and legislation for "upland farming communities." Also, "climate smart approaches such as intercropping, crop rotation, agroforestry, innovative forest restoration, are still largely in the pilot stage" and not upscaled [126].

The Lao Farmer Network, a group of more than 4,000 farmers, is a national farmer organization (established in 2014) that has been participating in national-level policy dialogues [127].

Among many other issues, farmers' access to credit—including access to crop insurance— is limited and early-warning systems and response mechanisms are weak. For instance, a recent locust outbreak resulted in a loss estimated at US$13,890 [128].

While the country's economic growth has been 7 percent over the past decade, the agricultural sector has grown only at 3 percent over the past two decades and this has been attributed to inefficiency in the agricultural sector. The government aims to strengthen the sector and diversify financing mechanisms and extension services for both farmers and micro/small enterprises to enable investments to modernize smallholder farming and agro processing [129].

Foreign direct investment (FDI) flow to Lao PDR has increased, but much of it has been in electricity generation, whereas FDI in agriculture attracted only US$184 million. Meanwhile, China has been the biggest investor in Lao PDR, accounting for more than 77 percent of investment in 2017 [130]. Information sharing in the agriculture sector in Lao PDR has been through face-to-face meetings with limited use of information technology. The ICT infrastructure was weak in rural areas, but has now been developed by the private sector, including 3G Internet connectivity. Inexpensive computing devices and solar technology are in use across the country [131].

One of the notable developments is the strategic partnership between the United Nations University International Institute for Software Technology and the Ministry of Agriculture and Forestry to support the design of software for capacity building at the grassroots level [132].

The COVID-19 pandemic triggered the use of the Internet and smartphones in the agriculture sector. For instance, experts from Chiang Mai University were teaching field workers in the remote province by using the LINE app: Lao Farmer Network made videos and uploaded them on YouTube to explain to policymakers the impact of the lockdown; Sub-Sector Working Group for Farmers and Agribusiness (4,000 people) used Lao-FAB Google Group to send daily updates; Lao Upland Rural Advisory Service (LURAS) created WhatsApp groups such as Young Agripreneurs, Control of Fall Armyworm, Coffee Processing and Marketing, and Project Admin and Finance [133].

Climate smart agricultural practices in Lao PDR are still at a nascent stage. The farmers in Khammouane Province, for instance, are still learning new techniques, need financial support for skill development, and need technical information on soil and water management, livestock, poultry, pest and disease control, and climate change [134]. However, roving workshops under the CSA program have been organized in Vientiane and Savannakhet Province to enhance participants' knowledge of CSA techniques and practices using community-based approaches, which include women, and have proved successful in Laos [135].

Gender equity and social inclusion

Women's engagement, including farmers, is a priority for the Lao government's Agriculture Development Strategy to the year 2025 and Vision to 2030. Nearly 30 percent of female personnel and farmers are expected to be involved in "implementing strategic plan[s] and participate in capacity building, upgrading of knowledge, exchange of lessons on new techniques" [136]. Women traditionally manage the marketing of agricultural products and livestock production, and nearly 81 percent of women contribute to agricultural export [137].

Women from ethnic groups in remote rural areas are encouraged to learn "production techniques, have access to information, appropriate mechanisms of fund, credit, finance and marketing" [138]. Laotian women's engagement in organic farming is quite impressive. At Thong Mang Organic Vegetable Farm, nearly 700 families work together in an organized manner to grow a wide variety of vegetables, and more than 60 percent of the farmers are women [139]. However, the size of women's landholdings is considerably smaller than men's.

COVID-19 pandemic challenges

According to a rapid assessment of socioeconomic impact of COVID-19 that was submitted to UNDP Lao PDR by a group of researchers , the COVID-19 pandemic has impacted the agriculture sector with "declined agricultural sales in local markets and mobile buying activities by traders." The situation has been further exacerbated by the 2019 "drought in the north and flood in the south," resulting in food shortages in affected villages [140].

TrC viability

India–U.S. Strategic Partnership identifies issues of common interest such as climate change, energy, environment, education, science and technology, agriculture, space, and oceans, and these are intrinsically related to CSA [141]. Also, convergences between MUSP and the MGC can potentially trigger a robust TrC [142] [143].

Agriculture landscape in Fiji

The 320 islands of the Republic of Fiji cover a land area of 18,274 square kilometers. Viti Levu and Vanua Levu are the largest and account for 85 percent of the total land area. It has 1,129 kilometers of coastline and claims an Exclusive Economic Zone (EEZ) of 1.26 million square kilometers. Several islands are mountainous with navigable rivers and ample water for irrigation, and the rich soil makes them suitable for agriculture.

The estimated population of Fiji is 896,445 people and the majority reside on 110 islands. The country has a warm tropical climate with two seasons throughout the year. It receives 1,500 mm to 4,000 mm of rain from southeast trade winds.

Agriculture accounts for nearly 20 percent of the national GDP, constitutes nearly 43 percent of Fiji's foreign exchange earnings, and employs half the population; however, the sector's contribution to GDP has declined to around 16 percent, with the labor force shifting to the service, manufacturing, and other sectors [144].

Evolution, policy, and practice

Fiji is adversely affected by climate change with extreme and unpredictable weather conditions such as severe tropical cyclones and changing rainfall patterns. Frequent cyclones result in saltwater inundation of agricultural land. Its vulnerability to a rise in sea level has necessitated relocation of 80 coastal communities to higher ground. It has also leased land from Kiribati to relocate its population [145].

Photo Credit: Department of Foreign Affairs and Trade (DFAT)
A farmer in Fiji.

The Fiji government acknowledges the critical need for CSA [146] and the 20-Year Development Plan places food and nutrition security as a national priority. This important policy deliverable, according to the Plan, will be ensured by increasing agriculture and fisheries outputs through programs such as "local production, raising farm efficiency and productivity, and effective distribution systems [147]"

The Fiji 2020 Agriculture Sector Policy Agenda complements the National Green Growth Framework and emphasizes "sustainable intensification" to increase production and "pursue sustainable development with an inclusive approach that will modernize Fiji's Agriculture Sector by 2020" [148].

Sugarcane production has been declining for the past 15 years [149] and has been exacerbated by the COVID-19 pandemic. Sugarcane is the primary crop and a major revenue earner. The sugar industry employs over 200,000 people. The government has stressed the importance of increasing the production capacity, improving transportation, implementing a new cane-quality payment system and generating additional revenue in the sugarcane industry. [150].

The Ministry of Sugar Industry has been allocated $53.6 million in the 2020–2021 Budget (FBC News 2020) [151], and the industry plans to raise sugarcane production to around 3.9 million tonnes to match the crushing capacity of the mills (estimated at around 4.2 million tons per annum).

The Ministry of Agriculture has also established the Agriculture Marketing Authority (AMA) and provides "effective marketing support without crowding out the private sector" [152]. It is being strengthened by enhancing links between farms and markets to create greater synergy within the agricultural sector. The Ministry of Agriculture continues to promote organic farming, production of traditional crops and niche agricultural and fisheries products.

Actors and active projects

The government's priority to CSA has focused on "mechanized land preparation and harvesting, modern seed-breeding methods, and hydroponic and greenhouse farming techniques to address the issues of poor soil fertility, declining farm productivity and intermittent local supply" [153].

The 2020 Agriculture Sector Policy Agenda provides new directions for CSA through innovations, adaptation, and mitigation [154]. Climate resilient and environmentally sustainable production is given high priority, and there are plans for climate change adaptation and increased funding for agriculture research into crop varieties that are more resilient to expected changes in weather patterns. Extension training is also being prioritized to "ensure that farming practices adapt to changes due to climate change" [155].

As far as exports are concerned, "favourable trade and quarantine arrangements allow exports of agricultural produce to Australia, New Zealand, the U.S., Europe, Canada, China, and neighbouring Pacific Island countries." Furthermore, "opportunities to expand Fiji's exports for sale in mainstream supermarket chains overseas will also be pursued in the future" [156].

Gender equity and social inclusion

In Fiji, women work as farmers, wage earners, entrepreneurs, and custodians of traditional knowledge that is crucial for their community's livelihoods, resilience, and culture. In addition, women make a unique contribution to natural resource management [157]. The key priorities of the 2017–2021 action plan for implementing the 20-Year Development Strategy also include "achieving social inclusion and empowerment, including through the improved participation of women in

development, and undertaking regulatory reform to increase the private sectors contribution to development" [158].

Similarly, the national gender policy emphasizes women's empowerment, and opportunities for greater participation in leadership and decision-making across all sectors. It fosters gender equality in "agriculture and rural development sectors and promote[s] strategies to increase the participation of women in decision-making at all levels, including issues of land rentals, applications for financing from banks and financial institutions, and the distribution of rental and lease monies under the Land Use Decree 2011" [159].

The national policy also "investigates national agricultural data, disaggregated by sex, to identify the gender differentials with regard to ownership, earnings, crop selection, marketing, and other aspects of agriculture to develop gender-aware initiatives required to enhance the agricultural sector" [160].

FemLINKPacific through its Women's Weather Watch (WWW) campaign has "developed as a model for monitoring approaching storms and disaster management in their communities, providing real-time information with a local touch" [161]. A cadre of women leaders from across Fiji, including women with disabilities, have partner networks in PNG, Solomon Islands, Tonga, and Vanuatu.

TrC viability

The U.S. and India can develop a sophisticated technical–technological CSA architecture for Fiji that enables sharing of knowledge tailored to the island nation's requirements, assessment of technology needs, and helps build policies for easy implementation of CSA. These will also have to be supplemented by necessary fiscal support. In this context, the WWW can be augmented by designing focused meteorological capacity-building programs with shared technology from India and the U.S.

Started in India in 2012, CSVs are platforms to test—through participatory methods—technological and institutional options for dealing with climate change in agriculture. The CSV sites are generally a cluster of villages where such options are tested in collaboration with multiple stakeholders (farmers, researchers, local institutions, etc.) to generate evidence on synergies as well as trade-offs between different options in terms of productivity, adaptation, and mitigation. In Fiji, this proven approach is poised to be piloted to attain multiple benefits of resilient agricultural communities; higher yield potential, and thereby higher farm incomes; enhanced livelihood opportunities; and gender and social inclusion in agriculture strategies among others.

Agriculture landscape in Papua New Guinea

Papua New Guinea (PNG) is made up of 1,400 islands, atolls, and coral reefs in the Bismarck, Solomon, and Coral Seas. Among these the larger islands are Manus, New Ireland, New Britain, Bougainville, and the Milne Bay Province, comprising an island chain. These account for 5,152 kilometers of coastline and the country claims 2.7 million square kilometers EEZ [162]. Its land area of 461,690 square kilometers is mountainous and rugged and endowed with vast natural resources. Nearly 75 percent of the land area comprises tropical rainforests and the Sepik River flows across lowland plains in the northwest of the country. The population is estimated at 9 million (2021).

Papua New Guinea is a lower-middle-income agrarian economy and over 85 percent of the population is engaged in the agriculture sector, which constitutes nearly 25 percent of the national

GDP. Despite the abundance of starchy staples, the country imports rice and vegetable oil.

Evolution, policy, and practice

The country has a slew of policies, plans, and legislations for the agriculture sector. Climate, market shocks, and other unexpected events (El Nino, pest infestations, and pandemics) affect PNG's agricultural economy and food security. The Papua New Guinea Development Strategic Plan 2010–2030 prioritizes agriculture, and the Medium-Term Development Plan III (2018–2022) prioritizes "inclusive Economic Growth with renewed focus in Agriculture" [163]. Other plans include the National Agriculture Development Plan (NADP) 2007–2016; National Rice Policy 2015–2030; and NARI Strategy and Results Framework 2011–2020.

Papua New Guinea also claims a strong national agriculture research capacity through national institutes and universities, and these are considered important for scientific outputs for the agriculture sector and associated value chains, including service providers. The extension services involve a variety of well-coordinated arrangements of public, NGO and private players including farmers and supply chain groups.

Actors and active projects

The PNG government focuses on embracing and harnessing emerging technologies and exploiting the opportunities to bridge information and knowledge. The political leadership is "leading a digital transformation agenda that aims to harness the potential of technology to spur development and trade" [164].

The National E-agriculture Strategy (2017–2023) [165] is designed to "transform PNG agriculture through innovative information and communication technologies by 2023" to ensure "food security, income and economic growth."

The action plan follows the government's five-year planning cycle 2017–2023. For instance, data digitizing is conducted at the climate section of the PNG National Weather Service under the supervision of experienced climatologists [166]. The country acknowledges that public and private investment in the agriculture sector can potentially help achieve the goal of food security [167].

In 2017, PNG signed US$5 billion worth of projects, including an integrated agriculture industrial park, and a scientific and technological research base and training center [168]. A delegation was sent to China for training in agriculture, and the latter offered to invest and export agricultural products and machinery to PNG [169].

The ADB is leading the Strategic Program for Climate Resilience (SPCR) aimed at achieving transformational change in addressing current and future threats from climate change and mainstreaming climate resilience into development planning. The SPCR identifies risk factors across four sectors—including agriculture—against potential impacts from climate change and variability [170].

The World Bank has provided long-term IDA credit of US$40.0 million for a project involving diversified agriculture value chains for selected commodities in targeted provinces [171]. It also supported the Productive Partnerships in Agriculture Project which concluded in 2019, and the next phase of this collaboration is the PNG Agricultural Commercialization and Diversification Project (PACD) [172].

According to a report by the International Monetary Fund, COVID-19 and climate- and pest-related risks continue to threaten PNG's agri-food economy [173]. The International Monetary Fund approved a disbursement of US$363.6 million to PNG under the Rapid Credit Facility to cover urgent balance of payments needs stemming from the global pandemic [174].

The European Union External Action for Support to Rural Entrepreneurship, Investment and Trade in Papua New Guinea is supporting the FAO on a project on "agrivalue development and is expected to sustainably increase production of selected crops (cocoa, vanilla) and fisheries" [175].

Through the Australian Center for International Agriculture Research (2019–2023), the Government of Australia is facilitating the use of seasonal climate information by PNG farming communities to make informed food production decisions and improve food security and outcomes for rural communities [176].

Gender equity and social inclusion

Women farmers constitute 70 percent of the agricultural workforce of PNG, and they are especially vulnerable to the impact of climate change due to a lack of access to information, implementation of CSA practices, adaptation to climate change, and climate mitigation practices. Women are also the major players in agriculture for food and income through subsistence farming systems. The Papua New Guinea National Food Security Policy 2016–2025 notes that the agriculture sector can "provide an important entry-point for enhancing women's control and management of resources, knowledge and status; plus, child nutrition outcomes can improve along with women's empowerment through agriculture" [177]. The policy encourages women's participation in "consultations, trainings and planning process" related to gender activities. Food sector participation is also changing slowly as women's income makes up a large share of the household income. Therefore, it is critical to ensure that women are included as beneficiaries and as decision-makers in the agriculture value chains.

The PNG Women in Agriculture Development Foundation is a major player in the development of agriculture in the country and promotes the "Voices of Women in the Food Chain." It "provide[s] effective advocacy for women to be recognized as equal partners in all facets of development including agriculture," and offers an "enabling platform that promotes innovation and the advancement of the role of women in agriculture for development" [178].

A World Bank study has found that when women in PNG are empowered to make decisions in the sale of cocoa and coffee, their households ultimately benefit [179].

TrC viability

The U.S. government, through USAID, supports "disaster preparedness, relief and reconstruction, and promotes biodiversity conservation and sustainable natural resource management" in PNG [180].

India too has a similar approach and the 2016 MoU for agriculture research cooperation between the University of Technology, Lae (PNG) and the ICAR offers opportunities to share CSA practices [181].

A potential collaboration would be to set up an institute for sustainable coastal and ocean research and a network of marine biology research laboratories.

Annexure III provides a summary of the potential demand for climate smart agriculture-related interventions and knowledge in these five countries and the relevant CoEs from India that can address these gaps and needs.

9

Assessment of triangular cooperation viability and recommendations

Based on the literature review, supply and demand assessments of CSA in India and the Indo-Pacific—including the inputs received from the two respective convenings with overarching and embedded GESI aspects—this diagnostic study presents actionable recommendations on the potential and viability of TrC CSA partnership over the next three years, along with challenges and opportunities in the immediate, medium, and long term.

Globally, the concept of TrC is on the rise. It connects continents, countries to countries and contributes towards achieving the SDGs by using the complementary strengths of different partners to bring about co-created development solutions. A recent report by Global Partnership Initiative (GPI), Triangular Co-operation in the Era of the 2030 Agenda, Sharing Evidence and Stories from the Field (2020), states that "Triangular co-operation integrates very diverse partners who base their actions on different logic and principles of co-operation." [182] The 2030 Agenda for Sustainable Development sets out SDGs to facilitate equal, sustainable, and inclusive growth across the world, while promoting peace. The Second High-Level United Nations Conference on South-South Co-operation held in 2019 (known as BAPA +40) has given further impetus and opportunity for building TrC around the globe. It has proved to be a mechanism that brings together different perspectives and incorporates the diversity and multiplicity of today's development stakeholders.

The state of TrC in the Indian context

India has a long legacy of development assistance with a remarkable journey from aid receiver to an emerging donor. Despite its own development challenges, the country has embraced its global commitments and engages in wilful development cooperation with other developing countries for mutual benefit. India has championed the cause of industrialization and responded to the demands of many countries in trade, investment, technology, and capacity building. It started with the India Development Initiative (IDI) (2003), which paved the way for the Indian Development and Economic Assistance Scheme (IDEAS) in 2004, later increasing engagement with OECD and DAC members and initiating new forms of partnerships under the Development Partnership Administration (DPA) within the MEA to coordinate India's bilateral, regional, and triangular development cooperation. A diagrammatic presentation of the evolution and timeline of TrC in India is given in Annexure V.

India–U.S. relationships and the prospect of TrC

Over the past two decades, the U.S. and India have fortified their relationship. In September 2014, the two countries conceived a bilateral relationship based on the principle of "Chalein Saath: Forward Together We Go," mentioned in the first "Vision Statement for the Strategic Partnership" catering to the fulfilment of SDG 17. This vision statement serves as a manual for reinforcing and developing collaboration for global stability and job-led growth over the next 10 years. The statement also includes other sectors, such as energy and climate change, defence and homeland security cooperation, high technology, space and health cooperation, and other global issues. Further expanding their collaboration in the agricultural innovation sector, TrC focused on new sectors, such as agricultural productivity,

Photo Credit: Thanyapatm
Farmer using soil PH measurement tools to check the quality before planting, in Bihar, India.

clean energy, health, women's empowerment, and disaster preparedness. During the second bilateral summit held in 2015, TrC was further deepened to promote growth in Africa. Moreover, The Feed the Future India Triangular Training (FTF-ITT) Programme was a step forward in the U.S.–India TrC program for Africa. It was implemented by MANAGE, Hyderabad. In 2021, both countries signed a five-year extension to the Statement of Guiding Principles on Triangular Cooperation for Global Development, particularly in Asia and Africa. However, while India's engagement in development cooperation activities has made an impact and the U.S. and India are working together to promote global progress and achieve shared development goals around the world, it is believed that India–U.S. agreements are not comprehensive enough, are limited in scale and diversity, and need to move with greater speed. Despite this, agriculture is emerging as a niche sector and several projects are in the pipeline.

The demand side analysis of the identified countries reveals several gaps in the implementation of climate-smart practices and technologies in agriculture. This is where India's experience, with U.S.'s support, can be beneficial, as described in the table below.

CSA Supply and Demand Analysis, Gap Areas, and Action Plan

Indian CSA supply outlook

There is a large repository of knowledge and practice areas emerging in various agro-climatic zones in India with technical expertise and capacity-building efforts being undertaken by the government, and private and development sector organizations.

Through various policy measures, there is a marked shift in adopting climate-smart approaches in agricultural extension services. There are several reputed national- and local-level institutions that can act as CoEs on CSA and have expressed willingness to extend support to upscale and transfer related technologies, in India and in other countries. These organizations have developed CSA solutions, have the relevant expertise to share and transfer CSA technology, have developed training curricula, and some of the organizations have recently adopted remote learning in response to the COVID-19 pandemic.

All these organizations have an explicit commitment to gender and social inclusion. There are many AgTech companies providing new generation agricultural advisory and digital extension services, both in the private and public sectors. The political economy factors are conducive and favorable for India's engagement in taking forward the CSA TrC mandate by establishing partnerships in the selected countries. However, COVID-19 pandemic restrictions may constrain Indian expertise, including lead time in designing customized solutions.

Demand scenario from five potential countries

The demand-side analysis for CSA has been done for five countries in Asia and the Pacific (Vietnam, Cambodia, Lao PDR, Fiji and PNG) which looked at their needs, resources, and capacities in CSA. The conducive political economy of these countries, India's existing relations, provides a strong ground for TrC for CSA in these countries. The CSA demand analysis section has focused on country-specific CSA challenges, priorities, plans, and existing resources.

The stakeholders from the identified countries, who attended the demand-side convening on CSA, expressed their current needs. Based on these needs, the study has identified potential institutions from India to address the demand, while also integrating gender and equity in the design of such potential TrC partnerships.

The political economy of the five countries have been considered as they may affect a successful TrC engagement and their current engagement with other countries and international agencies. The analysis has captured the resource options for future investments in CSA—public, private, and international—in view of the few ongoing CSA programs, particularly in Vietnam and Cambodia.

Given the geo-political-economic factors, TrC possibilities could include an integrated approach including technology as a crucial component. Triangular cooperation programming should also identify how to integrate gender equality and women's empowerment and other inclusive development approaches in the process. Based on our primary and secondary studies in India, the analysis of the five countries in the Indo–Pacific region, and discussions with domain experts, institutions of repute, policymakers and practitioners, supplemented by two separate convenings (Annexure VI-A and B), it was found that country-specific demand assessments were successful because of the willingness of the identified partner countries. Additionally, since there is no single source of information on CSA practices and technologies and because good practices are not easily accessible, there is a need to synthesize this evidence and the good practices by creating an exchange unit/hub.

Prioritization of Indian CSA Models and Technologies and Exploration of Demand-led Opportunities for TrC

This prioritization and shortlisting exercise are based on the outcomes of the joint meetings held between The Asia Foundation and Global AgriSystem Private Limited (GAPL). The most promising thematic domains are drawn from the list of action areas recommended in the diagnostic report. This will help facilitate a roll-out framework for TrC and formulate concept notes based on the recommendations of the study. The shortlisting takes into account both horizontal and vertical mapping and scoping of the CSA models and technologies that India can offer. However, considering that the prevailing COVID-19 protocols were a barrier to in-person consultations and meetings with stakeholders in the five proposed countries during the study period, it was necessary to put in concurrent efforts to reach out to these key stakeholders while developing the roll-out framework and concept note outlines. This will help in facilitating dialogues with stakeholders and policymakers in the respective countries, preferably through in-person meetings and mission visits to present and gauge the width and depth of the need to develop tailor-made CSA solutions.

The suggested feasible areas of intervention have been categorized as:

1. Quick impact projects (QIP), horizontal in nature, for all five proposed countries. These projects are cross-cutting and address several needs for various types of crops through a specific set of interventions and practices.
2. Commodity- and country-specific vertical program on sugar in Fiji. Vertical programs address the agriculture needs for a specific type of crop.
3. Second phase interventions can include creation of Communities of Practice and knowledge sharing platforms for CSA practitioners.
4. Innovations with a commercial focus.

Sl. No.	CSA technology thematic areas	Activities to be undertaken	Potential Indian supply partner	Potentially identified demand country
QIP and Horizontal Programs				
1.	Digitization and smart agriculture Digital mapping through satellite imagery, use of drones, etc., and providing advisory services	Stage 1: Mapping the whole country or target area Stage 2: Providing on-line advisory services	1.Excel Geometrics 2. CropIn	Vietnam Cambodia Lao PDR
2.	Integration of CSA through FPOs	Preparing a regulatory framework and setting up FPOs	APMAS	Vietnam Cambodia PNG
3.	Weather index-based crop insurance	Setting up weather stations at different locations and advisory services	Skymet	Cambodia Lao PDR PNG
4.	Climate modelling and forecasting	Training and computer modelling	TERI	Vietnam PNG Fiji
5.	Sustainable agriculture/ organic farming/natural farming	Scoping and training on organic and natural farming processes	Centre for Sustainable Agriculture, Hyderabad	Vietnam Cambodia Lao PDR
Commodity and country-specific vertical program				
6.	Climate smart sugarcane farming in Fiji and conversion of waste-to-energy	Preparing detailed project report and implementation of complete utilization of bagasse and co-products	GAPL	Fiji
Second Phase Interventions				
7.	Common platform of CSA related practices and technologies for policy direction and implementation	Setting up a coordinating organization/network at the central level	ICAR (NICRA) GoI and the associated Institutions	All countries
Innovations with Commercial Orientation				
8.	Market place through digital platforms	Setting up a digital marketplace	NeML, a wholly owned subsidiary of NCDEX	Vietnam Cambodia
9.	Farm mechanization as a tool for CSA technology adoption and CHCs	Setting up of CHCs	EM3	Vietnam Cambodia

The potential areas of TrC activities defined in the table above have been described below:

QIP, Horizontal Programs

1. **Digitization and CSA:** Technology is changing the narrative of Indian agriculture. With the increasing digitalization of Indian agriculture, technology-led solutions are progressively addressing most of the challenges that farmers face—soil issues, more accurate weather forecasts, irrigation and water management, price discovery, and supply chain gaps. Farmers can now use smartphones to receive timely updates, relevant information, and monitor their crops. More farmers are beginning to understand how leveraging solutions that use the latest digital technologies such as sensors, location data derived from GPS and satellite imagery, use of drones, robotics and analytics are changing the face of agriculture in India. Artificial Intelligence (AI), Machine Learning (ML), and Cloud help them develop greater climate resilience, higher crop yield, and better price control. Precision agriculture uses Internet of Things (IoT)-based approaches that make farming more accurate and deliver more precise outcomes. Based on this, farmers can make informed decisions. It utilizes deep data about a specific location and crops to optimize processes, making them more efficient, both in terms of resource utilization as well as cost. It also leads to more sustainable agricultural practices.

A two-pronged approach is proposed: (a) digital mapping through satellite imagery, use of drones, etc.; and (b) providing customized advisory services. Two potential Indian organizations have been identified that have the relevant expertise in this area:

(a) **Excel Geomatics Private Limited** for digital mapping through satellite imagery, use of drones, etc. They provide advisory and value-added services in the fastest-growing technology sectors using tools and techniques such as Satellite Remote Sensing, LiDAR, Photogrammetry, GIS, and Survey (Ground and Airborne) that can help clients address problems and opportunities in different domains.

(b) **CropIn** for providing customized advisory services. CropIn is an intuitive, intelligent, self-evolving system that delivers future-ready farming solutions to the entire agricultural sector. It delivers decision-making tools that bring consistency, dependability, and sustainability to agribusinesses. CropIn enables farm digitization while managing the entire ecosystem with live reporting, analyses, interpretations, and insights that span geographies. Its innovative agri solutions are powered in real-time and it helps to archive patterns and predict trends. In addition to the featured programs in India and other countries, CropIn has been piloting projects in Vietnam and Cambodia.

2. **Integration of CSA through FPOs/Collectives:** FPOs are fast emerging as one of the most effective means to cater to the needs of small and marginal farmers and in bringing transformation. In India, FPOs have been in existence for over two decades. There are more than 8,000 FPOs in India presently, and another 10,000 will be formed in the coming two years. A study of 190 FPOs across the country reveals that farmers have amply benefited by adopting various agronomy practices, particularly CSA technologies. One of the reputed and impactful organizations in this area is APMAS, based in Hyderabad. It has demonstrated the integration of CSA technologies through the FPO platform and has an excellent infrastructure for in-house training with a vast network in this space.

3. **Weather Index-based Crop Insurance:** In the Indian context, the idea of weather index-based insurance products as a measure of mitigation is gaining popularity, and GoI has launched schemes incorporating weather-based crop insurance products. For example, in Bihar, the Indian Farmers Fertilizer Cooperative and Tokio General Insurance have offered a weather index-based crop insurance scheme. To achieve widespread implementation of such schemes, India has made massive investments in weather station infrastructure.

Skymet Weather Services is the largest weather monitoring and agri-risk solutions company. It has expertise in measuring, predicting, and managing climate risks to agriculture. Founded by Jatin Singh in 2013, it is the first private sector company in India to provide weather forecasts and weather graphics. Skymet provides weather service and graphics to most Indian media companies and weather service information to most of the major insurance companies and the agriculture sector. Skymet, along with a few NGOs, is working closely to improve farmer sustenance in remote blocks of many states. It also caters to different companies for marine weather forecasting. Skymet has recently launched a weather website that allows a common user to get accurate weather information at no cost. It also launched an android app and App Store (iOS) that gives weather information in multiple regional languages. Skymet has developed many software tools for weather and climate decision-support systems.

4. **Training on Climate Modelling and Forecasting:** In the post-Paris Agreement era, accelerated climate action is vital to ensure a safe future for all. In this regard, TERI focuses its work on climate modelling to acquire a better understanding of climate variability at the regional scale by studying key sectors such as water, agriculture, industry, etc. It has a state-of-the-art supercomputer to undertake the modelling and they are willing to extend their expertise, knowledge, and research base to emerging economies. Customized training on climate modelling and CSA targeted at young professionals for the two most willing countries, Cambodia and Vietnam, can be done on an experimental pilot basis as innovations under the TrC, and in succession for the other countries. TERI can play an anchor role in hosting sponsored representatives and qualified youth, particularly women, to join the customized programme.

5. **Sustainable Agriculture/Organic Farming/ Natural Farming:** This can be undertaken in countries that are interested and already have buy-in and demand for organic products and natural farming practices. India can transfer its knowledge and expertise to strengthen and streamline the value chain system as it has experience in better organic farming. The Centre for Sustainable Agriculture, with nearly 20 years' experience, has offered its services. It is a professional resource organization engaged in establishing models of sustainable agriculture, working in partnership with governments, NGOs, and CBOs by scaling up successes. It works in Andhra Pradesh, Telangana, Maharashtra, and Punjab with direct reach to more than 50,000 farmers organized into 30 producer organizations marketing their produce under the brand name "Sahaja Aharam."

Commodity and country-specific vertical program

Climate Smart Sugarcane Farming in Fiji and Conversion of Waste to Energy: Fiji remains a developing country with a large agriculture sector which accounts for 18 percent of the national GDP. Sugarcane production and subsistence farming are the dominant activities in the agricultural sector, with the former providing a livelihood to approximately 15 percent of the population. Recognizing the adverse impact of climate change on agriculture, the Government of Fiji is proactively engaged in dialogues with farmers to stress the importance of applying best agricultural practices to mitigate the effects of climate change. According to media reports, apart from wreaking havoc in sugarcane fields through extreme weather conditions such as severe tropical cyclones, climate change is also affecting how and when sugarcane is planted in the country. The Sugar Research Institute of Fiji has been studying the cropping pattern of sugarcane and how farmers are enslaved to weather patterns. The Institute advocates more environmentally friendly fertilizer applications and husbandry practices. The government has also placed emphasis on green growth with a Green Growth Framework in place.

The sugar industry has shaped the development of Fiji's economy for over a century. However, the current production is below 2 million tonnes per year, down from about 4 million tonnes prior to 2000. This significant decline is primarily due to lower output prices, high production costs (including fertilizer, transportation, and harvesting costs), a decline in hectares under cultivation because of non-renewal of land leases, shortage of labor, and the increasingly negative attitude of farmers towards the industry. Globally, the average production per hectare is between 60 to 65 tonnes every year, well above Fiji's current (2015) rate of 47 tonnes per hectare. The sugar industry has suffered from the

Photo Credit: Ashwini Chaudhary (Monty)
Sugarcane farmer utilizing solar power during harvesting in Bhalsona, Uttar Pradesh, India.

withdrawal of preferential sugar price arrangements that Fiji has enjoyed since 1975 under the European Union Lomé Convention.

The cultivation of sugarcane farming in Fiji is mainly manual. Farmers have traditionally used bullocks and horses to plough their farms, and small farmers do not invest in mechanization, particularly for harvesting. The recommended age of ratoon (new shoot or sprout springing from the base of a crop plant) crops is less than four years, but the farmers keep them for 11 years. This has a significant impact on yield per hectare and profitability in sugarcane farming. The logistical facilities are inadequate and the cost of transporting cane to the mills from the farms is one of the major concerns for farmers. The sugar mills in Fiji are over 100 years old, and their regular breakdown further adds to the cost to farmers from lost cane weight and increased burnt cane penalty.

Besides the production of sugar from sugarcane, there are residues and by-products like bagasse and molasses. Bagasse is generally used as fuel for the boilers and molasses is mostly used to produce alcoholic beverages, leaving behind a lot of unused waste material. However, experience from Brazil and India shows that this residue can be used to produce several valuable by-products. The development of innovative cascading processes using these residual biomass fractions could significantly reduce final disposal costs, improve energy output, reduce GHG emissions, and extend the product portfolio of sugarcane mills in a process of circular economy.

Sugarcane, a cash crop, requires large quantities of water and vast land to cultivate, making its cultivation a tremendous challenge. Research findings on sugarcane in India reveal that producing ethanol from sugarcane juice instead of molasses can help make resources like land and water more sustainable. A shift to using the crop as a source of energy generation can be beneficial for not just increasing access to nutrients, but also help in transitioning to renewable energy. India's biofuel policy allows the use of sugarcane juice in ethanol production, in addition to molasses.

In the recent past, GAPL was engaged in introducing a package of practices for sustainable sugarcane production and adoption by farmers in India. The project was supported by IFC and co-created with the private sector partner. The project was successful and resulted in a productivity increase of over 82 percent in three years using precision agriculture practices. In Fiji, a special program on sugar cultivation and processing of co-products like bioethanol and power, package of practices, and CSA integration can be considered.

Interventions for Second Phase TrC programming

Setting up/Strengthening CSA-related Platform/ Network in Respective Countries: At the apex level, India has demonstrated that it has a structured platform and a network for research, technology demonstration, capacity building and grant awards on CSA technologies. The network project NICRA aims to enhance the resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. Location-specific technologies have been demonstrated in a participatory mode in the districts that are most vulnerable to climate change. It is done through KVKs and several centers of AICRPDA to enhance adaptive capacity of farmers and enable them to cope with current climatic variability, which is essential to achieving climate resilience in agriculture. Establishing/strengthening such a CSA platform-cum-network in each country can lead to better solutions in specific contexts.

Through dialogues with the ICAR at the GoI level, this activity can be facilitated like NICRA to foster

innovations, research, extension, training, etc. Further, GAPL can play an active role in facilitating the process and exchange with the ICAR.

Innovations with Commercial Orientation

Digital Market Place for Market Linkage: India has been successful in digital agri commodity exchanges and marketplaces, facilitating online trading between farmers and big market players. Of the four commodity trading stock exchanges in India, NCDEX and NMCE focus on agricultural commodities. The National Agriculture Market (eNAM) is a pan-India portal for agricultural trading that has set up a network with agriculture market produce companies (APMC) in states to create a unified national market for agricultural commodities. The Government of Karnataka has established a joint venture with NCDEX to modernize agricultural produce market committee markets in the state by bringing in electronic auctions. Besides, there are regional players as well. The NCDEX is the largest agricultural commodity stock exchange in the country. In the AgTech Startup ecosystem, there are many emerging players like Arya Collateral and Dehaat. The oldest and most credible organization is NeML, a wholly owned subsidiary of NCDEX.

Farm Mechanisation as a Tool for CSA Technology Adoption and CHCs: Custom hiring centers (CHCs) have proved to be an innovative strategy in mechanizing agriculture for small and marginal farmers, without bearing the economic burden associated with it. A recent (September 2020) case bulletin published by CGIAR's CCAFS highlights that increased access to agricultural technologies leads to a significant increase in crop production and farmers' incomes, thereby increasing their adaptive capacity. It further shows that the engagement and association of CHC members have provided them knowledge of, and exposure to, various climate resilient technologies. Members of CHCs act as catalysts in spreading awareness among other community members, as well as a medium of change. In this case, 13 CHCs in three project districts are run by a group of women farmers, thereby contributing to gender integration and women' empowerment in the local farming community. The CHCs enable farmers to access farming equipment on a pay-per-use basis, facilitating efficient use of inputs, and supporting an increase in income.

With more than 80 percent of the farmers in India being small and marginal, purchasing agricultural machinery such as tillers, threshers, and harvesters is not an economically viable option. For this reason, most of the small and marginal farmers in India engage in time- and cost-intensive traditional methods of farming, making it difficult to adopt climate-smart technologies. To address this issue, and as part of the project on CSVs in India, 13 CHCs have been established in the project districts, with the vision of making CSA technology available to all. These CHCs facilitate easy access to agricultural machinery such as weeders, sprayers, threshers, small harvesters, tillers, happy speeders, and portable solar pumps for irrigation to farmers on rent at affordable rates. There are governing principles on usage, service charges, maintenance of the[3] equipment and running it as a business model.

Under the NICRA project, common machinery made available through the CHCs has benefited the farmers who participated, particularly seed drills, groundnut threshers, and sprayers. CHCs have worked well in more than 100 villages to support CSA technology adoption. A Compendium of Key Climate Smart Agriculture Practices in Intensive

3 https://cgspace.cgiar.org/handle/10568/109725

Cereal Based Systems of South Asia (published by CIMMYT, CGIAR, CCAFS, and ICAR)[4] provides examples of laser land levelling, happy seeder, spatial zero-till drill, direct seeded rice, and solar power pumps.

These common facilities available on rent are equally important in promoting precision agriculture among smallholder farmers. A recently published case study on CSA technologies explains the utility applications of CHCs.

It has vast potential to engage with private sector actors who are active in successfully running CHCs in rural India. In this context, EM3 offers farmers on-time, on-demand, and professional mechanization services at transparent prices. EM3's end-to-end service platform across the growing chain increases reliable access to a wide variety of farm services. This reduces the cost of mechanization for smallholder farmers, leading to increased farming productivity and yields. EM3 has provided mechanization services to over 200,000 acres of land and to 24,000 farmers in Madhya Pradesh, Rajasthan, and Uttar Pradesh. It has created over 300 farm equipment centers in Rajasthan, providing monitoring and auditing functions on behalf of the CHCs to report to the government. EM3 also provides high-end implements to the CHCs and offers training and other support to improve the quality of services that the CHCs provide their farmers.

Approaches for TrC on CSA

Triangular cooperation is increasingly attracting attention as a key to the global development landscape. In the context of CSA, a TrC arrangement presents opportunities to shape new types of partnerships that create synergies between India and the Indo-Pacific countries. The following approaches are recommended, keeping in view political-economic factors.

1. Identifying an anchor/facilitating host organization in the respective countries for better stakeholder engagement. Establishing/identifying an existing CSA innovation platform will facilitate useful exchanges as greater private sector engagement will accelerate the pace of technology transfer. This aligns with the fact that TrC is increasingly becoming multi-stakeholder engagement. While governments and international organizations (IOs) are still the main actors in TrC, the engagement of non-state actors is on the rise. Agenda 2030 was a signal to non-state actors that their involvement in development cooperation is crucial for the fulfillment of SDGs. Apart from CSOs, academia, and the private sector, philanthropies, regional and local governments are also actively encouraged to contribute to TrC to mobilize further resources (expertise, finance, human resources) and to implement existing and locally driven projects more effectively.
2. Packaging the technologies to match the requirements of the countries in need/placing the demand. Technologies for enhancing climate resilience can be divided broadly into two categories: matured technologies that have been sufficiently developed and commercialized like solar panels, and emerging technologies, such as artificial intelligence, blockchain, precision agriculture.
3. Creating cooperation modalities for the private and public sectors to engage separately to address climate smart agriculture needs of a country to streamline the process.
4. Dialogues with institutions such as ICRISAT/MANAGE/NIRD/CRIDA/ICAR for thematic track-wise technology transfer.
5. Active engagement of private sector organizations like TERI, CropIn, Digital Green, APMAS, Global AgriSystem, Centre for Sustainable Agriculture.
6. Exploring the possibility of a public-private partnership/consortium approach. In the case of FTF, MANAGE did play an anchoring role, joined

4 http://www.indiaenvironmentportal.org.in/files/file/Final%20CSA%20Compendium.pdf

by ICAR institutes on various themes, and ICRISAT.

7. An incubator model can also help country-specific start-ups and agri-entrepreneurs learn from models in agriculture universities like AgHubs.

8. A knowledge center model wherein Indian institutes/organizations share their knowledge and help formulate strategies for CSA technology transfer.

9. In the extension model, extension personnel are sponsored by the designated countries to be trained in Indian CSA approaches and technologies.

10. Partners are identified and selected with respective institutions/themes for transfer in the partnership model.

11. Exploring options for QIP since CSA technology transfer first requires hardware, software, and Orgware, then moves on to short- and long-term TrC.

12. Exchange programs for women farmers for sharing and new learnings.

13. Capacity building through short-term exchange programs/courses, study tours and secondment programs in relevant institutions to provide direct technical assistance, including programs targeted at women at various levels.

A Set of Voluntary Guidelines

It is worth reproducing the voluntary guidelines for effective TrC developed by the GPI. These guidelines will be crucial to ensure that the program is successful [182].

- **Country ownership and demand-driven cooperation:** TrC should have ownership of partner countries and needs to be aligned with their national priorities, as well as those of the 2030 Agenda for Sustainable Development.
- **Shared commitment:** Partners agree to develop collaborative projects and share responsibilities for identifying, designing, implementing, contributing, monitoring, and evaluating the projects.
- **Focus on result-oriented approaches and solutions:** All partners commit to achieving agreed upon results, as well as demonstrating and systematizing results.
- **Inclusive partnerships and multi-stakeholder dialogues:** Responding to the needs and objectives of all parties, partners aim to involve multiple actors with a view to foster knowledge sharing, and to find sustainable development solutions.
- **Transparency and mutual accountability:** All partners are accountable for commitments made and agreed upon. They agree to share information on their TrC activities in accordance with the standard to enable monitoring, evaluation, and accountability.
- **Innovation and co-creation:** Through new and existing partnerships, intelligent risk-taking, evidence-based policy and programming, technology, and flexible approaches to locally driven innovative solutions, with a view to improving development results.
- **Joint learning and knowledge sharing for sustainable development:** Through horizontal exchanges and co-creation of development solutions, all partners mutually benefit from sharing their knowledge, capabilities, and strengths.
- **Advance gender equality and the empowerment of women and girls:** TrC should contribute to gender equity in its multiple dimensions to accelerate the progress of sustainable development.
- **Leaving no one behind:** TrC furthers inclusive multi-stakeholder partnerships, including those that provide support to the most vulnerable.

Challenges that may prevent Indian institutes from participating in a TrC partnership

Adopting CSA practices may be perceived as challenging for farmers, particularly smallholder farmers, who focus on agriculture as a source of livelihood. This may affect their ability to adopt CSA practices. This premise holds good in the context of both India and other countries. Farmers need technologies and capital at a macro level to deal

with CSA, but it is equally necessary to consider the production and profitability risks. CSA strategy and policy must be aligned with its implementation, for which understanding farmers' requirements is critical.

Finally, the action boils down to what the farmer understands and adopts. In the context of India, despite being an agrarian economy and a top producer and exporter of several agricultural commodities, multiple challenges such as high weather dependency, supply chain inefficiencies, depleting resources, and low productivity hold back the sector from optimal performance in TrC partnerships. The challenges faced by the agriculture sector in India by both men and women include: lack of awareness of agricultural inputs; inadequate data on supply-demand of farm inputs; scarcity of capital to invest in mechanization; frequent disease outbreaks in livestock and pests affecting crops; inadequate irrigation infrastructure; lack of price discovery and market information; structural barriers that block women's access to land ownership; lack of recognition and acknowledgment of women's importance as farmers; denial of land rights to women farmers; lack of awareness and access to knowledge, technology, information, training, productive resources—including climate finance, among others; insufficient gender-disaggregated data; and lack of decision-making and employment opportunities for women.

On the other hand, despite the positive outcomes that TrC can provide, there remain some challenges that need to be tackled to make the modality more effective:

- The potentially higher transaction costs of TrC initiatives and financing mechanisms.
- Limited avenues to mainstream TrC as a potential approach to development partnerships as a regular instrument by various development stakeholders.

Lack of clearly defined comparative advantages vis-à-vis bilateral or regional cooperation.

- Lack of regular evaluations, systematic report and project assessments to generate lessons and improve the partnership modality.
- Limited enabling environment for potential opportunities for establishing TrC.

Impact of COVID-19 on TrC partnerships

The COVID-19 pandemic has impacted the global economy and affected all countries in varying ways. Mobility, travel, possibilities for knowledge exchange -- all have been curtailed due to restrictions imposed by the pandemic. However, most countries, including India, have vaccinated majority of their populations. Lockdown measures are now gradually being lifted, international travel has resumed, and new opportunities for cooperation and partnerships in a post-pandemic world are emerging.

Even though the pandemic continues, it is quite possible, in the case of TrC for CSA, to adopt hybrid models for expanding such partnerships. Going by the contemporary approach with the enlarged scope of TrC as advocated by GPI—which includes new development actors and working methods—India is well positioned to bring (a) beneficiary partners, (b) pivotal partners, and (c) facilitating partners together, with possibly several actors for each role at each edge of the TrC. This establishes India's growth as a partner in development cooperation and its commitment to TrC programs.

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Photo Credit: Thala Bhula
Micro irrigation (drip and sprinkler) watering a new budding wheat field in Rajasthan, India.

Annexures

Annexure I - Defining Climate Smart Agriculture

Climate Smart Agriculture is an approach for transforming and reorienting agricultural development under the new realities of climate change [183]. It is not a one-size-fits-all set of practices that can be adopted by every farmer. In each location, its form needs to be defined by the context (i.e., extent of vulnerability to climate change, varying community risk profiles, availability of resources, and livelihood options). It can be applied on a single farm or over entire landscapes, and it often needs the involvement of diverse agricultural stakeholders and coordination across different agricultural sectors, as well as other related sectors such as energy and water.

The three pillars of CSA are:

Productivity: CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock, and fish, without leaving a negative impact on the environment. This, in turn, will raise food and nutritional security. A key concept related to raising productivity is sustainable intensification.

Adaptation: CSA aims to reduce farmers' exposure to short-term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and long-term stresses. Particular attention is paid to protecting the ecosystem services provided to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.

Mitigation: Wherever and whenever possible, CSA should help to reduce and/or remove GHG emissions. This implies that we reduce emissions for each calorie or kilo of food, fiber, and fuel that we produce; that we avoid deforestation from agriculture; and that we manage soils and trees in ways that maximize their potential to act as carbon sinks and absorb CO2 from the atmosphere.

Key Characteristics of CSA

CSA addresses climate change: Contrary to conventional agricultural development, CSA systematically integrates climate change with the planning and development of sustainable agricultural systems [184].

CSA integrates multiple goals and manages trade-offs: Ideally, it is not possible to achieve all three triple-win outcomes of CSA. For its implementation, there must be trade-offs based on identifying synergies and weighing the costs and benefits of different options depending on the objectives of stakeholders identified through participatory approaches.

CSA maintains ecosystems services: Ecosystems provide farmers with essential services, including clean air, water, food, and materials. It is imperative that CSA interventions do not contribute to their degradation. Thus, CSA adopts a landscape approach that builds on the principles of sustainable agriculture but goes beyond narrow sectoral approaches that result in uncoordinated and competing land uses, to integrated planning and management [1, 13].

CSA has multiple entry points at different levels: CSA should not be perceived as a set of practices and technologies. It has multiple entry points, ranging from the development of technologies and practices to the elaboration of climate change models and scenarios, information technologies, insurance schemes, value chains, and strengthening institutionally and politically enabling environments. As such, it includes the integration of multiple interventions at the food system, landscape, value chain, or policy level.

CSA is context specific: What is climate smart in one place may not be climate smart in another, and no interventions are climate smart everywhere or every time. The fact that CSA often strives to reach multiple objectives at the system level makes it particularly difficult to transfer experiences from one context to another.

CSA engages women and marginalized groups: To achieve food security goals and enhance resilience, CSA approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands which vulnerable to climate events like droughts and floods. They are, thus, most likely to be affected by climate change. Women typically have limited access and legal rights to the land they farm, or to other productive and economic resources which could help build their adaptive capacity to cope with droughts and floods [185]. CSA strives to involve all local, regional, and national stakeholders in decision-making. Only by doing so is it possible to identify the most appropriate interventions and form the partnerships and alliances needed to enable sustainable development.

Being an integrated approach, CSA can address several challenges related to climate change, but it requires a full value chain approach.

Climate Smart Villages

Started in 27 villages, first in Haryana and Bihar, the concept of CSVs has been adopted in many villages and they are now disseminating key climate smart agricultural interventions, focusing on water, energy, nutrient, weather, and knowledge implemented through innovative partnerships and farmer cooperatives. They have positively impacted the population's livelihood and development.

- *weather-smart* activities (weather forecasts, ICT-based agro-advisories, index-based insurance, stress-tolerant crops and varieties, and climate analogues);

- *water-smart* practices (resilient water management practices, aquifer recharge, rainwater harvesting, community management of water, laser land levelling, water conservation, drip irrigation, raised bed planting, crop diversification, alternate wetting and drying in rice, direct seeded rice and on-farm water management);

- *carbon-smart* practices (agroforestry, livestock and manure management, conservation tillage, diversified land-use systems, and residue management enhancing carbon content in the soil);

- *nitrogen-smart* practices (leaf-colour charts, hand-held crop sensors, and nutrient decision-maker tools for site-specific nutrient management and precision fertilizer application using nutrient expert decision support tools, residue management, and legume catch cropping);

- *energy-smart* technologies and practices (fuel-efficient agricultural machineries, residue management, biogas systems, and minimum tillage to conserve energy and reduce GHG emissions); and

- *knowledge-smart* activities like cross-site visits of farmers, farmer-to-farmer learning, capacity building, enhancement of CSA, seed packets of adapted varieties, community seed and fodder banks, a market and off-farm risk management system.

Annexure II - Climate Smart Agriculture Technologies, Practices and Services in Vulnerable Areas of Odisha

Sr. No.	Technology	Implementing agency	Impact
1.	Stress-tolerant varieties impart resilience to farmers in flood-prone areas	OUAT and IRRI	Demonstration of rice variety Swarna Sub 1 in flood-prone ecosystem of Odisha showed that it could tolerate submergence for up to two weeks and could perform significantly better compared to other local and improved cultivars.
2.	Lodging-resistant paddy cultivar in cyclone and heavy rainfall situations	OUAT	In CSVs of Odisha Lodging-resistant varieties that can withstand up to maturity were demonstrated to farmers. Variety Bina Dhan 11 was demonstrated in farmers' fields in frequently affected areas. Although its duration was five to seven days more, it sustained completely against lodging. It also registered tolerance to a certain extent against Brown Plant Hopper. Delayed harvesting also did not increase any significant loss.
3.	Non puddled transplanting rice (NPTR) –a resource-saving approach	OUAT	Adoption of climate resilient conservation agriculture practice of non-puddled transplanted rice through access to appropriate farm machinery at a reasonable cost brings precision to agricultural operations and efficiency in use of resources. Thus, non-puddled transplanting is a suitable substitute which enables transplanting with low water, energy, cost, as well as timely establishment.
4.	Diversification with green gram and groundnut for resource conservation	OUAT	Green Gram (variety IPM 02-14) was grown by utilizing the residual moisture from rabi rice crop. With one supplemental irrigation at the flowering or pod formation stage, the crop performed well. This variety shows resistance to yellow vein mosaic virus (YMV) which is quite common in the locality. Under the prevailing situation, groundnut was also a suitable alternative and the variety Devi was grown utilizing the residual moisture succeeding kharif paddy. Green Gram and groundnut showed potential to diversify from the rice–rice system in Odisha.
5.	Climate smart adaptation packages	ICRISAT	The evaluation of adaptation strategies (combination of biophysical, economic, and policy options) across diverse farms in Kurnool district of Andhra Pradesh using the multi-model approach revealed: • Increase in chickpea productivity on average by 40 percent in the district. • Increase in the net farm returns to the tune of 60 percent. • Increase in the per capita income by 34 percent. • Reduction in the poverty rate in the region from 26.8 percent to 16.4 percent across the farm households in Kurnool district.

Sr. No.	Technology	Implementing agency	Impact
6.	Stress-resilient maize hybrids for drought-prone environment	CIMMYT	The overarching goal of the stress-resilient maize program has been to improve upside yield potential with downside risk reduction. The new generation of stress-resilient hybrids possesses a combination of traits, including tolerance to drought/ waterlogging/heat stress, and resistance to key diseases with respectable yields under optimal trial. These hybrids were licensed to partners (on a semi-exclusive basis), including OUAT and two Odisha- based SMEs. These high-yielding, stress- resilient hybrids are being extended for deployment and scale-out to reduce yield losses under stress-prone conditions in farmers' fields.
7.	System of crop intensification adopted in rice and finger millet	PRAGATI	System of crop intensification, especially in rice and millets, is an innovation in technology that can adapt to changing climate and withstand adverse effects of climate change. It has been practiced in Koratpur district and has impacted the soil in multiple ways: • Increased yield • Improved resource use efficiencies • Increased net profit • Contributed to mitigation
8.	Drought-tolerant tole and high-yielding fodder varieties, hydroponic fodder cultivation and processing, and storage of feed and fodder	ILRI	ILRI has been promoting new varieties of fodder crops such as drought-tolerant perennial sorghum (COFS-29 and COFS-31), and Hybrid Napier Bajra (CO-5 and Sampoorna) and fodder trees (Agasti, Morigna and Hedge leucern). In addition, new feeding practices based on availability of local feed and fodder. This gives farmers an opportunity to improve their livestock productivity. **Impact:** Improved feed and management practices will reduce the cost of livestock production. Cultivating new varieties of fodder and following better management practices have enabled mitigation of the effects of climate change, thereby increasing productivity in the following ways: • Reduced the cost of milk production/feed up to 45 percent. • Increased milk quality (FAT) by 10 percent • Increased milk yield by 20 percent • Reduced dependency on grazing land • Increased digestibility, leading to reduced methane emission • Increased the total income of farmers by ₹6,000 per lactation

Sr. No.	Technology	Implementing agency	Impact
9.	Improved maize production practices for plateau ecology of Odisha	CIMMYT	Production of commercial maize under best bet agronomic practices is the intervention to address climatic risks and ensure income security. Commercial maize is the cultivation of hybrids that can be readily bought by institutional buyers. These hybrids should be of long maturity class (120 days) as their yield potential is high and they can surpass post-monsoon rains. Best bet agronomic practices include planting in rows with optimal plant population, appropriate fertilizer application, and proper weed management. Maize planting in rows should preferably be done through a seed-cum-fertilizer drill. Fertilizers should be applied at the rate of 150 kg urea, 100 kg DAP, and 80 kg potash per hectare. In addition, 5 to 10 tonnes/ha of compost should be applied. Good weed management can be achieved through application of one post-emergence herbicide followed by one manual/ mechanical weeding. Weeding should be performed by mechanical power weeders so that weeding and earthing-up can be done simultaneously and reduce costs. Output market integration can be achieved through produce aggregation at the village level and establishing linkages with the proximate feed millers.
10.	DSR for better resource management	OUAT	A comprehensive water management program was conducted for the farmers. Different methods of irrigation were discussed, including DSR, which reduced water use by reducing the number of irrigation events required; it can reduce water use by up to 25 percent. It can help farmers cope with water scarcity and increase reliability of downstream irrigation water supply. It is also a water management practice for irrigated lowland rice that saves water and reduces GHG emissions while maintaining yields.
11.	AWD for saving water and labor	OUAT and IRRI	Water and labor-saving AWD technique of irrigation of rice is a feasible option to reduce irrigation water consumption in the rice fields of Odisha without compromising on yield. In AWD, irrigation water is applied a few days after the ponded water finishes, which is observed through irrigation tubes. Hence, the field gets alternately flooded and dried. The number of days of non-flooded soil between irrigations may vary depending on a number of factors such as soil type, weather, and crop growth stage. AWD irrigation was accompanied with irrigation via channels, which allowed the exact amount of water required into the field and drainage was easier. Time required for irrigation was also reduced. The AWD method can increase grain yield because of enhancement in root respiration and growth, remobilization of carbon reserves from vegetative tissues to grains, and grain-filling rate. AWD can reduce the cost of irrigation by reducing pumping costs and fuel consumption. This method could also reduce labor costs by improving field conditions at harvest so as to allow mechanical harvest. AWD leads to firmer soil conditions at harvest, which is suitable to operate machines in the field. Therefore, AWD increases net return of farmers and reduces cadmium accumulation in rice grains. It can dramatically reduce the concentration of arsenic in harvested rice grains. Periodic soil drying reduces the incidence of fungal diseases and other insect pests.

Sr. No.	Technology	Implementing agency	Impact
12.	Intensifying rice fallows with green gram variety IPM 02-14	OUAT	The Green Gram variety IPM 02-14 was introduced in rice-fallow/ pulse cropping. In this system, rice is harvested early, allowing cultivation of pulses by taking advantage of the residual moisture stored in the soil with minimum tillage. To utilize the stored moisture effectively, green gram is drill seeded instead of traditional broadcasting. Yellow sticky trap (YST) was installed to protect the crop from YMV by trapping the vectors. Drill seeding ensured sufficient plant population through proper utilization of residual moisture. Green gram variety IPM 02-14 was tolerant to high temperature, With YST, it was found free of YMV. As a result, it yielded (7.2 q/ha) advantage of 57 percent over the broadcasted traditional variety. The gross return realized was ₹41,400 with a B-C ratio of 1:6.
13.	IWM technology for higher productivity	ICAR-NRRI and OUAT	7.1 unit in manual method of weed control. The gross return (₹92,196) and net return (₹43, 217) increased by 13.7 percent and 53.8 percent, respectively, with B-C ratio of 1:9.
14.	Field-specific nutrient management for rainfed rice RCM	IRRI	The SSNM (site-specific nutrient management) based approach for irrigated rice to irrigated rice was developed and evaluated and found suitable for adjusting nutrient application for smallholding farmers of Odisha. For rainfed conditions, the SSNM method was developed and further evaluated through on-farm testing carried out in different agro ecological zones of Odisha. The idea behind this decision support tool is to assess how to deal with fertility issues that constrain yield under rainfed conditions due to unpredictable water situations. Farmers in this region often apply fertilizers inefficiently, unaware of the concept and benefits of site-specific nutrient management. It results in lower yields and poor soil health. The SSNM based approach ensures better nutrient management under both rainfed and irrigated conditions. In the rainfed scenario, water availability at the time of fertilizer application is considered helpful in improving the agronomic efficiency of the applied nutrient. The SSNM approach is the integrated nutrient management (INM) system which considers all available sources of nutrients, and the use of nutrients based on supply and demand for a particular field to improve productivity and soil health.
15.	Solar power as a remunerative way to minimize climate risks	BISA-CIMMYT and IWMI	The pilot project has generated income from both improvement in agricultural production and the sale of surplus energy. It has also promoted a range of CSA interventions, such as efficient technologies for water use in vegetable farming, improved seed and nutrient management, minimum tillage, and introduction of crops that require less water. Cooperative members use solar energy to irrigate their own crops and sell irrigation services to neighboring farmers before selling the residual energy to the power company. Between January and May (the dry season), cooperative members had solar energy to meet their own and their neighbors' irrigation needs, and from May 2016, they could sell it to the power company. This model was also effective in reducing the use of power and water in agriculture without impinging on farmer incomes.

Sr. No.	Technology	Implementing agency	Impact
16.	Climate resilient rice varieties for risk reduction and sustainability in stress-prone areas	IRRI	Climate resilient rice varieties, often popularly known as STRVs (stress-tolerant rice varieties), have been developed so that the crop remains unaffected or relatively less affected compared to other high-yielding varieties under stress conditions like drought, flood, or salinity. When used in appropriate ecological conditions, these varieties can withstand the stress, giving considerable yield advantage, and no yield penalty under normal conditions as compared to other locally grown high-yielding varieties. The STRVs give farmers a range of options to deal with the problems of drought, flood, salinity, or even multiple stresses (drought and flood, abiotic and biotic stresses). Many of the flood-tolerant varieties have been developed from the local mega or popular varieties by adding a flood-tolerance trait in them and have the potential to completely replace the older varieties by keeping other traits almost the same, e.g., Swarna Sub1 (SS1), a flood-tolerant variety well accepted by the farmers in the flood prone ecology in Odisha, by replacing the mega variety Swarna. SS1 has a 14-day submergence tolerance as an additional trait. Similarly, Bina Dhan 11, Samba Mahsuri Sub 1 and many more varieties for flood-prone areas, and Shahbhagidhan, DRR44 and others for drought-prone areas have the potential for large scale adoption in the state.
17.	Solar powered irrigation system (SPIS)	BISA-CIMMYT OUAT	SPIS is a climate smart and sustainable approach to simultaneously extend the area under irrigation while using renewable sources of energy. It offers both adaptive and mitigating benefits to curtail climate change through solarization of agriculture and agricultural pumping. Burgeoning technological innovations are reducing investment cost in SPIS. This, coupled with a substantial number of subsidy schemes being rolled out by the present government, is giving the necessary fillip to SPIS installations. With increasing focus on solar energy use in agriculture, several pilots and models of solar irrigation systems have been rolled out and has led to a significant increase in farmers' incomes. Apart from ensuring higher crop yields through timely farm operations and mitigating GHG emission and climatic risks, it may also promote a range of CSA interventions, such as: efficient technologies for water use, improved seed and real time nutrient management, minimum tillage, and introduction of crops with lower water requirements. As has been done in Gujarat, solar cooperatives may be formed where cooperative members use solar energy to irrigate their own crops and sell irrigation services to neighboring farmers before selling the balance energy to the local power company. It offers farms the opportunity to reduce the cost of energy as they no longer need to invest in diesel to run the pumps or depend on the vagaries of electricity supply, a possibility the state government is aggressively popularizing. Solar power generation offers a solution which amalgamates clean energy technology with increased food production.

Sr. No.	Technology	Implementing agency	Impact
18.	Residue management for improving soil health and yield enhancement	OUAT and IRRI	There are many proven residue management practices that can help farmers adapt to the adverse effects of increasing weather variability and climate change. These can, in many cases, also reduce agricultural GHG emissions. In order to encourage farmers to change to this practice, residue incorporation/mulching will be introduced in the selected villages. The residue can be chopped into small pieces, spread and incorporated in-situ thoroughly by machines with varying efficiencies, depending on the leftover residue. This can be well decomposed within a short period with the use of microbial inoculation.
19.	Mechanization of farming for tackling labor scarcity	OUAT and IRRI	Adoption of climate resilient practices is linked to timely access to appropriate farm machinery at a reasonable cost. Several options are now available to increase the efficiency and timeliness of agricultural operations, even on small farms, by using farm machinery. Mechanization brings timeliness, uniformity, and precision to agricultural operations, greater field coverage over a short period, cost effectiveness, efficiency in use of resources and applied inputs, conservation of available soil moisture under stress conditions, and provision of adequate drainage. Farm implements could successfully empower farmers to tide over the shortage of labor and improve efficiency of agricultural operations.

Annexure III - Indian Centers of Excellence and Potential Thematic Areas to Address the Demand in Indo–Pacific Nations

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Vietnam
Forecasting, modelling, and training	• TERI
Establishment/strengthening of an integrated platform/network at country level *(on innovation, strategic research, technology demonstration and dissemination, capacity building, and planning)*	• NICRA • NIRD–PR • NAARM • GAPL
Sustainable agriculture practices, zero budget natural farming, and organic farming	• Centre for Sustainable Agriculture, Hyderabad • MSSRF • APCNF
Weather forecasting and dissemination to smallholder farmers	• Skymet • Fasal • IFFCO Kisan
Custom hiring center *(mechanization and automation)*	• EM 3 • Sonalika • Tafe
Extension and training (country- specific customized program for extension personnel, youth internship)	• MANAGE • IRMA • NAARM • AgHub, PJTSAU
Digital platform for precision agriculture *(advisory- and technology-based solutions)*	• CropIn • Digital Green • Dehaat
Water smart technologies	• WOTR • GRAVIS • BAIF
Mountainous areas	• Institute of Himalayan Bioresource Technology

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Vietnam
River basin management	• National Mission for Clean Ganga, Ministry of Jal Shakti, GoI • River Basin Programme in Meghalaya
Climate smart technologies for productivity improvement	• Nano Urea – IFFCO • Seaweed Growth Promoters • Integrated Rice Farming
Climate financing	• NABARD • Samunnati • IREDA
Gender integration and CSA	• APMAS • JEEViKA • SEWA
Financial inclusion	• Sa-Dhan • Samunnati • BASIX
Community-based organizations like CSVs and FPOs	• SFAC • APMAS • GAPL • Sayadri Farms

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Cambodia
Forecasting, modelling, and training	• TERI • ICRISAT
Establishment/strengthening of an integrated platform/network at country level *(on innovation, strategic research, technology demonstration and dissemination, capacity building, and planning)*	• NICRA • NIRD & PR • NAARM
Sustainable agriculture practices, zero budget natural farming, and organic farming	• Centre for Sustainable Agriculture, Hyderabad • MSSRF • APCNF

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Cambodia
Weather forecasting and dissemination to smallholder farmers	• Skymet • Fasal • IFFCO Kisan
Custom hiring center *(mechanization and automation)*	• EM 3 • Sonalika • Tafe
Extension and training (country- specific customized program for extension personnel, youth internship)	• MANAGE • IRMA • NAARM • AgHub, PJTSAU
Digital platform for precision agriculture *(advisory- and technology-based solutions)*	• CropIn • Digital Green • Dehaat
Water smart technologies	• WOTR • GRAVIS • BAIF
Mountainous areas	• Institute of Himalayan Bioresource Technology
River basin management	• National Mission for Clean Ganga, Ministry of Jal Shakti, GoI • River Basin Programme in Meghalaya
Climate smart technologies for productivity improvement	• Nano Urea – IFFCO • Seaweed Growth Promoters • Integrated Rice Farming
Climate financing	• NABARD • Samunnati • IREDA
Gender integration and CSA	• APMAS • JEEViKA • SEWA
Financial inclusion	• Sa-Dhan • Samunnati • BASIX
Community-based organizations like CSVs & FPOs	• SFAC • APMAS • Sayadri Farms

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Lao PDR
Establishment/strengthening of an integrated platform/network at country level *(on innovation, strategic research, technology demonstration and dissemination, capacity building, and planning)*	• NICRA • NIRD & PR • NAARM
Extension and training (country-specific customized program for extension personnel, youth internship)	• MANAGE • IRMA • NAARM • AgHub, PJTSAU
Digital platform for precision agriculture *(advisory and technology-based solutions)*	• CropIn • Digital Green • Dehaat
River basin management	• National Mission for Clean Ganga, Ministry of Jal Shakti, GoI • River Basin Programme in Meghalaya
Climate smart technologies for productivity improvement	• Nano Urea – IFFCO • Seaweed Growth Promoters • Integrated Rice Farming
Climate financing	• NABARD • Samunnati • IREDA
Gender integration and CSA	• APMAS • JEEViKA • SEWA
Community-based organizations like CSVs & FPOs	• SFAC • APMAS • Sayadri Farms

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Fiji
Establishment/strengthening of an integrated platform/network at country level *(on innovation, strategic research, technology demonstration and dissemination, capacity building, and planning)*	• NICRA • NIRD & PR • NAARM
Sustainable agriculture practices, zero budget natural farming, and organic farming	• Centre for Sustainable Agriculture, Hyderabad • MSSRF • APCNF
Extension and training (country- specific customized program for extension personnel, youth internship)	• MANAGE • IRMA • NAARM • AgHub, PJTSAU
Efficiency improvement in sugar value chain (processing of co-products)	• GAPL • DCM
Climate smart technologies for productivity improvement	• Nano Urea – IFFCO • Seaweed Growth Promoters • Integrated Rice Farming
Climate financing	• NABARD • Samunnati • IREDA
Gender integration and CSA	• (APMAS) • JEEViKA • SEWA
Community-based organizations like CSVs and FPOs	• SFAC • APMAS • Sayadri Farms

CSA technology thematic areas	Suggested Indian organizations for CSA partnership with Papua New Guinea
Establishment/strengthening of an integrated platform/network at country level *(on innovation, strategic research, technology demonstration and dissemination, capacity building, and planning)*	• NICRA • NIRD & PR • NAARM
Extension and training (country specific customized program for extension personnel, youth internship)	• MANAGE • IRMA • NAARM • AgHub, PJTSAU
Climate smart technologies for productivity improvement	• Nano Urea – IFFCO • Seaweed Growth Promoters • Integrated Rice Farming
Climate financing	• NABARD • Samunnati • IREDA
Gender integration and CSA	• (APMAS) • JEEViKA • SEWA
Community-based organizations like CSVs and FPOs	• SFAC • APMAS • Sayadri Farms
Setting up of institute for sustainable coastal and ocean research, and network of marine biology research	• ICAR • National Centre for Sustainable Coastal Management, Chennai under MoEFCC

Annexure IV - Climate Finance

Digital Climate Advisory Services (DCAS): A World Bank discussion paper, Making Climate Finance Work in Agriculture, examines innovative ways in which smallholder farmers and SMEs in the agriculture sector can use climate finance to improve and increase access to finance while delivering positive climate outcomes, such as increased resilience and reduced emissions intensity. The report recommends using climate finance to address key constraints in the agriculture finance landscape, such as inadequate enabling environments, insufficient capacity to manage agricultural risks, and high transaction costs. It aims to do so by using climate finance as a catalyst to unlock additional sources of public and private sector capital, strengthen the links between financial institutions, smallholder farmers and SMEs, and build the capacity of both lenders and borrowers. The report makes recommendations for how climate finance can accelerate climate smart investments in the agriculture sector.

Weather-based Insurance Products: These products aim to mitigate the hardship of the insured farmers against the likelihood of financial loss on account of anticipated crop loss resulting from adverse conditions of weather parameters like rainfall, temperature, frost, humidity, etc.

Warehouse Receipts (WHR): WHR is an external financing mechanism that encourages scientific storage of post-harvest crops in a warehouse that serves as collateral to provide immediate financing to farmers. The Warehousing (Development and Regulation) Act enacted by the GoI in 2007 introduced negotiable warehouse receipts (NWRs) and laid down procedures for development and regulation of warehouses, negotiability of warehouse eceipts, and obtaining loans from banks.

In 2020, Telangana launched the **Artificial Intelligence for Agricultural Innovation (AI4AI)** program in association with the Centre for the Fourth Industrial Revolution, India, World Economic Forum. It aims to scale up the use of predictive insights to issue advisories on sowing, use of inputs, pest incidence, and harvest, and support farm mechanization, disbursement of subsidies, and procurement.

Moo Farm on farmer-centric advisory model

An award-winning start-up called **Moo Farm** offers dairy farmers in India a range of services to meet all their cattle-rearing needs through an innovative application. Farmers can network with fellow farmers on frequently asked questions, schedule a veterinarian consultation, get access to an e-market place for cattle trade, and access to dairy farming inputs as well as credit. The application has been lauded by farmers in north India and Maharashtra and has ensured encouraging cost savings for them. The company's mission is to reach out to 100 million dairy farmers in the country and make them prosperous.

(Source: World Business Council for Sustainable Development)

NABARD has several products with lending and investment instruments. Over 28 percent of NABARD's cumulative disbursements have links with climate change adaptation and mitigation. Moreover, gender equality is central to NABARD's mandate for supporting millions of small and marginal farmers, landless laborers, and women engaged in agriculture and rural development.

NABARD recognizes that incorporating gender sensitivity into its business and development practices will help increase equity and social justice for women. There was a need for a gender policy to institutionalize the practices and gender focus across the organization. NABARD endeavors to not only mainstream gender, but also make most activities/schemes gender transformative, giving due importance, weightage, and right to women in business and developmental activities, asset creation, income generation, and environment protection, making the activities sustainable.

Carbon Finance

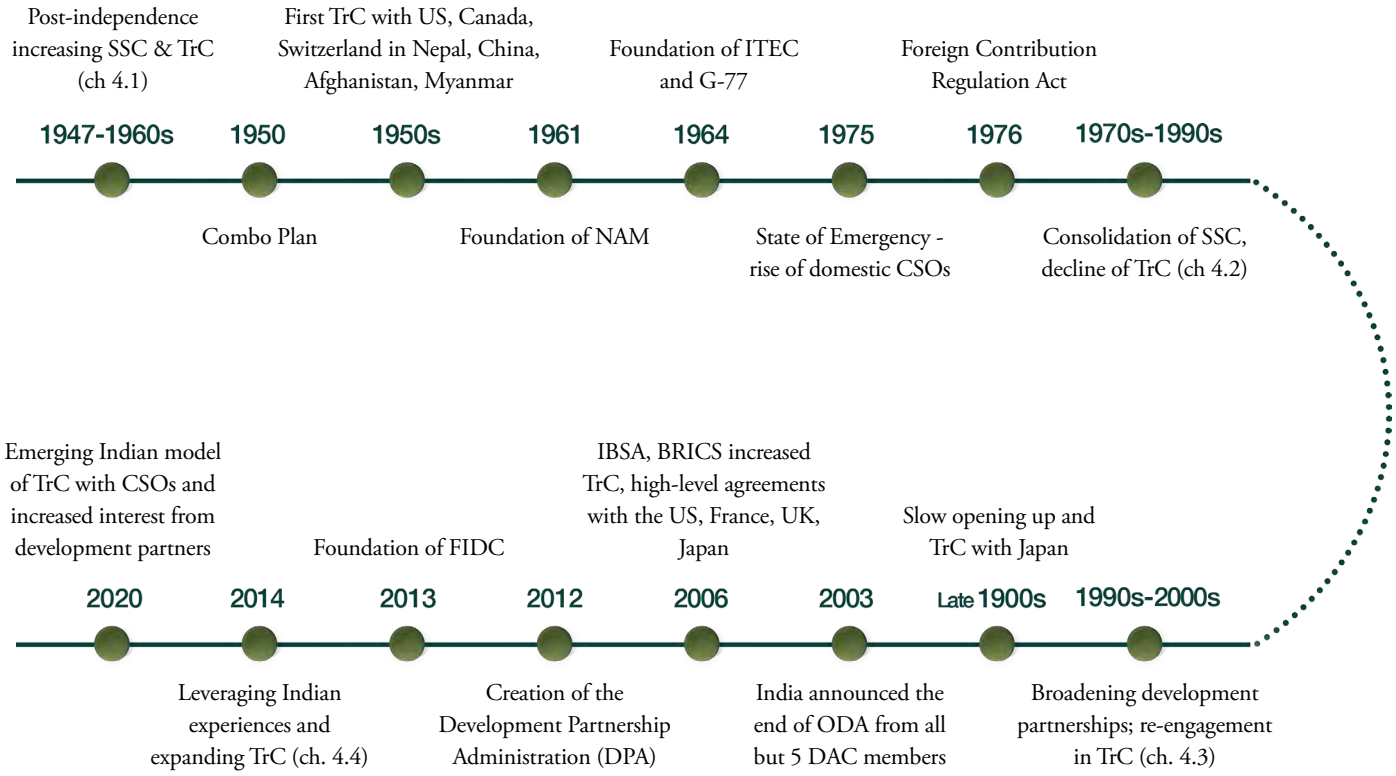
A new branch of environmental finance, carbon finance, is applied to investments in GHG reduction projects and the creation of financial instruments that are tradable on the carbon market. India is leading in smallholder carbon (intersection of agri-forestry-horticulture) financing (Boomitra, ITC-Sunehra Kal), and carbon farming (Mangrove financing–Sundarbans) initiatives.

Key initiatives of the central and state governments that support digital advisory

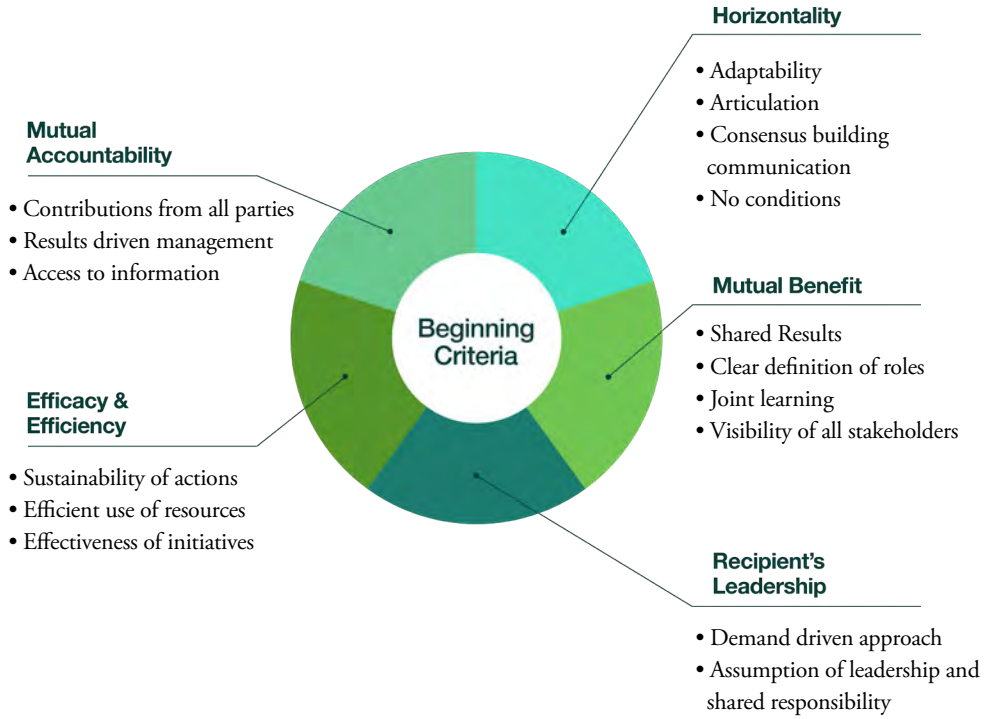
A recently announced initiative called AgriSTACK aims to build a database of farmers in the country, which will be crucial for delivery of services of agri-technology companies. Digitalization of land records under this initiative will help in providing agri-finance. Agri Udaan, a food and agribusiness accelerator organized by a coalition of various government departments, is supporting agribusiness start-ups through rigorous mentoring, industry networking, and investor pitching.

Annexure V - Evolution and Timeline of TrC

An example of Triangular Cooperation from the Global Partnership Initiative



Triangular Cooperation Principles and Criteria in Ibero-América



Annexure VI - Stakeholder Meetings to identify potential demand and supply opportunities for TrC in CSA

A. Meetings to identify supply-side opportunities

Sl. No.	Sectors	Organization	Name	Designation	Purpose
1.	GoI	Ministry of Agriculture	Prasanta Kumar Swain	Additional Secretary (Marketing, Policy, RFS, NRM, RTI,O&M,PG)	Informal interview and consultation
2.	GoI	National Rainfed Area Authority	Dr. Ashok Dalwai	Chief Executive Officer	Informal interview and consultation
3.	Industrial association	Federation of Indian Chambers of Commerce & Industry	Ruchira Saini	Joint Director & Team leader-Agriculture	Informal interview and consultation
4.	Research institute	ICAR	Dr. Trilochan Mohapatra	Secretary (DARE) & DG, ICAR	Informal interview and consultation
			Dr. Suresh Kumar Chaudhry	Deputy Director General, NICRA	Virtual meeting to get insights of NICRA work profile on CSA
5.	Research institute	Central Arid Zone Research Institute	Dr. O.P Yadav	Director	Informal interview and consultation
6.	Research institute	ICRISAT	Dr. Arabinda Kumar Padhee	Director	Virtual meeting to get insights of ICRISAT work profile on CSA and CoEs
			Dr. Mukund Dhavaji Patil	Senior Scientist (Soil Physics) ICRISAT Development Center Asia Program	Virtual meeting on CSA related action research programme in India undertaken by ICRISAT and as a CoE
			Dr. Suhas Wani	Former Director	Sector expert on CSA and seeking insights on Indian experience and also other countries in Asia and Pacific
7.	Research institute	IFPRI	Arndt Channing	Director of Environment and Production Technology Division	Virtual meeting on work of CGIAR on CSA

Sl. No.	Sectors	Organization	Name	Designation	Purpose
8.	Research institute	TERI	Dr. Prodipto Ghosh	Former Secretary (Ministry of Environment and Forests, GoI); Distinguished Fellow; TERI	Virtual meeting on CSA experience in India and TERI's programme
9.	Research institute	ICRIER	Dr. Ashok Gulati	Infosys Chair Professor, Agriculture-ICRIER (former Chairman)	Informal consultation
			Siraj Hussain	Former Union Secretary, Agriculture& Visiting Senior Fellow ICRIER	Informal consultation
10.	Institutional body	Wadhwani Institute of Artificial Intelligence	Rajesh Jain	Senior Director Programs	Informal consultation
11.	Institute	Xavier Institute of Management	Gautam Prateek		Informal consultation
12.	Educational body	IRMA	Prof. C. Shambu Prasad	Strategic Management and Social Sciences	Virtual meeting on IRMA as CSA CoE
13.	University	S. K. Rajasthan Agricultural University	Dr. Prakash Singh Shekhawat	Director	Informal consultation
14.	University	IDP NAHEP, G B Pant Agri University	Dr. Tej Pratap	Vice Chancellor	Informal consultation
			Dr. S. K. Kashyap	Dean	Informal consultation
15.	Organization	APRACA	Dr. Prasun Kumar Das	Secretary General, Asia Pacific Rural and Agricultural Credit Association (APRACA)	Virtual meeting on CSA perspectives in Asia and Pacific
16.	Organization	CropIn Technology Solutions	Kunal Prasad	Founder & CEO	AgTech solutions on CSA and work profile as CoE under TrC
17.	NGO	Bharat Krishak Samaj & UN Food Systems Champion	Ajay Vir Jakhar	Chairman	Informal consultation as a sector expert

Sl. No.	Sectors	Organization	Name	Designation	Purpose
18.	NGO	Bihar Rural Livelihoods Promotion Society	Manoj Kumar	State Project Manager, JEEViKA, Bihar	Practitioner and point person for World Bank supported SLACC project in Bihar
19.	NGO	GRAVIS	Dr. Prakash Tyagi	Executive Director	Virtual meeting as a potential CoE on water smart CSA technologies
20.	NGO	Transforming Rural India Foundation	Anish Kumar	Team Member-PRADAN	Informal consultation
21.	International funding agency	GIZ	Navin Vivek Horo	Senior Advisor GIZ	Informal consultation
			Rajat Shubhroto	Senior Advisor GIZ	Informal consultation
22.	Private organization	Digital Green	Rikin Gandhi	Co-Founder & Executive Director	Digital AgTech solutions on CSA and as a potential CoE
			Dr. Krishnan Pallassana	Country Director India	
23.	Private organization	DCM Shriram Private Limited	Roshan Lal Tamak	Executive Director & CEO	Sugar farming
			Raja Srivastava	Joint Vice President	
24.	NGO	Samunnati	Rajnesh Kumar	Associate Vice President	Informal consultation on Agri and CSA financing
25.	Financial institution	NABARD	Raji Jain	C. General Manager	Informal consultation to know the work of NABARD
			Sudhanshu Mishra	General Manager	Informal consultation on CSA
26.	Financial & resource institution	Caspian	Emanuel Murray		Informal consultation
27.	Financial & resource institution	Bill & Melinda Gates Foundation	Anjani Singh	Senior Programme Office	Informal consultation
28.	Financial institution	Rabo Bank	Rishabh Sood	Senior Manager	Informal consultation
29.	Financial & resource institution	Arya Collateral	Prasanna Rao	Founder and CEO	Virtual meeting as a potential CoE on warehouse receipt and CSA financing products

Sl. No.	Sectors	Organization	Name	Designation	Purpose
30.	Financial institution	IFAD	Meera Mishra	Country Representative	Informal consultation
31.	Non-profit organization	Grameen Foundation	Prabhat Labh	CEO	Informal consultation
32.	Private organization	National Commodity and Derivatives Exchange	Aleen Mukherjee	COO, NeML	Informal consultation
33.	Private organization	TechnoServe	Love Kashyap		Informal consultation
34.	Private organization	ACCESS Development Services	Shubhedu Dash		Informal consultation on FPO model and CSA
35.	Corporate	Reliance Foundation	Ashutosh Deshpande	Head of FPO Units & Value Chain	Informal meeting on FPO model and CSA
36.	Private organization	Skymet	Jatin Singh	Founder cum CEO, Skymet	Virtual meeting on climate and weather forecasting and insurance and as a CoE
			Yogesh Patil	CEO, Skymet	Virtual meeting on weather forecast and insurance
37.	Private organization	Excel geomatics	Dr. Rajesh Paul	CEO and Co-founder, Excel Geomatrics Pvt. Ltd	CSA modelling and AgTech solutions, advisory services as a CoE
38.	Research institute	CRIDA	Dr. G Ravindra Chary	FISA, FISPRD, Project Coordinator	Understanding NICRA and CSV programme in India and CRIDA's research
39.	Research institute	IIMR	Dr. Sangappa	Scientist Agri business Incubation Program	Understanding IIMR's work and CSA programme through Millet Mission, including the incubation support

Sl. No.	Sectors	Organization	Name	Designation	Purpose
40.	Research institute	TERI	Dr. Vibha Dhawan	Director, Bioresources & Biotechnology Division	TERI's CSA modelling, nano technology solutions. Water and climate as CoE
			Dr. Suruchi Bhadwal	Research Fellow	TERI's CSA modelling, nano technology solutions. Water and climate as CoE
41.	Educational body	NAARM	Dr. Ranjit Kumar	Head and Principal Scientist	Understanding and assessing NAARM's work as a CoE
42.	Educational body	NIRD	Dr. Krishna Reddy Kakumanu	Associate Professor, CNRM, School of Sustainable Development	Understanding various programmes and international training programmes being undertaken by NIRD as a CoE
			Dr. Subrat Kumar Mishra	Associate Professor	Understanding various programmes and international training programmes being undertaken by NIRD as a CoE
			Dr. S. Ramesh Sakthivel	Associate Professor & Head, CIAT	Understanding various programmes and international training programmes being undertaken by NIRD as a CoE and Rural Technology Park
			Dr. R. Divakar	Faculty Agrarian Studies and FPOs	Understanding various programmes and international training programmes being undertaken by NIRD as a CoE
43.	Educational body	MANAGE	Dr. N Balasubramani	Director (Climate Change and Adaptation (CCA)	Understanding full sense on TrC and CSA related work that MANAGE has undertaken as a potential CoE
			Dr. K. C. Gummagolmath	Director (M&E)	

Sl. No.	Sectors	Organization	Name	Designation	Purpose
44.	State university	PJTSAU	Kalpana Sastry RegulageddaSS	Managing Director, AgHub Professor Jayashankar Telangana State Agricultural University	Assessing the work and capacity of Professor Jayashankar Telangana State Agricultural University as a CoE
45.	Non-profit organization	Centre for Sustainable Agriculture	Dr. G.V. Ramanjaneyulu	Executive Director, Centre for Sustainable Agriculture	As a potential CoE on sustainable agriculture practices and CSA
46.	Private organization	AgHUB	Vijay Nadiminti	Chief Executive Officer	As a potential CoE on agri-start-ups and CSA
47.	NGO	APMAS	C. S. Reddy	CEO	As a potential CoE on CSA and CSVs including FPOs
			N. Madhu Murthy	Executive Director	As a potential CoE on integrated model on CSV, CSA and FPOs
48.	Private organization	EM3	Rohtash Mal		Consultation on potential CSA partner on mechanization and CHC

B. Meetings to identify demand-side opportunities

The research team and representatives from the TriDeP program reached out to several organizations for virtual meetings to inform the demand-side opportunities for TrC in the study. The meetings were organized to understand the CSA landscape and current practices and technologies being implemented, and the potential demand for new CSA practices in these potential partner countries. The meetings also helped gather country specific data, insights on CSA related work, and helped the TriDeP team identify other relevant organizations that the team could engage with.

The following is a list of the most relevant organizations that the study team virtual met:

- Madan Mohan Sethi, Counsel General, Consulate General of India, Ho Chi Minh City, Vietnam
- Le Phuong Hoa, Head of Department of Academic Management and International Relations, Institute for Southeast Asian Studies, Vietnam
- Grant Vinning, Agriculture expert, Fiji
- Pham Thi Tuyet, Commercial Assistant, Consulate General of India, Ho Chi Minh City, Vietnam
- Cambodian Institute for Cooperation and Peace (CICP), Phnom Penh, Cambodia
- Mekong Institute, Thailand
- APRACA based in Bangkok for all the 5 countries

The representatives from the following organizations, including international organizations, in the potential partner countries attended the convening organized to understand the demand for CSA practices and to share their experiences.

Sl. No.	Name	Organization
1.	Francis Mani	University of the South Pacific, Fiji
2.	Sophoan Sourn	Cambodia-Australia Agricultural Value Chain
3.	Celia Del Campo Aragonés	DCA, Cambodia
4.	Sokhomony Sin	GIZ, Cambodia
5.	Reema Prakash	University of the South Pacific, Fiji
6.	Dr Prasun Kumar Das	Asia Pacific Rural and Agriculture Credit Association (APRACA)
7.	Penelope Nagel	Persistence Data Mining
8.	Van Trinh Mai	Institute for Agricultural Environment
9.	Nikita Singla	Bureau of Research on Industry and Economic Fundamentals (BRIEF)
10.	Zafiar Naaz	University of Fiji
11.	Pankaj Jha	O P Jindal Global University
12.	Le Phuong Hoa	Institute for Southeast Asia Studies
13.	Karen Mapusua	The Pacific Community
14.	Anshuman Varma	UNESCAP

Sl. No.	Name	Organization
15.	Cien Henzo	Agri High Tech Vocational Centre, Vietnam
16.	Sereyvathana Ken	Cambodia-Australia Value Chain Program
17.	Dr M.A. Kader	University of South Pacific, Fiji
18.	Dr Swati Nayak	International Rice Research Institute
19.	Dr. B. Renuka Rani	National Institute of Agriculture Extension Management (MANAGE)
20.	Renaud Mathieu	South Asia Regional Center- International Rice Research Institute
21.	Dyna Eam	WorldFish Center
22.	Amit Srivastava	International Rice Research Institute
23.	Vikram Patil	International Rice Research Institute
24.	Gibson Susumu	The Pacific Community
25.	Soumya Chattopadhyay	Asian Development Bank
26.	Pinida Leelapanang Kamphaengthong	PACT, Thailand
27.	Rithysen Men	SCRECA Project, GIZ, Cambodia
28.	Pham Cao Khải	Management Board of Agriculture Hi-Tech Park (AHTP)

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