March, 2022

Project Synthesis Report (2016-2021)

Increasing Adaptive Capacity of Farmers to Climate Change thru Climate-Smart Villages in India

CIMMYT
International Maize and Wheat Improvement Center

BISA
Borlaug Institute for South Asia

Enduring Value

About BISA

Borlaug Institute of South Asia (BISA) is an international research institute established in October 2011 through a joint initiative between the International Maize and Wheat Improvement Centre (CIMMYT) and the Indian Council of Agricultural Research (ICAR), New Delhi to implement the vision of Norman E. Borlaug. It is a non-profit international research institute dedicated to food, nutrition, livelihood security, and environmental rehabilitation in South Asia, home to more than 300 million undernourished people. BISA aims to harness the latest genetic, digital, and resource management technologies, and use research for development approaches to invigorate the region's agriculture and food systems while enhancing productivity, resilience, livelihood, and nutrition security to meet future demands.

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Citation: Shirsath, P.B., Pimpale, A.H., and Aggarwal, P.K. 2022. Increasing adaptive capacity of farmers to climate change thru climate-smart villages in India. Project synthesis report. BISA-CIMMYT, New Delhi, India.

Acknowledgement

This synthesis report of the project "Increasing Adaptive Capacity of Farmers to Climate Change thru Climate-Smart Villages in India" was prepared by the Borlaug Institute for South Asia (BISA) in partnership with ITC Limited. This acknowledgement is an effort to recognize the efforts and inputs provided by institutions/individuals in putting together the databases, field observations on CSV implementation, and policy analysis. ITC contributed generous financial support for implementing this project from 2016 to 2021. BISA expresses its gratitude to all staff and NGO partners of ITC Limited, India who worked hard to establish climate-smart villages in the states of Rajasthan, Madhya Pradesh, and Maharashtra and collected primary field data from farmers' fields and government records and validated it. BISA-CCAFS staff added value to the data by calculating indicators of climate smartness. BISA would especially like to acknowledge the support of Dr. Ashesh Ambasta, Prabhakar Lingareddy, Vijay Vardhan, Akhilesh K Yadav, Giriaj Shah, Jayaprakash Ramaswamy, Munesh Saxena, Nilesh Karpe, Bhuvnesh Sharma, all ITC state managers, and technical staff throughout the program.

The team would also like to express humble gratitude toward all farmers who participated in the present study. They deserve special thanks for giving their time in interacting with the researcher and actively supporting the process of data collection by ITC staff and their partners.

The document was prepared under the co-leadership of Pramod Aggarwal, Paresh B Shirsath, and Arun Khatri-Chettri of BISA. The project team of BISA also comprised of Anil H Pimpale, Nitya Chanana, Shalika Vyas and Mansi Nagpal. The main authors of this report are Paresh B Shirsath, Anil H Pimpale, and Pramod Aggarwal.

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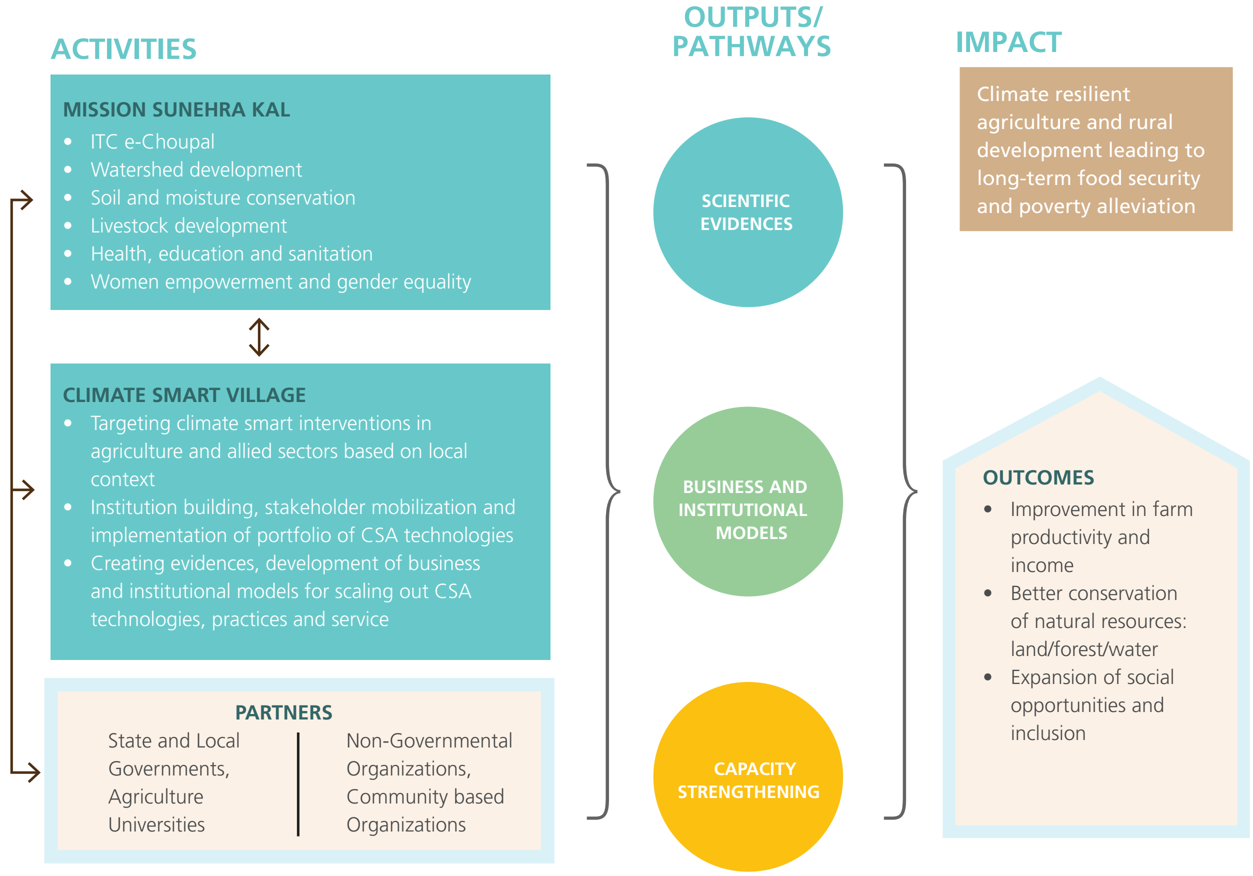
Executive Summary

Current climatic variability and increasing weather risks associated with climate change threaten agricultural production systems and food security all over the world. Several technological, institutional and policy interventions have been proposed to help farmers adapt to current and future weather variability. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) developed a Climate-Smart Village (***SGSK***) approach in 2013 to promote agriculture research for development that tests technological and institutional options for dealing with climatic variability and climate change in agriculture using participatory methods. Researchers, local partners, farmers' groups, and policymakers collaborate to select the most appropriate technological and institutional interventions based on global knowledge and local conditions to enhance productivity, increase incomes, achieve climate resilience, and enable climate mitigation. The focus is on a portfolio of synergistic options rather than on single interventions and technologies. The major initiatives in setting up ***SGSK*** include: i) proposing the strategic design of land use options based on agroecological analysis and farmer typologies, ii) promoting climate-smart technologies and maximizing synergies among various interventions; iii) providing value-added weather services to farmers; iv) promoting weather-based insurance for climate risk management; v) facilitating community partnerships for knowledge sharing, and vi) building capacity in climate change adaptation. One set of interventions would not be suitable for each place. These interventions may differ based on the region, its agro-ecological characteristics, level of development, capacity, and interest of farmers and the local government. The ***SGSK*** approach aims to scale up and scale out the appropriate options and draw out lessons for policymakers. Results from initial studies in 20 countries indicate that the CSV approach has a high potential for scaling out climate-smart agricultural technologies, practices, and services.

Phase-1 (2016-2019):

ITC Limited partnered with the BISA-CIMMYT in 2016 to use this approach for building resilience among small, marginal, and women farmers across ITC outreach areas and to raise the capacity of ITC staff and its partners in implementing this approach. The joint program used the following strategy for creating an impact.



Initially, the program was launched for horizontal scaling of the SGSK approach in 30 villages in Madhya Pradesh, 22 villages in Maharashtra, and 21 villages in Rajasthan. The key interventions here were:

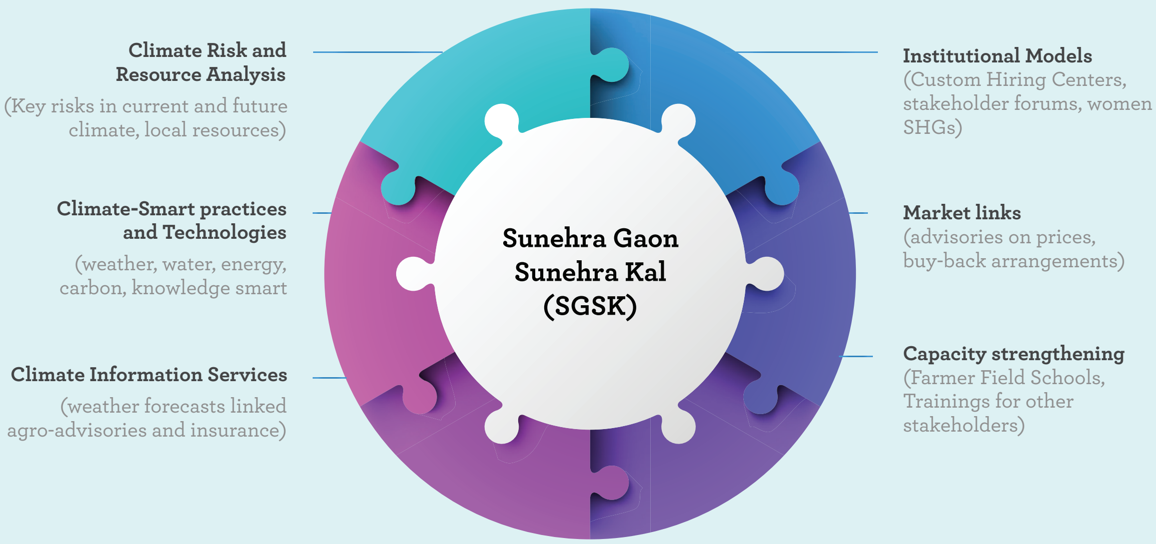
- Assessment of agriculture and climate risks, and identification of climate-smart agriculture technologies, practices, and services to improve agricultural production and minimize climatic risks in the outreach villages.
- Prioritize technological options based on stakeholders' (farmers, local government, NGOs, and community-based organizations) preferences and integrate them with ITC-MSK activities in the outreach villages.
- Strengthen the capacity of the ITC Ltd. team and its local partner organizations to implement, monitor, and evaluate technological interventions in the farmers' fields and communities.

A range of training on a package of practices of CSA interventions, data collection, monitoring, and evaluation of CSA interventions in the farmers' fields were organized by CCAFS-BISA to raise the capacity of ITC staff and its partners in all aspects of the SGSK approach. This included face-to-face workshops like prioritization of CSA technologies for the state of Rajasthan, Maharashtra, and Madhya Pradesh, on-site visits and training, field visits to BISA-CIMMYT SGSK in Punjab and Haryana prioritization of CSA technologies for the state of Rajasthan, Maharashtra, and Madhya Pradesh, on-site visits and training, field visits to BISA-CIMMYT ***SGSK*** in Punjab and Haryana.

By the end of 2019 (the first phase of the partnership), the following outputs were achieved:

- Site-specific climate-smart agriculture and rural development options (e.g., climate-resilient and improved seed and breeds of livestock, conservation agriculture, agroforestry, water management, and fodder management) increase resilience.
- Demonstration of location-specific CSA technologies and scientific evidence of climate-smart interventions in adapting climatic risks for the improvement of farm productivity and income.
- Capacity building to support smallholder farmers, women, and marginalized farmers by effectively linking supply and demand sides of the agriculture value chain, climate-smart technologies, and agriculture extension system.
- Capacity building to support ITC staff in calculating CSA indicators of productivity, income, resilience, and GHG mitigation

Buoyed by the success of the initial work, the CSV approach was integrated into ITC's Mission Sunehra Kal (MSK) program for the promotion of a wide range of portfolios of climate-smart agriculture technologies. This resulted in a successful climate-smart village program- henceforth labelled as 'Sunehra Gaon Sunehra Kal' (tentative name). A Sunehra Gaon Sunehra Kal (SGSK) is a village/landscape where ITC and BISA have strengthened the capacity of farmers and other stakeholders to adopt site-specific practices, technologies, services, and innovative institutional models that lead to increased agriculture production and income, build adaptation to key current and future climatic risks, contribute to net-zero emission targets of the country, and provide a foundation for improved risk management policies and schemes. A typical SGSK involves some or all the key elements shown in the following diagram:

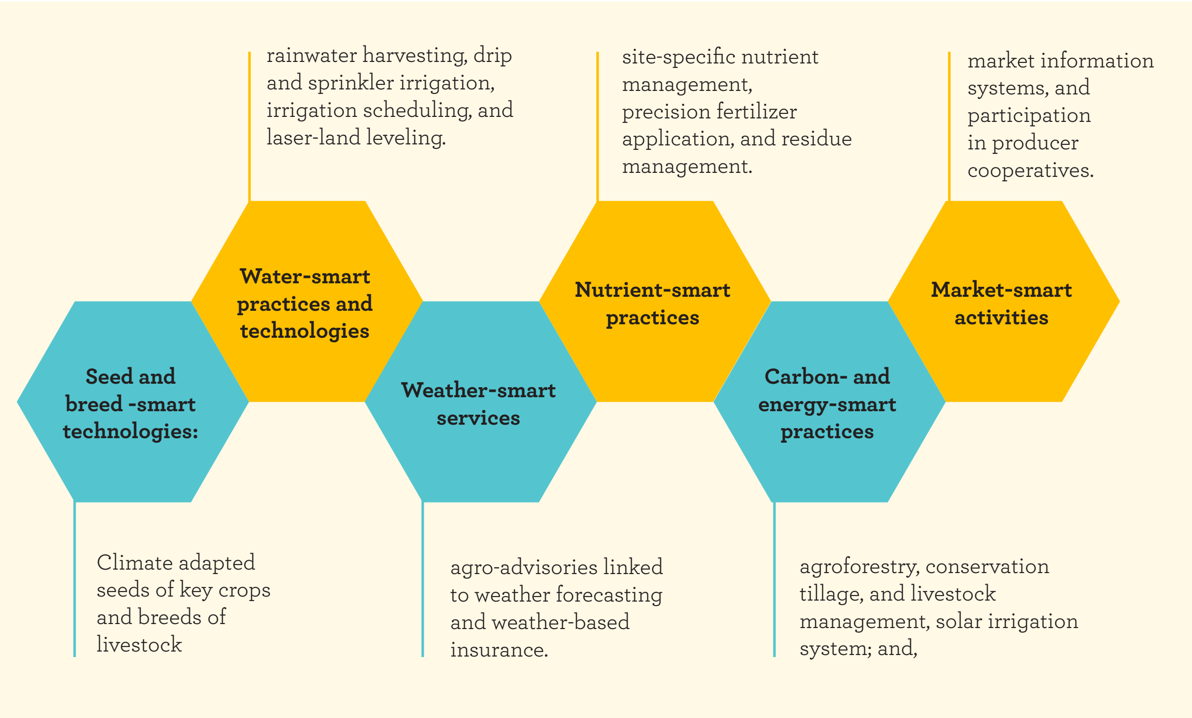


Increased agriculture production and income	Adaptation to current and future climate risks	Contribute to net zero emissions targets of the country	Improved policies and schemes for resilience in agriculture

Setting up ITC-BISA 'Sunehra Gaon Sunehra Kal' involves three key steps:

1 **Village baseline:** Key current future and climate-related risks and vulnerabilities to agriculture at the village/ landscape level are identified by analyzing the historical climate data and future climate scenarios for rainfall variability, drought and flood probability, and periods of heat/cold stresses. A baseline assessment is also made of the soils, water resources, markets, technologies, knowledge gaps, relevant institutions, ad private and public finance availability.

2 **Portfolio of interventions and its field evaluation:** Based on the village baseline, a portfolio of climate-smart[1] technologies from the MSK programs, KVKs, and elsewhere; and Climate Information Services- weather-linked advisories, and crop and livestock insurance- are selected for implementation. The portfolio, identified based on a participatory process by the stakeholders, includes some of the following practices/technologies:



A 'Hub and spoke' model is used for farmer-to-farmer extension. Farmer's capacity is raised to evaluate their portfolios of interventions in key 'Hub' villages under the overall guidance of an SGSK Village Committee. The evidence is further showcased in 'Spoke' villages through Farmer Fairs, etc. Farmer Field Schools of the ITC MSK program are used for the capacity strengthening of stakeholders.

3 **Monitoring, evaluation, and scaling up:** Simple, location-specific indicators to measure Climate smartness is used to understand the progress in time and space. Data on key indicators related to changes in yields, income, resilience, and GHG emissions are collected by the ITC field teams. This is complemented by a participatory assessment of technology suitability for current and future climatic risks, implementation feasibility, and adoption barriers. The institutional and financial needs of selected interventions are determined at the farmer, village, and sub-national scale. The potential for convergence of current agricultural development schemes/plans in the region is explored to minimize transaction costs and maximize synergies in SGSKs.

1 Climate-smart agriculture refers to interventions that aim to sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

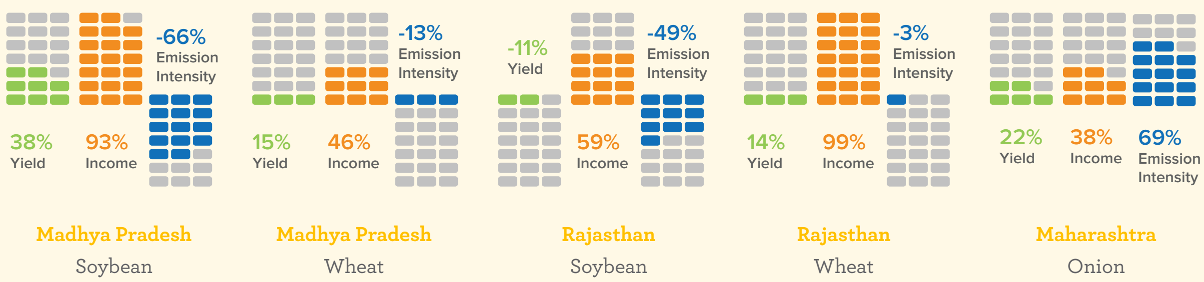
Phase-2 (2019-2021):

Following the development and success of the SGSK approach in phase 1, the partnership was further continued until 2021. In phase-2 of the partnership, the SGSK approach was strengthened in Maharashtra, Madhya Pradesh, and Rajasthan, and the capacity of stakeholders was raised in 12 other states of ITC operations. The focus in this phase was on three major areas: raising the capacity in implementing the SGSK approach in 15 states; developing state-specific agriculture adaptation plans for vertical scaling of the SGSK lessons SGSK and 3) helping ITC in setting up SGSK models in three states for capacity building of stakeholders. Key activities and the outcomes of the phase-2 are summarized below:

Raising the capacity for implementation of the SGSK approach: The project built the capacity of the ITC Limited project staff to enable them to independently design, implement, monitor, and scale-out SGSK across different project sites. The training was structured into five different modules, each module focused on a key step in the SGSK implementation process like baseline, SGSK design, implementation, monitoring and evaluation, and scaling. The training was designed for knowledge exchange and learning by including interactive sessions, tutorials, hands-on exercises, and participatory feedback. Each module was designed and presented by subject matter specialists from different BISA-CIMMYT and CGIAR partner institutions. Emphasis was given to combining science with actionable insights from the field, to impart practical knowledge.

Monitoring the progress of climate smartness of SGSK villages

SGSK program was implemented in almost 600 villages by ITC and its partners in Madhya Pradesh, Rajasthan, and Maharashtra during 2016-2021. ITC and its partners collected data from the farmers' fields over this period. We have assessed the progress of climate-smartness over this period using indicators of Climate-Smart Agriculture (CSA). The initial analysis shows a large increase in yield, income, and GHG mitigation in soybean, wheat, and onions (see figure below). There was a slight decrease in yield in soybean presumably because of flooding in several fields for which we had no suitable adaptation interventions. This figure shows that the technological interventions made in farmers' fields and capacity strengthening of ITC staff and its partners have yielded rich dividends.



Development adaptation strategies for managing current and future climatic risks in agriculture: Most states in India have developed State Action Plan on Climate Change, which provided several strategic action items for the agriculture sector, aimed at reducing the sector's vulnerability to climate risks and building its resilience. These plans focus on building farming systems resilience through diversified cropping patterns, soil conservation, and value addition. While these recommendations are important, there is a need to determine more specific sub-regional actionable items. There are several potential adaptation options available to mitigate moderate to severe climatic risks in agriculture. Strategies to build resilience in agricultural systems will need to have a clear understanding of prioritized interventions that promote Climate-smart Agriculture (CSA), and address resources, policy, and institutional bottlenecks for their implementation. They also need to align with annual agriculture development plans and budgets including the government's flagship programs/ missions. BISA-ITC together with all the relevant stakeholders prepared a guiding framework for developing adaptation strategies to manage current and future climate risks to agriculture in Maharashtra, Rajasthan, and Madhya Pradesh. We have used a six-step approach which included preparation of a long list of CSA technologies, prioritization, and characterization of technologies, checking their implementation feasibility, reprioritizing the technologies based on their performance and feasibility index, and the development of crop and region-specific portfolio of CSA technologies.

Risk Categories	Very low Risk	Low Risk	Medium Risk	High Risk

Frequency of yield loss	Severity of yield loss			
	Very Low Severity	Low Severity	Medium Severity	High Severity
High frequency	Low	Medium	High	Very High
Medium frequency	Very Low	Low	Medium	High
Low frequency	Very Low	Low	Low	Medium
Very low frequency	Very Low	Very Low	Very Low	Low

This hybrid approach, combining participatory prioritization and scientific analysis of data and literature, is used to identify crop and district-specific portfolios of technological interventions and climate services to strengthen CSA. Participatory prioritization of technologies for various agro-climatic regions is based on a multi-criteria decision-making framework. This was done by stakeholders including researchers of SAUs, the private sector, NGOs, farmers' groups, and policymakers based on their expert knowledge and judgment about their on-ground performance in terms of productivity, climate risk reduction, and mitigation potential. These are further assessed for their implementation feasibility in the states.

Understanding the yield variability, its intensity, and frequency of resulting yield losses, and the reasons behind those losses are very important to planning the coping strategies and overall adaptive actions. We calculated for every crop and district combination probability of yield loss and loss intensity (magnitude of loss). These were classified into high, medium, low, and very low-risk categories based on the risk matrix template shown in the inset figure. We then used a risk management layering approach to match the prioritized technological options to relevant crop and district-specific risk categories. We have classified various technologies based on expert judgment for their likely need and benefits in terms of yield growth, adaptation/ risk mitigation, risk transfer, and GHG mitigation. Consideration of current yield level, climatic risks, and level of current development, especially irrigation, have been factored in while doing this exercise. Based on the production risk category, we have proposed yield promoting, risk mitigation, risk coping, and risk transfer strategies that should be encouraged to strengthen resilience in agriculture systems in the states. We have also investigated how the proposed strategies could be linked with the current development schemes of the Government to minimize the need for new resources. We have illustrated this risk matrix and adaptation strategies for all crops in three states.

Following are the key recommendations emerging from this analysis.

1. Raise the bar for setting up SGSK (Climate-smart Agricultural Villages) in the states by investing in greater coverage of climate-smart technologies.
2. Develop a real-time Early Warning System linked with ICT services for monitoring and mitigating agrarian distress and accelerate the development, dissemination, and use of weather forecasts linked to value-added agro advisories
3. Re-strategize and target the crop insurance program and risk finance for increasing the effectiveness and efficiency of large subsidies of the PMFBY scheme for ensuring risk protection while promoting agriculture growth.
4. Intensify development and deployment of climate risk-specific high yielding/stress-tolerant seeds/breeds.
5. Manage water resources sustainably to increase the water use efficiency of agriculture. It should include management of extremely heavy rainfall events in Maharashtra and MP and their impact on agriculture production and its value chain
6. Promote diversification of agriculture for increasing income and for strengthening resilience.
7. Develop international partnerships to manage the increasing risks of transboundary pests in Rajasthan and Madhya Pradesh
8. Reduce carbon footprints from agriculture by exploring opportunities for reducing GHG emissions from the livestock sector.
9. Strengthen long-term climate risk management and implementation by using dynamic land use and contingency planning.
10. Develop appropriate strategies to manage climate-induced immigration/out-migration in agriculture/rural areas.

Key learnings and way forward:

1 Scaling climate-smart agriculture is complex since it involves the development of location-specific practices and technologies and climate information services. Implementing this requires dealing with diverse partners such as farmers, industry, input suppliers, KVKs, government functionaries, and policy planners at different scales. This anyways must be addressed since the problem at hand is also large and complex. ITC and BISA developed the SGSK model for scaling up CSA which provides an opportunity to build climate-resilient communities by integrating various stakeholders' knowledge and experience on CSA interventions, mobilizing the stakeholders through participatory design, prioritization of the CSA interventions, and linking cross-scale activities and players. The participatory project design and implementation process also ensure coherent linkage of the CSA process with stakeholders' needs and challenges. Results of CSA technologies and practices demonstration in the selected ITCs outreach villages in Madhya Pradesh, Rajasthan, and Maharashtra show that there is a large scope of CSA for improving crop yields and farmers' income, building resilient and reduction of emissions. Today ITC has successfully scaled up the SGSK approach in more than 2000 villages.

2 The state-level adaptation strategy developed under this project is important for the vertical scaling of SGSK. It is critical to integrate the results of the SGSK program with state and local government programs, schemes, and policies for the sustainability and long-term impact of the program. Development of farmers groups, strengthening existing Self-Help Groups (SHGs), development of service provision centers such as custom hiring and cattle development centers, promotion of community resource persons such as super champion and champion farmers, and linking farmers to the private sectors (seed suppliers, livestock services, ICT based agro-advisories, and farm machinery) are necessary. The state-level adaptation strategy developed under this project is an important step toward the vertical scaling of SGSK. However, it must be noted that the learnings at the local farmer scale would remain critical to building upscaling strategies.

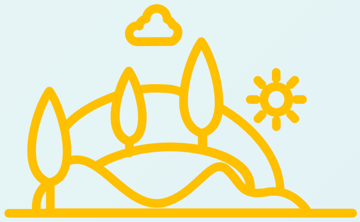
3 Knowledge and experience on new CSA innovations such as ICT-based weather and agro-advisory services, climate-resilient seeds/breeds, and agriculture insurance were inadequate for most stakeholders and therefore there is a need to build their capacity on these CSA interventions. Training and capacity building of the technical staff plays a crucial role in the transfer of climate-smart agriculture knowledge, technologies, and skills to the local farmers and farming communities, and other stakeholders. Right tools and effective communication are needed to facilitate the use of these complex approaches for resilient development.

4 There is a need to further understand the current barriers such as technical knowledge, cost of technologies, and incentive mechanisms that can facilitate SGSK (CSVs) reaching the scale. In the process of further replicating this approach in other regions, it is important to pay due to emphasis on SGSK (CSV) design protocols, which require a detailed risk profiling of climatic, socio-economic, and edaphic factors, design, prioritization of interventions, and monitoring and evaluation of the program. The data collection, verification, and analysis must be made fully digital for the calculation of indicators at the farm and village-scale for productivity, resilience, and GHG mitigation for internal and external viewers. Monitoring the SGSK (CSVs) at a large scale can be further facilitated by exploring the use of advanced analytics including remote sensing, crop models, and statistics.

Introduction

Climate change is one of the greatest threats faced by agricultural systems in the world today. Further other events like economic and health crises (like the Covid-19 pandemic) further add to the vulnerability of the farming systems across the world, especially for smallholders in developing nations. Enhancing the resilience of agriculture to unforeseen events is thus vital to food and nutritional security. Adaptation is essential to safeguard agriculture from unexpected shocks, including risks from extreme weather events. Without adaptation, on a global scale, agricultural productivity is projected to decrease by 15 to 20% in the 2080s. The regional impacts are even greater for tropical countries in Africa, Central, and Southern Asia, where the loss in productivity can reach up to 50% (Aggarwal et al., 2019). There are several potential adaptation options available to mitigate moderate to severe climatic risks in agriculture. Changes in agronomic practices (altering inputs, timing, and location of cropping activities), adoption of new technologies (use of improved seeds, improvement in input use efficiency, conservation practices, and pest/disease/weed management and water management), and the use of relevant information (climate information based agro-advisories and weather index-based insurance) at the farm level can be key components in improving the adaptability of agriculture to climate change. These options can significantly improve crop yields, increase input-use efficiencies and net farm incomes, and reduce greenhouse gas emissions. Many of these interventions have been successful individually in raising production and income and in building the resilience of farming communities in several regions. These interventions have, however, varying costs and economic impacts, and their implementation requires appropriate investment decisions in both on-farm capital and for wider agricultural outreach programs.

Climate-smart agriculture (CSA) has recently been proposed as an approach for transforming agricultural development under the new realities of climate change. It is defined as “agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security. Broadly, CSA focuses on developing resilient food production



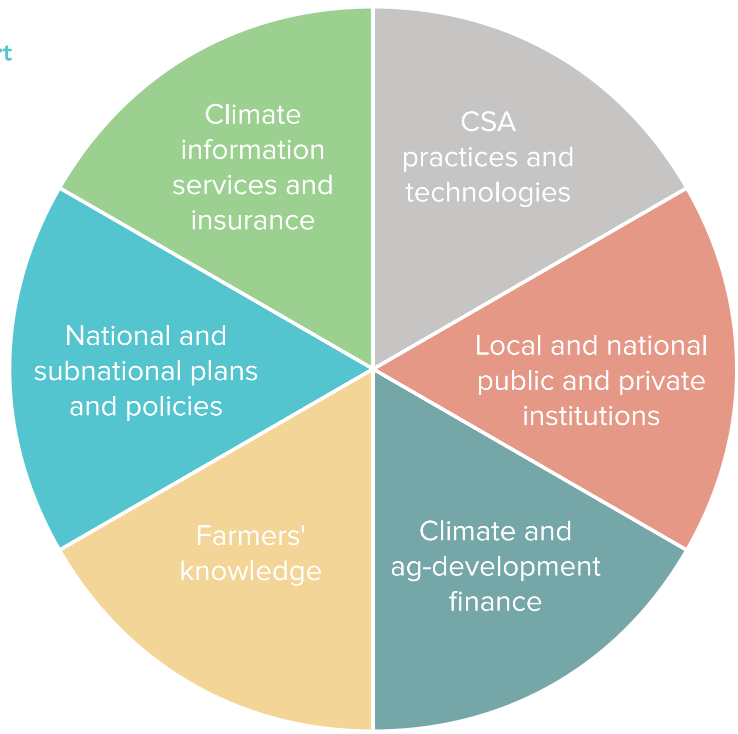
Climate-smart agriculture (CSA) has recently been proposed as an approach for transforming agricultural development under the new realities of climate change. It is defined as “agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security.

systems that lead to food and income security under progressive climate change and variability. Many agricultural practices and technologies such as minimum tillage, different methods of crop establishment, nutrient and irrigation management, and residue incorporation can improve crop yields, water, and nutrient use efficiency, and reduce Greenhouse Gas (GHG) emissions from agricultural activities. Similarly, rainwater harvesting, use of improved seeds, ICT-based agro-advisories, and crop/livestock insurances can also help farmers to reduce the impact of climate change and variability. In general, the CSA options integrate traditional and innovative practices, technologies, and services that are relevant for a location to adopt climate change and variability. CSA can help in enhancing the resilience of the agricultural supply chain in many ways. Not only can CSA help in adaptation and mitigation but can also increase resilience by improving recovery after a shock and transforming food systems through sustainable pathways. One way to implement CSA is through the establishment of a climate-smart village.

Climate-Smart Village (CSV) approach uses synergistic action of locally relevant technologies, climate information services, local farming knowledge, and development plans, and convergence with state and country development plans to build food security and resilience of farmers and the region (inset diagram for the CSV components). Figure 1 shows key elements of the climate-smart village approach. There is no fixed package of interventions or a one-size-fits-all approach. Options differ based on the CSV site, its agroecological characteristics, level of development, and capacity and interest of the farmers and the local government. The results of the CSV approach are usually a portfolio of CSA options and institutional and financial mechanisms that enable their successful adoption. Promising innovations are then available to be scaled out by the national/subnational governments, nongovernmental organizations (NGOs), and private-sector actors in regions with similar agro-ecological conditions. The approach is currently being used globally and in several states of India.

In 2016, ITC Limited in collaboration with the CGIAR research program on climate change, agriculture, and food security (CCAFS) envisioned developing a resilient agricultural production system in the ITC's outreach areas across India. To realize this vision CGIAR's Climate-Smart Village (CSV) approach was integrated into the ITC's Mission Sunehra Kal (MSK) program. Since then, this CSV-MSK integration program has been focusing on building a resilient agricultural production system through the promotion of a range of climate-smart agricultural technologies and practices. This report provides a brief synthesis of phase-1 (2016-2019) and phase-2 (2019-2021) of the ITC-BISA collaboration on "Increasing Adaptive Capacity of Farmers to Climate Change thru Climate-Smart Villages in India".

Figure 1:
Elements of climate smart village approach



Phase-1 (2016-2019):
Increasing Adaptive Capacity of Farmers to Climate Change through Climate-Smart Villages in India

The CSV approach brings together global and regional knowledge to help mitigate the adverse impacts of climate change upon agriculture systems and ensure a resilient sector. By converging global scientific knowledge within local contexts, it seeks to attain goals of food security under the new realities of climate change by deploying various technologies, models, and approaches. The phase-1 (2016-2019) of the ITC-BISA partnership aimed to develop a resilient agriculture production system in the ITC's outreach areas across India using the SGSK approach

The Climate-Smart Village (CSV) model has been designed as an integrated and participatory approach to scale out a portfolio of climate-smart agricultural technologies and practices in different agro-ecological zones across the globe. In India, one of the routes for scaling the CSV approach has been through engagement with the private sector which plays an equally important role in advancing sustainable growth pathways. ITC's 'Mission Sunehra Kal' (MSK) is one such initiative that seeks to strengthen rural livelihoods through its rural retail initiative e-Choupal, wasteland development through social forestry, soil, and moisture conservation programs, livestock development initiatives, building skills, and social infrastructure. Against this backdrop of common goals for attaining sustainable growth, rural livelihood strengthening, and environmental sustainability, ITC and BISA came together to collaborate on a project titled 'Developing Resilient Agriculture to Climate Change in India'.

The Climate-Smart Village (CSV) approach was integrated into the ITC's Mission Sunehra Kal (MSK) program. This CSV-MSK integration program focus on building a resilient agriculture production system through the promotion of a range of climate-smart agricultural technologies and practices including e-Choupal, wasteland development, soil and moisture conservation, and livestock development, health and education, and gender and social inclusion program of MSK. This phase had the objective of building resilient agriculture and rural communities by primarily focusing on targeting climate-smart intervention based on local context. ITC's outreach areas across India comprise diverse climate, agro-ecology, and socio-economic conditions that demand targeted interventions. Well-targeted and prioritized CSA technologies and practices with proven benefits and low perceived risks can lead to diffusion among farmers to farmers' levels the first phase, ITC's outreach areas in Madhya Pradesh, Maharashtra, and Rajasthan (figure 2) were focused to implement a range of CSA technologies and practices integrating with the MSK program. ITC's agriculture and natural resource management-related activities cover more than 600 villages in Madhya Pradesh, Maharashtra, and Rajasthan. In the first phase, five districts were selected in each state: Madhya Pradesh (Chhindwara, Indore, Sehore, Ujjain, and Vidisha), Maharashtra (Ahmednagar, Amaravati, Pune Ratnagiri, and Satara), and Rajasthan (Baran, Bundi, Jhalawar, Kota, and Pali).

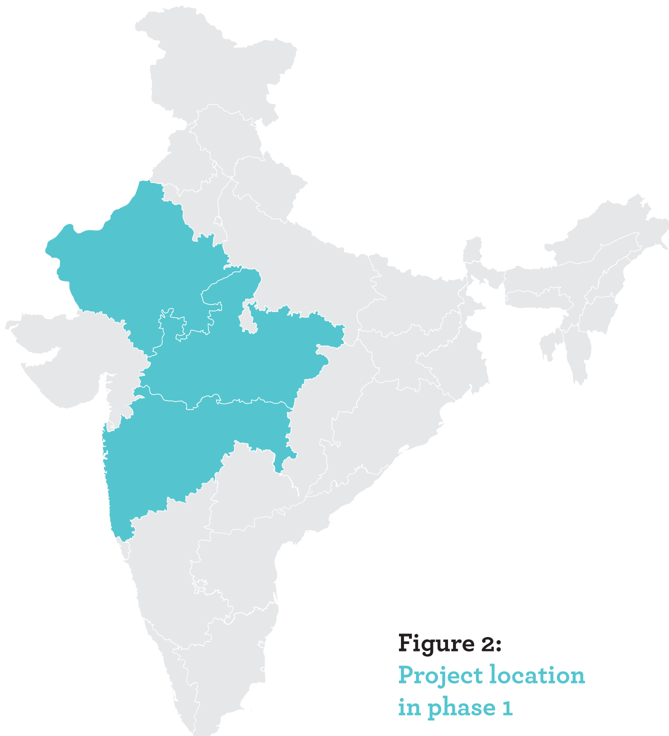
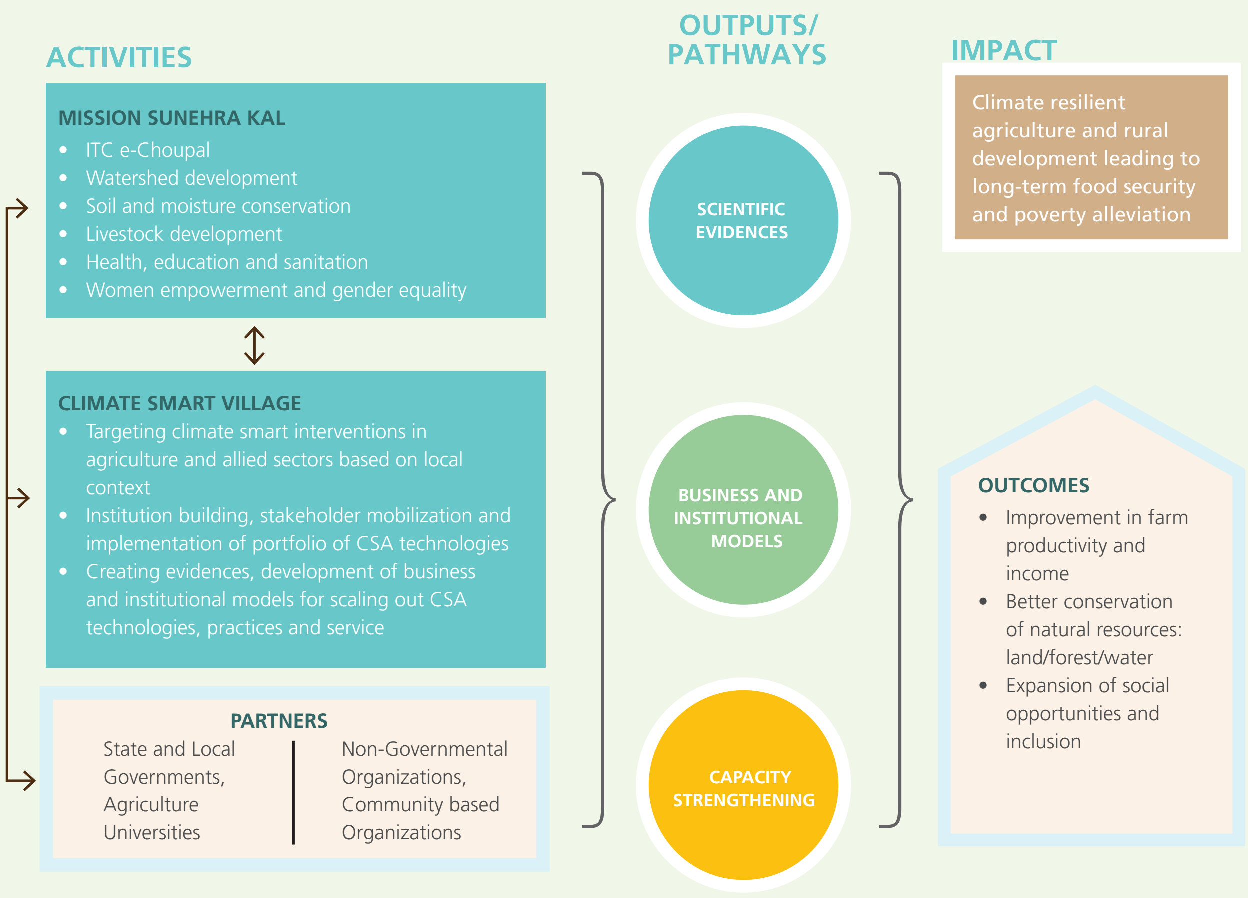


Figure 2: Project location in phase 1

ITC-BISA Partnership Model

In the first phase (2016-2019), ITC's outreach areas in Madhya Pradesh, Maharashtra, and Rajasthan were focused on, implementing a range of CSA technologies and practices integrating them with the MSK program. Figure 3 below presents an impact pathway of the 'MSK and CSV integrated' model. This model envisions better conservation of land, water, and forest resources, expansion of social opportunities and inclusions, and improvement in farm productivity and income leading to long-term food security and poverty alleviation in the rural communities.

Figure 3: Impact pathway model of MSK and CSV integrated' model



Activities in phase 1

In the first phase of the project, the climate-smart village program has focused on the following activities:

A) Baseline Survey

The baseline study was conducted in 2017 by using a household survey questionnaire. This survey was conducted in the ITC's outreach areas of Madhya Pradesh, Maharashtra, and Rajasthan states. The survey was done by an ITC's local partners working in the outreach villages. The survey covered a total sample of 3,603 households in three states. In the baseline survey, all sampled farmers were asked to tell their experience with climatic risks over the past 15 years. Top-ten weather-related risks experienced by the farmers in the project districts were high temperature (82% farmers), less rainfall (75% farmers), heat waves (71% farmers), frost (62% farmers), cold waves (60% farmers), stronger winds/storms (57% farmers), late start of monsoon (55% farmers), low water table (54% farmers), frequent hailstorm (53% farmers), and prolonged drought (48% farmers). Very few farmers experienced prolonged droughts, cyclones, early/late stop of rainfall, and more rainfall in the winter season. In all areas, conservation and use of water resources were one of the major concerns of the farmers for their agricultural production.

B) Targeting Climate-Smart Interventions

SGSK's approach to building resilient agriculture and rural communities primarily focuses on targeting climate-smart intervention based on local context. ITC's outreach areas across India comprise diverse climate, agro-ecology, and socio-economic conditions that demand targeted interventions. Considering the possibility of many climate-smart interventions in the ITC's outreach areas, a comprehensive list of technologies and practices suitable for agriculture production systems was prepared. Portfolios of climate-smart interventions for the particular location were designed based on the current level of yield gaps, climatic risks, and greenhouse emission reduction potential in the ITC's outreach areas. Prioritize technological options based on stakeholders' (farmers, local government, NGOs, and community-based organizations) preferences.

Stakeholders' workshops were organized for each state to prioritize the CSA interventions. Accordingly, the state of Madhya Pradesh, Maharashtra, and Rajasthan have prioritized a range of climate-smart interventions based on the experiences of local farmers, technical experts, and government officials from the respective area which were more suitable for the local context. Portfolios of climate-smart agriculture interventions were developed based on existing climatic risks, local crop and cropping systems, and stakeholders' priorities in the ITC's outreach areas. Table 1 presents prioritized CSA interventions in Madhya Pradesh, Rajasthan, and Maharashtra.

Most of the stakeholders preferred irrigation water management-related interventions such as underground water withdrawal systems (tube well/dug well), micro-irrigation technologies, and water harvesting structures. In the project areas, the availability of water for irrigation in the dry season is a major issue for agricultural production. Technologies for crop nutrient management, improved and resilient seed varieties, and agroforestry management was also preferred by most of the stakeholders in the study area. The prioritized portfolios also include nutrient management practices, crop sowing methods, use of improved seeds, and crop diversification received medium-level ranks in the stakeholders' evaluation.

Table 1 List of prioritized CSA technologies

Madhya Pradesh	Rajasthan	Maharashtra
Drip Irrigation	Tube well/ Dug well	Dug well /Tube well
Area Specific Mineral Mixture for Livestock	Alternate Wetting and Drying	Agroforestry
Concentrate Feeding for Livestock	Check dams	Alternate Wetting and Drying
Conservation Furrow	Climate Smart Housing for Livestock	Broad Bed Furrow
Fodder Management	Conservation Trenches	Conservation Furrow
Furrow Irrigated Bed Planting	Direct Seeded Rice	Conservation Trenches
Green Manuring	Farm Bunding	Drip Irrigation
Improved Short Duration Variety	ICT Based Agro-Advisory	Farm Bunding
Intercropping with Legumes	Irrigation Scheduling	Farmyard Manure
Livestock and Fishery as Diversification Strategy	Laser Land Levelling	Laser Land Levelling
Rainwater Harvesting	Rainwater Harvesting	Minimum Tillage
Raised Bed Planting	Site-Specific Integrated Nutrient Management (Using LCC)	Rainwater Harvesting
Site-Specific Integrated Nutrient Management (Using LCC)	Solar Pump	River/Stream Beds
Sprinkler	Sprinkler	Sprinkler
System for Rice Intensification	Stress Tolerant High Yielding Breeds of Livestock	Site-Specific Integrated Nutrient Management (Using LCC)

C) Model of Implementation and farmer categories:

The implementation pathway of the integrated climate-smart village approach follows a 'hub and spoke' model (figure 4) wherein evidence is generated in the 'hub' (comprising of farmer groups) by implementing different portfolios of CSA interventions. This evidence then gets disseminated via various mediums like on-site demonstrations, participatory videos, capacities training, etc. as 'spokes' from the hub to reach other farmers in the same village or nearby villages. For the field implementation of portfolios of climate-smart interventions three types of farmers: super champion, champion, and CSA farmers. Super-Champion farmers are large landholders, can implement a large portfolio of technologies and practices, proactive and financially well-off, and can influence other farmers in the village and play a leadership role in developing a climate-resilient agricultural production system. Champion farmers are medium-large landholders and can implement a relatively limited number of technologies and practices (compared to super-champions). CSA farmers are small landholders and resource-poor farmers who can implement a very limited set of technologies and practices.

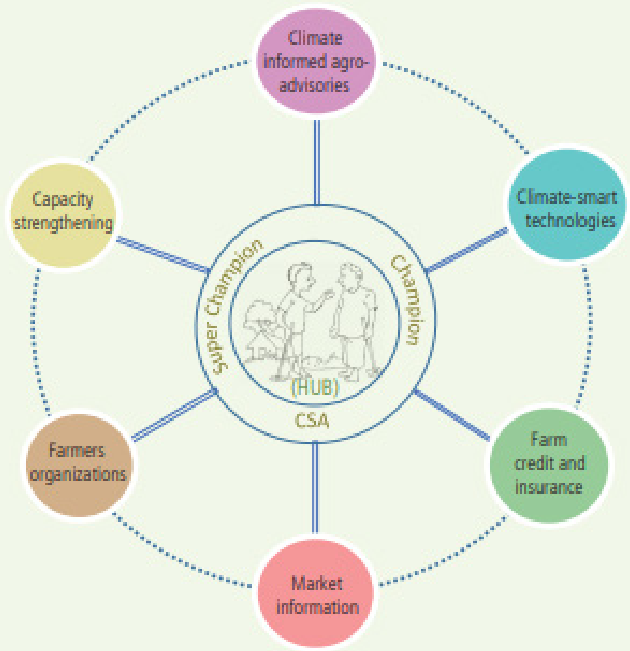


Figure 4: The hub-and-spoke model of technology transfer

D) Capacity Building:

The capacity building started from the baseline assessment of project villages to identify local needs and resources for climate change adaptation in agriculture. Agriculture and climate risk assessments included methods to estimate current and future climatic risks in agriculture such as probably of drought, excess rainfall, changes in rainfall pattern, and temperature-related stresses. Participants were also trained to assess land use patterns and changes, crop, and cropping patterns, cropping intensity, and yield gap analysis. Once the scope for the prioritization initiatives such as production system, agro-ecological zones, nature of climatic risks, type of farmers, and other baseline information is identified, participants were also trained to develop a list of relevant technologies, practices, and services. ITC staff and its local NGO partners participated to prioritize CSA interventions with key stakeholders. A detailed framework was provided to conduct stakeholders' prioritization of CSA options based on crop, livestock, and cropping system in the project areas. These prioritization exercises help to develop portfolios of CSA interventions for each project village. Stakeholders' mobilization was one of the key components of this project to implement the portfolios of CSA interventions in the farmers' field. ITC-BISA conducted several training activities on farmers' selection and institutional building, the inclusion of existing community-based organizations such as Self-Help Groups, women farmers groups, farmers' producer groups, and forest and water user groups. During the project period, a range of training on a package of practices of CSA interventions, data collection, monitoring, and evaluation of CSA interventions in the farmers' fields to the ITC staff and local NGOs.

Field Evidence of CSA Interventions in Phase-1

The first phase of the ITC-BISA climate-smart village initiative covered 1,668 farmers and 1,945 hectares of land to demonstrate a range of climate-smart interventions in the super champion and champion farmers' fields. The purpose of this demonstration of climate-smart technologies and practices in the pilot SGSK was to increase farmers' awareness of climate-smart technologies and their benefits, strengthen knowledge and skill to implement CSA technologies and practices, and disseminate suitable technologies to other farmers and villages in the project districts and states. CSA interventions in the farms of Super-Champion and Champion farmers were evaluated based on their contribution to improving crop productivity and income compared to baseline (before interventions). A significant level of improvement in crop yields was observed in soybean, wheat, and paddy in all project districts. Below, we present a summary of the impact of CSA interventions by the state.

Madhya Pradesh

The CSA practices, like improved wheat variety, seed treatment, site-specific nutrient management, ICT-based weather information, agro-advisory services, and smart irrigation practices like sprinkler irrigation, were implemented. These interventions helped in increasing the average yield by 0.54 t/ha and 1.38 t/ha in soybean and wheat, respectively. The average change in yield in soybean and wheat was 65% and 18% respectively. The average yields have significantly increased, and the yield variations also showed initial indications of a decrease among the super champion, champion, and CSA farmers over the baseline. The average income from the cultivation of soybean and wheat has also increased in season one and season two. This project has promoted the reduction in nitrogen input by either promoting efficient use or replacing some of it with vermicompost. This has resulted in reduced Green House Gas (GHG) emissions. CSA practices resulted in a large reduction of emission intensity (CO_2 eq kg/kg of wheat production) in Madhya Pradesh. In some villages in Madhya Pradesh, the emission intensity of soybean cultivation has increased despite the increase in yields largely resulting from the increased use of nitrogen fertilizer compared to baseline.

Rajasthan

CSA interventions in Rajasthan were mainly focused on soybean and wheat crops. The CSA practices like the improved seed of wheat, site-specific nutrient management, and the use of ICT-based weather information and agro-advisory services were implemented by farmers. The results also show that the CSA interventions are helping to increase crop yields as well as reduce yield variation among the farmers. The average change in yield in wheat was 14%. Yields of soybean in three districts (Jhalawar, Baran, and Budi) were reduced during the project period. Heavy rainfall during the harvesting time and medium levels of drought have contributed to reducing the yield. However, CSA intervention has prevented complete crop loss during the project period. In both wheat and soybean crops, the CSA interventions helped to increase crop yields. These yield improvements under CSA intervention were mainly contributed by a change in seeds with improved varieties, better water and nutrient management, and proper sowing method and time. These results show that climate-smart interventions with improvement and cost reduction technologies/practices can bring large improvement in poverty and food security. The average income from the cultivation of wheat has also increased in most villages, except in Pali. The average income from wheat in Pali was slightly lower than the baseline due to changes in market prices. Despite the increase in soybean yield in Rajasthan, income from soybean cultivation has decreased in most project villages. Two factors, the market price of soybean and the increase in input prices have contributed to a decrease in the income for soybean cultivation. The price of soybean was lower during the project period than at baseline. Farmers in one district (Bundi) have cultivated maize and the income from maize cultivation with CSA intervention has significantly increased. In addition, the project has promoted the reduction and efficient use of nitrogen which has resulted in reduced lower GHG emissions. Similarly, change in emission intensity was also calculated for soybean crops in all villages where CSA interventions were implemented. The emission intensity was compared between baseline and CSA intervention scenarios. Emission intensity in soybean cultivation was significantly reduced in all project villages from an average of 0.4 CO_2 eq kg/kg of soybean production to 0.25 CO_2 eq kg/kg of soybean production in the state.

Maharashtra

In case of Maharashtra, the ***SGSK*** interventions in the rabi season focused on the onion crop. The CSA practices like using improved seed of onion, seed treatment, agronomical practices like raising beds with smart irrigation systems like drip, site-specific nutrient management, ICT-based weather information, and agro-advisory services were implemented by farmers. The average change in yield of three major crops i.e., soybean, paddy, and onion yields were 26%, 33%, and 27%, respectively in the state. The average yields have significantly increased and the distributions of yields (yield variations) among the super champion, champion, and CSA farmers are lower than baseline. Results show that the CSA interventions are helping to increase crop yields as well as reduce yield variation among the farmers. The average crop incomes for most of the farmers were higher than the baseline line in Maharashtra. This indicates that CSA interventions are helping to improve crop yields as well as income in most farmers' fields. Emission intensity in soybean cultivation was significantly reduced in all project villages in Maharashtra. For instance, the average emission intensity for soybean in baseline was above 0.5 CO_2 eq kg/kg of soybean production in all villages of Amravati district of Maharashtra, which was decreased to an average of 0.25 CO_2 eq kg/kg of soybean production.


ITC MISSION SUNEHRA KAL
WATER SECURITY PROGRAM - MALUR
ರೈತ ಕ್ಷೇತ್ರ ಪಾಠಶಾಲೆ
Promotion Of Farmer Field School
Farmer Name :
Village :
Crop :
Method :

Sunehra Gaon Sunehra Kal
(ITC-BISA Climate-Smart Village) Approach

The CSV model of CCAFS-BISA was integrated with ITC's Mission Sunehra Kal program based on the lesson learned from the CSVs. Several initiatives of the ITC-MSK program such as technologies promoted, ITC field schools for capacity building, and custom hiring centers were integrated into the CSV program. The resulting model of ITC-BISA collaboration is henceforth tentatively labelled as **the Sunehra Gaon Sunehra Kal** program wherein initiatives focus on strengthening the capacity of farmers and other stakeholders to adopt site-specific practices, technologies, services, and innovative institutional models that lead to increased agriculture production and income, build adaptation to key current and future climatic risks, contribute to net-zero emission targets of the country, and provide a foundation for improved risk management policies and schemes. With this model, ITC aims to reach one million acres by 2030 and already efforts are made by starting the scaling of ***SGSK*** in new regions. Currently scaling of ***SGSK*** is traversing an exponential growth pathway and expanding its reach from three states to twelve additional states and planning to reach more than 2000 villages shortly. This ambitious target of rapid scaling of ***SGSK*** and reaching many villages in varying agro-ecologies needs carefully drafted plans and strategies for implementation, monitoring, and further upscaling. In the section below we present in brief the components and steps for establishing and scaling ITC-BISA ***SGSK***.

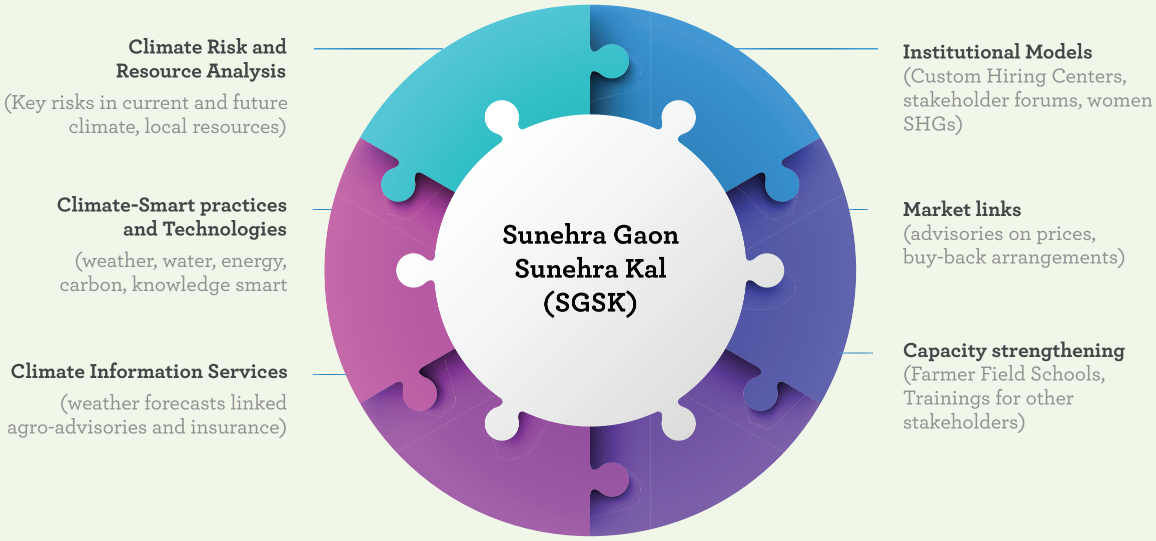
Establishing SGSKs Climate-Smart Village

The SGSK approach promotes local, incremental adaptation and transformative options and builds local capacities to continue to innovate, experiment, and adapt. The SGSK approach aims to have a positive impact on agriculture-dependent communities, and this includes ensuring the participation of women farmers and all social groups. Where possible, gender-differentiated aspects are assessed to ensure that prioritization and development of portfolios of climate-smart technologies, best practices, technologies, services, processes, and institutional options address gender and social inclusion.

An ideal ***SGSK*** site typically has six main components (figure 5).

1. Climate risk and resource analysis: Village/community agricultural land use plans and contingency plans considering current and future climate risks, soil and socio-economic conditions, and markets.
2. Climate Information Services: Tactical guidance to farmers on using real-time weather forecasts and value-added ICT-based agro advisories; on accessing good quality inputs and technologies for improving water/nutrient/energy use efficiencies, and on risk transfer through insurance mechanisms in case of crop and livestock losses.
3. Climate-Smart Practices and Technologies: Portfolios of the market and farmer-friendly CSA portfolios suitable for the key climate risks and resource base of the location are identified by a scientific participatory process.
4. Market links: Provide the advisories on commodity prices of nearby mandis as well as local markets, and buy-back arrangement
5. Capacity Strengthening: Build the capacity of stakeholders, and farmers through field training and field school. Policy level guidance on policy barriers and policy options to unlock CSA and local and national development. This includes consideration of the financial needs to drive scaling.
6. Institutional model: Strategic guidance before the planting season, was feasible based on seasonal forecasts, on the most suitable CSA practices, technologies, services, processes, and institutional options. This is done in a participatory mode with local farmer groups and due consideration is given to institutions in the region such as farmers' self-help groups, water-users associations, markets, and the availability of climate and agriculture development finance.

Figure 5 Component of ITC-BISA Climate-Smart Village



Increased agriculture production and income	Adaptation to current and future climate risks	Contribute to net zero emissions targets of the country	Improved policies and schemes for resilience in agriculture

Setting up the SGSK Climate-Smart Village

In establishing the ITC-BISA ***SGSK***, the very first step is to build trust and partnerships amongst diverse stakeholders through the inception meeting; and to get agreement and buy-in to a common approach. Once partners have agreed on the establishment of a ***SGSK*** site, the four major steps include

1

Village baseline assessment: Key current and future climate-related risks and vulnerabilities to agriculture at the village/landscape level will be identified by analyzing the historical climate data and future climate scenarios for rainfall variability, drought, flood probability, and periods of heat/cold stresses. A baseline assessment will also be made of the soils, water resources, markets, technologies, knowledge gaps, relevant institutions, ad private and public finance availability. Long time-series data of yields/NDVI/GPP for the last 10 years will be plotted against major climatic risks in the same period. Risks (identified by climate analysis and participatory method) could be early drought, late drought, terminal heat, etc. This could be used for baseline characterization of the resilience profile of all villages. Cannot be used easily for monitoring progress at least until 5 years of treatment. For a short period like for the 5 years, will try to use moving averages data to calculate the resilience.

2

Portfolio of interventions and its field evaluation: Based on the village baseline which included the biophysical, socio-economic, gender, policy, and institutional information, a portfolio of climate-smart technologies from the MSK programs, KVKs, and elsewhere; and Climate Information Services- weather-linked advisories, and crop and livestock insurance- will be selected for implementation. The portfolio will be identified based on a participatory process by the stakeholders including some of the practices/technologies viz., seed and breed-smart technologies like climate-adapted seeds of key crops and breeds of livestock, water-smart practices, and technologies such as rainwater harvesting, drip, and sprinkler irrigation, irrigation scheduling, laser-land levelling, weather-smart services such as agro-advisories linked to weather forecasting and weather-based insurance, nutrient-smart practices such as site-specific nutrient management, precision fertilizer application, and residue management, carbon- and energy-smart practices such as agroforestry, conservation tillage, and livestock management, solar irrigation system; and, market-smart activities such as market information systems, and participation in producer cooperatives.

A 'Hub and spoke' model will be used for farmer-to-farmer extension. Farmer's capacity will be raised to evaluate their portfolios of interventions in key 'Hub' villages under the overall guidance of a Climate-smart Agriculture Village Committee. The evidence will be further showcased in 'Spoke' villages through Farmer Fairs, on-field training, dissemination of videos and success stories, etc. Farmer Field Schools of the ITC MSK program will be used for capacity strengthening of stakeholders. Further to this, the SGSK program will be integrated into the existing agriculture and rural development programs and the adaptation policies at the state as well as national levels.

3

Monitoring, evaluation, and learnings: Simple, location-specific indicators to measure climate smartness will be used to understand the progress in time and space. Data on key indicators related to changes in yields, income, resilience, and GHG emissions will be collected by the ITC field teams. This will be complemented by a participatory assessment of technology suitability for current and future climatic risks, implementation feasibility, and adoption barriers. The institutional and financial needs of selected interventions will be determined at the farmer, village, and sub-national scales. The potential for convergence of current agricultural development schemes/plans in the region will be explored to minimize transaction costs and maximize synergies in SGSK. The trend of NDVI/GPP of villages/farmers could be used as a proxy of treatment effects and will compare with control villages in similar agro-ecologies. NDVI of Sentinel data for individual farmer fields can also be used for monitoring. A robust dashboard will be developed for the regular monitoring of SGSK.

Phase-2 (2019-2021):

Increasing Adaptive Capacity of Farmers to Climate Change through SGSK Approach in India

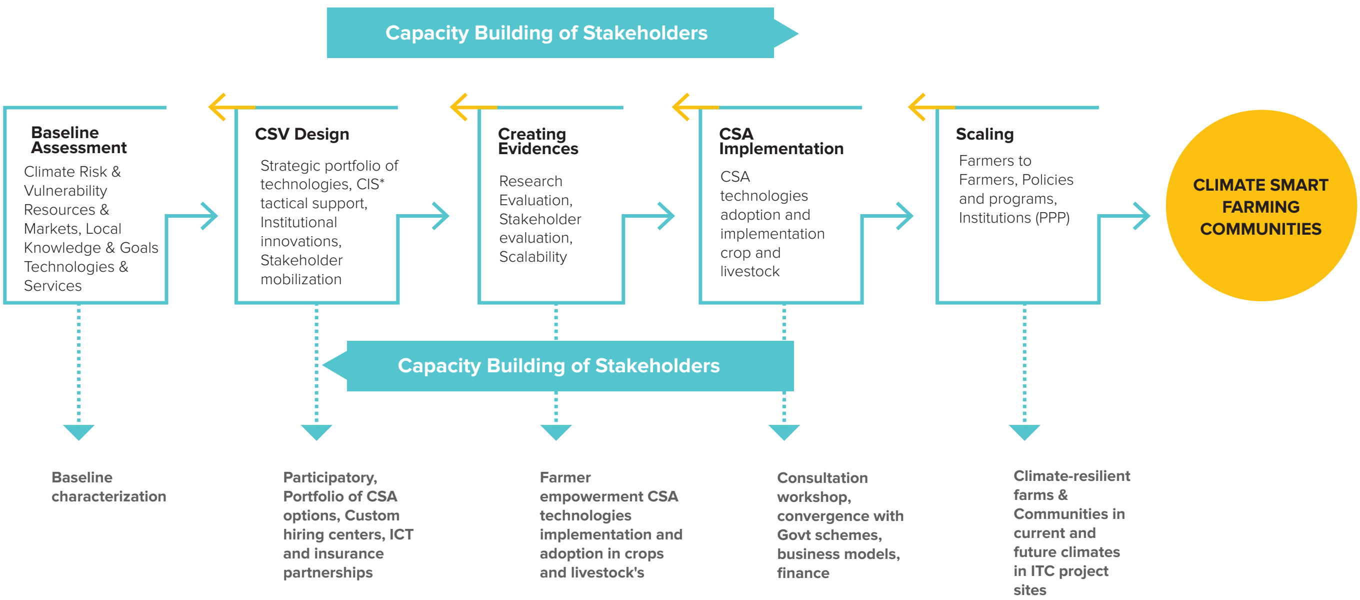
To rapidly scale the ***SGSK*** approach to 12 more states resulted in targeting three key activities in phase-2 viz., capacity building, vertical scaling through developing adaptation strategies, and development of guidelines for the establishment of model ***SGSK*** as evidence and demonstration sites. The first important element of the project was to strengthen the capacity of ITC staff and its local partners to transfer climate-smart agriculture knowledge, technologies, and skills to the local farmers and farming communities in the ITC outreach villages in the fifteen states across India. The second important element was to develop the adaptation strategies for managing current and future climatic risks in agriculture in the three states i.e., Rajasthan, Madhya Pradesh, and Maharashtra through a consultation workshop. The adaptation strategies were based on a participatory process of stakeholders' including researchers of SAUs, the private sector, NGOs, local farmers' groups, and policymakers' views on prioritized location-specific climate-smart interventions, their implementation feasibility, and consideration of potential adoption barriers and key incentive mechanisms and institutions required to promote the CSA technologies. The third element of the project was to support the ITC team to establish the Model Climate-Smart Villages for showcasing the potential of CSA in climate risk management and resilience-building at 3-5 sites identified jointly. ITC and its local partners have carried out all field-level implementation of model ***SGSK*** using learnings from the first phase, while CCAFS-BISA has provided technical backstopping for it.

The second important element was to develop the adaptation strategies for managing current and future climatic risks in agriculture in the three states i.e., Rajasthan, Madhya Pradesh, and Maharashtra through a consultation workshop

A) Capacity Building

This was a crucial part of the project to strengthen the capacity of the ITC Limited team and its partners for the implementation of the climate-smart village program across ITC's outreach areas. This involved the design of the training and creating five distinct modules for each step of the Climate Smart Village approach including a baseline assessment, ***SGSK*** design, creating evidence and monitoring and evaluation, scaling-out and finally revisiting all the steps through the refresher training module (figure 6). Each of the modules was linked with each other and the training includes knowledge exchange of methodologies, tools, and hands-on exercises to ensure participatory learning. Module one was designed to cover climate risk and vulnerability assessment, understanding resources and market linkages, local knowledge, and penetration of agricultural technologies and services. Detailed training materials have been developed for the baseline assessment. Module second focused on screening for no-regret technology options, developing a portfolio of practices and technologies dealing with food security, adaptation, mitigation, and climate information services required in the ***SGSK***. It covers participatory action research techniques and methods for stakeholder mobilization. The third module included methodologies/techniques for implementing interventions, monitoring field activities, and impact assessment methods. Customized monitoring and data collection application for CSA interventions were developed for ITC's outreach areas. It covers technical aspects of agricultural assessments linking climate risks, CSA requirements, and evaluation. A CSA indicator framework has been included in the module. The fourth module focused on horizontal and vertical scaling of ***SGSK*** portfolios, which have been successfully demonstrated. Horizontal scaling has been achieved through demonstration sites for farmer-to-farmer learning (often through self-help groups or producer organizations) and enabling the promotion of CSA through local government plans, programs, policies, and private-sector business models. Vertical scaling includes large-scale CSA investment plans, mainstreaming institutional changes, and influencing state or national policies. Finally, the last training module emphasized brushing up on technical knowledge for the development of ***SGSK***, introduction to the CSA indicators, and the dashboard which will be used to monitor the ITC's ***SGSK*** program in the next phase.

Figure 6: Steps in SGSK implementation



Module 1

Baseline Assessment

Baseline is the first step of implementation of the ***SGSK*** approach, the first training in this series of training was organized on Baseline Assessment from 27th to 31st January 2020 in New Delhi. This training was planned with the vision of capacitating the ITC Limited staff on the importance of baseline assessment, the methodology of baseline assessment, and the ways to overcome the challenges faced during baseline assessment. The training on baseline assessment included sessions on the assessment of the natural (land, water, and soil) and physical (infrastructure such as irrigation, technology, and markets) resources available in the selected area. It also included sessions on the assessment of socioeconomic resources such as human (labour and education), financial (source and amount of revenue and budget), and social (institutions and networks) resources. The training also discussed the assessment of the local community's knowledge of climatic risk management. Each session in the module was followed by a detailed discussion. We also developed the baseline proforma which contains the five broad sections such as household characteristics, land, agriculture, and livestock holding information, climatic risks and impacts, adoption of weather resilient technologies in agriculture, and household income sources, and reiterating the importance of baseline assessment in designing ***SGSK***. The module also included a hands-on exercise, participants were asked to independently fill the baseline proforma for one of the villages located in their area of work. The participants were also requested to give a short presentation on the status of ***SGSK*** in their area. In this training, we organized a field visit to Karnal, Haryana, one of the research project sites of CIMMYT. The BISA scientist and the team of system agronomists of CIMMYT accompanied the participants and explained the ongoing climate-smart interventions. CIMMYT field staff also explained various kinds of farm equipment used in CSA farming such as happy seeded, laser land leveller, thresher, and seed cum fertilizers among others. The interaction with the scientist and the team helped the participants better understand the use of the CSA portfolio in wheat farming. After visiting the research station, the participants visited the farmer's field and saw portfolios of CSA technologies implemented by the farmers on their farms. During the interactive session, the farmers shared their experiences which helped participants better understand the ground realities before the implementation of CSA. The participants were quite overwhelmed by the farm practices of the farmers and the knowledge displayed by them.

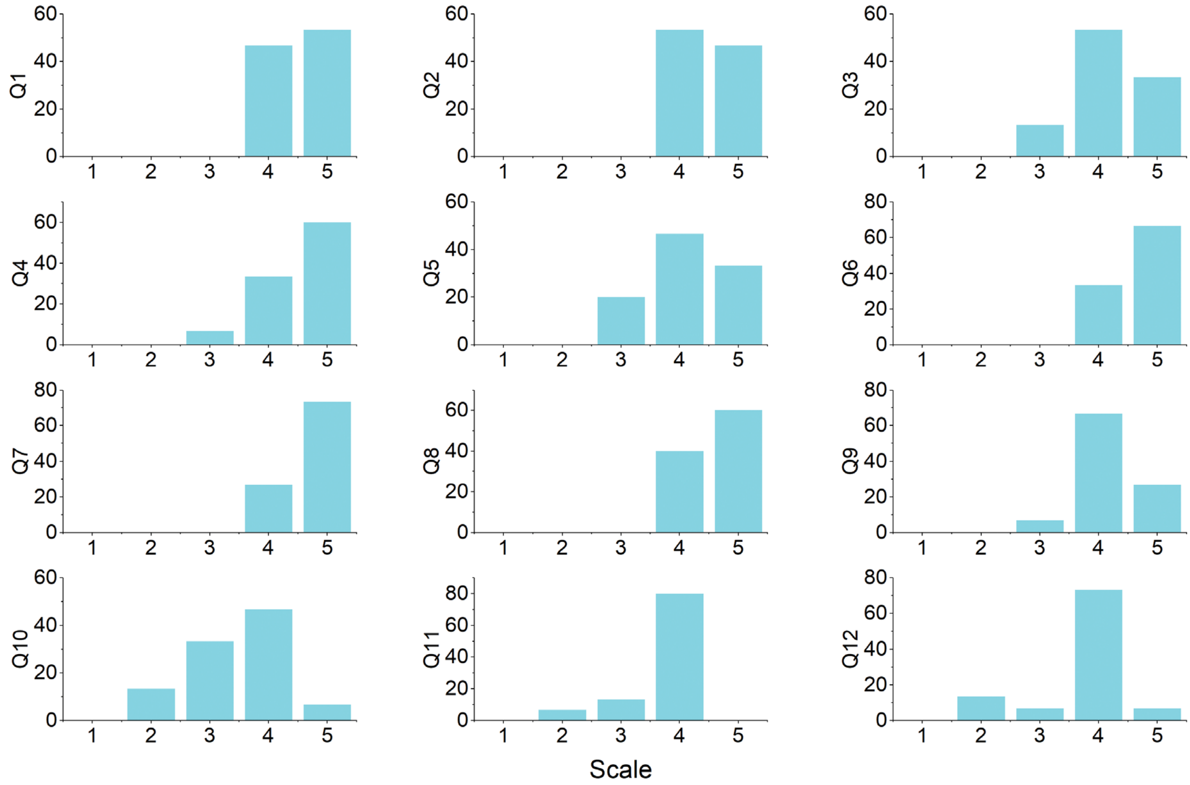
Module 2

Climate-Smart Village (SGSK) Design

After the training on baseline assessment, the second module of designing ***SGSK*** primarily focused on developing a portfolio of practices and technologies dealing with food security, adaptation, mitigation, and climate information services. A five-day virtual training was organized on zoom because of the COVID-19 lockdown situation. The five-day virtual training started on Monday, 11th May 2020. As discussed in Module-1 the first step of ***SGSK*** design is to collect the baseline information of the selected location. After the collection of baseline information, the second most important step is to prioritize the portfolio of technology for the climate-smart village. In this module we shared a technology characterization proforma for a sample village, this information was used in the design process including participatory prioritization with considerations of the climatic risk, local-level problems, and cropping pattern. The ***SGSK*** indicators on production, resilience, and emissions; implementation feasibility, and resource availability such as time, money, and human resource aspects are also to be kept in mind while participatory prioritization of the technologies. Hands-on exercises have also been done in the training module to prepare a sample technology prioritization list for a village by each participant. The module also included the introduction to the Climate Smart Agricultural Prioritization (CSAP) Toolkit which will be used for the prioritization of CSA technologies. One of the important aspects of the ***SGSK*** is to design the implementation approach and consider the learning from the existing ***SGSK***.

To evaluate and feedback on this virtual training, a questionnaire of 12 questions was designed and data for the same was collected from all the participants. Most of the participants ranked the training to be very satisfactory (average score above 3) (Figure 7). The content organization and ease of understanding was an issue highlighted in training 2 (Q3) because of the first-ever virtual mode of the training. Most of the participants noted how the trainers were knowledgeable and prepared, and more importantly, how the training was useful and will help them in their current work. Questions 10 to 12, on the time allocated to each session and the efficacy of virtual training was highlighted as an issue, with many stating the need for more time in understanding the technical aspects of the ***SGSK*** process. To address this, all the participants were encouraged to reach out to the trainers even after the training, for any doubts and clarifications. Participatory prioritization of ***SGSK*** technologies and the GeoFarmer tool was one of the most liked topics covered in the training.

Figure 7: Detailed results for feedback from training 2

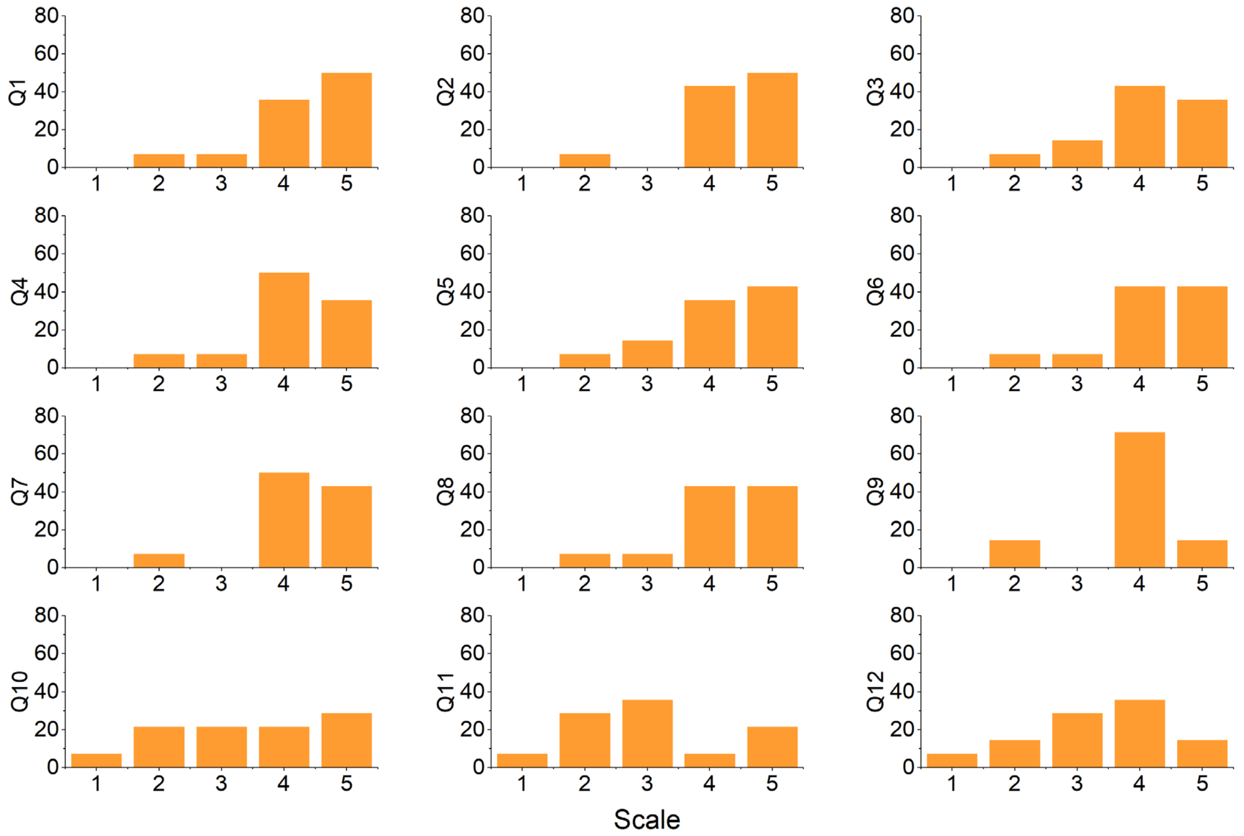


Module 3

SGSK Monitoring and Evidence Generation

The third training module focused on ***SGSK*** Monitoring and Evidence Generation. As the third step in establishing the ***SGSK***, the monitoring and evidence generation takes the ***SGSK*** design towards scaling. Once a portfolio has been designed, field evidence for this is developed in a two-step process. First, selected interventions/portfolios are evaluated by a multi-stakeholder research platform (including CGIAR, national agricultural research systems, NGOs, private-sector players, farmers, and their institutions). It includes an assessment of benefits, synergies, and trade-offs of the technologies from the perspective of individual farmers (men, women, and youth) as well as of the aggregate community/landscape. A detailed evaluation is conducted using surveys, farmer group evaluations, and ICT-based feedback tools. Modelling is often used to supplement the results of the on-farm evaluation, especially to estimate the benefits of resilience and mitigation benefits through time. In the second step, the final portfolios are evaluated by farmers on a larger scale. Crowdsourcing of data is used to understand farmers' preferences and technology adaptation domains across ***SGSK*** sites. Due consideration is also given to the identification and evaluation of constraints and barriers to the adoption of interventions, along with ways to overcome them. Like training 2, this three-day virtual training module was organized on zoom due to COVID-19. Feedback on training was collected through a survey questionnaire and presented in Figure 8. Most of the participants noted how the trainers were knowledgeable and prepared, and more importantly, how the training was useful and will help them in their current work. Mixed responses were received for question 10 which was about the time allocation to the training nevertheless most of the participants strongly agree with time allocation was sufficient for training. More than 70% of participants felt very satisfied about the training objective was well achieved.

Figure 8: Detailed results for feedback from training 3.

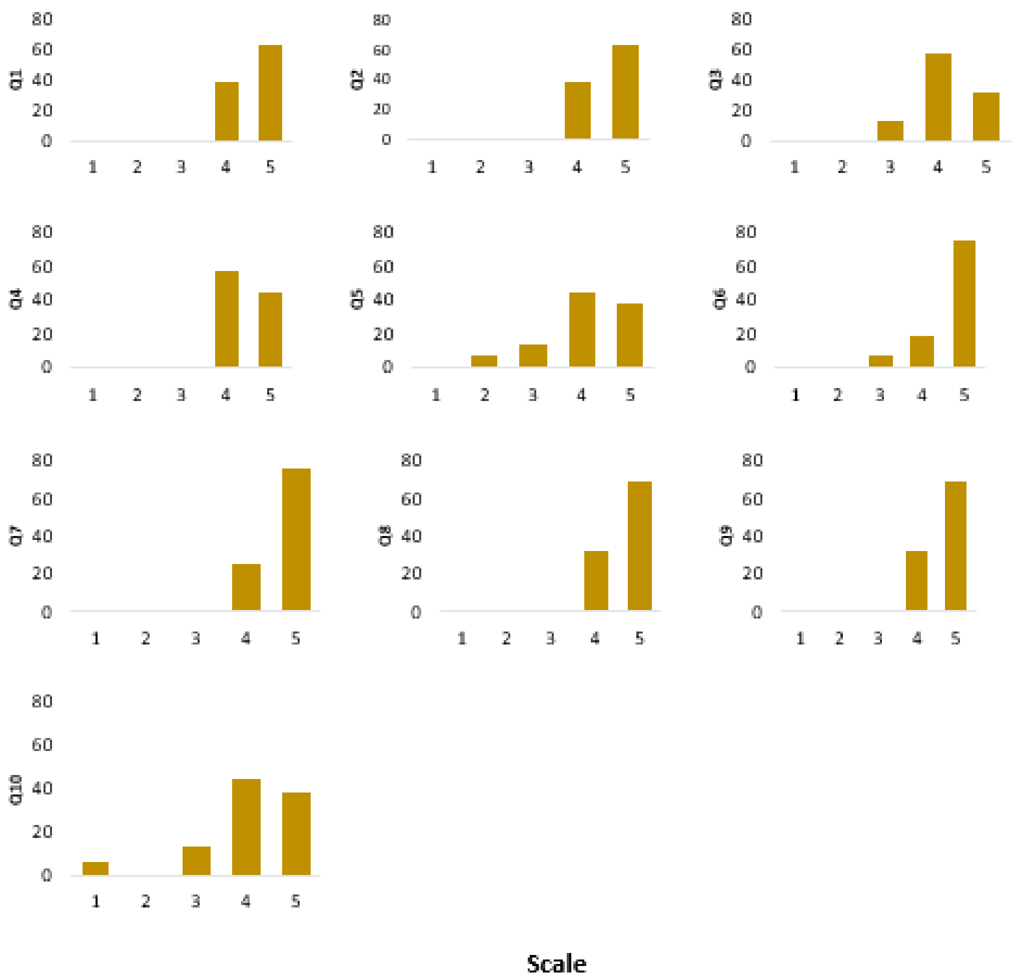


Module 4

Scaling Out CSA/SGSK

The fourth training module focused on scaling out ***SGSK*** using multiple channels and linkages. As the final step after monitoring and evidence generation, this step takes the ***SGSK*** design toward scaling. Once a portfolio has been designed and field evidence is collected, the concept is scaled out using different models. The models, linkages, and channels used to scale out ***SGSK*** are location-specific and depend on existing public-private policy support available at the local to national scale. The first step is therefore a detailed situation mapping, where different potential actors are mapped, linkages discovered, along with opportunities and constraints for each model. A detailed evaluation is conducted using surveys, stakeholder evaluations, literature reviews, public policy analyses, and ICT-based feedback tools. The second step is to choose a model which best suits the existing conditions, where different partnerships can be leveraged to their maximum potential. The final step is to integrate the climate-smart agriculture agenda with the chosen model and channel. This module focuses on presenting different types of models which have been used in India and abroad to scale-out ***SGSK***. This is an important step for ITC Limited, as scaling out and scaling up climate-smart technologies and practices can help in developing a sustainable and resilient supply chain network. Due consideration is also given to the identification and evaluation of constraints and barriers to the adoption of interventions, along with ways to overcome them. This three-day training module was also organized virtually on zoom because of COVID-19. Likewise in the training 3, a questionnaire of 10 questions was designed and data for the same was collected. Most of the participants ranked the training to be satisfactory (average score of 4) (Figure 9). Around 69% of participants strongly agreed to the training object was met well whereas the remaining 31% of participants also agreed with it. Around 75% and 25% of participants strongly agreed and agreed respectively that the trainers were knowledgeable and prepared, and more importantly, how the training was useful and will help them in their current work. Mixed responses were received for question 10 which was about the time allocation for the training nevertheless most of the participants strongly agree with time allocation was sufficient for training.

Figure 9 Detailed results for feedback from training 4.



Module 5

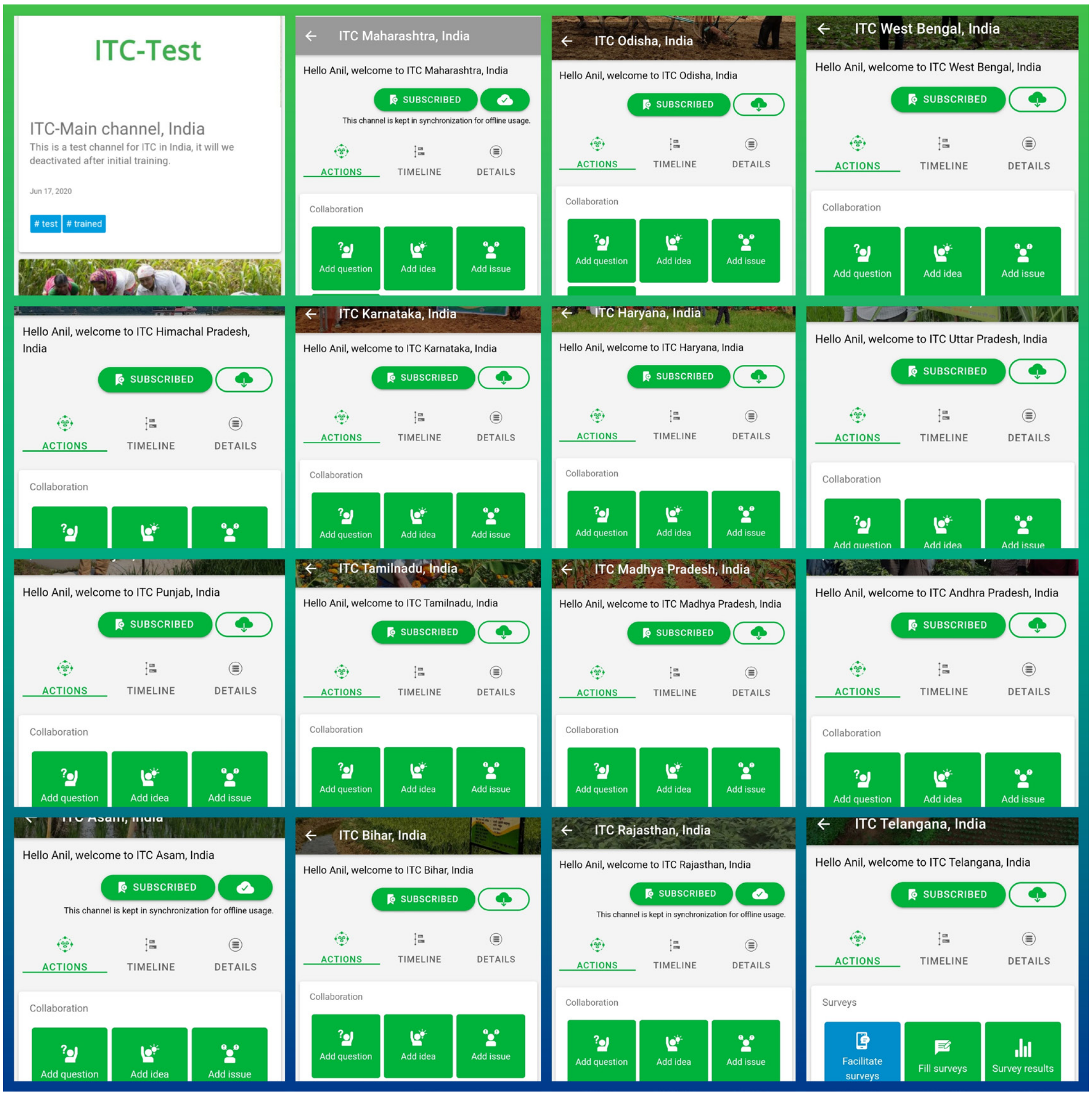
Refresher Training

The fifth training module focused on brushing up on the technical knowledge for the development of ***SGSK***, introduction to the CSA indicators, and the dashboard which is going to be used for the monitoring of the ITC'-BISA ***SGSK*** program in the next phase. The training module included sessions on a quick overview of climate risk assessments, quadrant analysis, a reintroduction to CCAFS-MOT and the Cool Farm Tool, and hands-on exercise for emission calculations by using the same, prioritization of CSA technologies, introduction to new CSA indicators, and its monitoring, ***SGSK*** dashboards, and its visualization, data extraction using Google Earth Engine, and use of remote sensing technique for the monitoring of CSA/***SGSK***. This two-day virtual training module was organized on zoom due to COVID-19.

Training on Use of GeoFarmer App

CCAFS has developed the effective and user-friendly ICT-based instrument called GeoFARMER that can be rapidly, reliably, and systematically deployed across the global CCAFS Climate-Smart Villages network to collect the baseline and other data and track CSA adoption, output, and outcomes in the field. It has multilevel communication among the farmers, field experts, researchers, and technical experts from the technical institutes. For example, if the development agencies want to do the baseline survey at the household level, they can use this tool to create the baseline survey channel within the app and can collect the real-time information and do the analysis simultaneously. Even they can track the information and enable give feedback to the facilitator for missing information. In addition, the farmer can access the information from the app and use the best farming practices suitable for their climatic area and the situation. This platform also acts as the monitoring app and the agency, and the researcher can do real-time monitoring of agriculture development projects. GeoFarmer channel has developed using Progressive Web Application (PWA) technology; therefore, it can be used on mobile phones and personal computers also. It has the facility to fill the information offline also. The GeoFARMER app has been customized for the collection of baseline data in the ITC-BISA ***SGSK*** program. As per the outreach area of ITC's program, fifteen channels (Figure 10) were created for each of the project states, and more than 7000 farmers' baseline data was collected through the app. These channels have specific unique characteristics, such as language, geographical location, topics, and target communities. To understand the functionality of the app well, the virtual training was organized for the ITC Limited staff and their partners. The training session included the offline collection of survey data, synchronization during an internet connection, and the use of unique keys generated for individual farmers.

Figure 10 **GeoFarmer tool for data collection and monitoring**



Field Evidence of CSA Interventions

Implementation of SGSK-CSV practices and technologies showed promising impacts across all the project sites. Context-specific interventions based on climate risk and need assessment were implemented, resulting in a different package of practices across the three states of Madhya Pradesh, Rajasthan, and Maharashtra. The practices not only helped in achieving an increase in income and crop yields but also contributed to mitigation by decreasing the agricultural emission intensities. The impact of SGSK-CSV interventions is reported for key pillars of the Climate Smart Agriculture approach viz., change in the agriculture production (increase in yield and income), adaptation (change in the agriculture input use), and mitigation (emission reduction). More than 54000 farmers' crop yield data (Table 2) were analysed for the evaluation of outcomes of the CSV program during the last five years of the project. The largest number of data points were analysed from Madhya Pradesh and Rajasthan both having Soybean and Wheat crops.

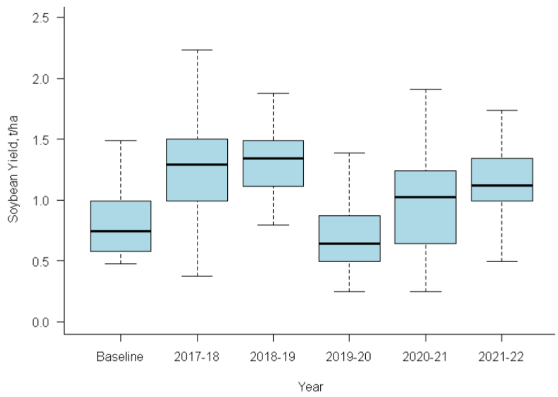
Crop-wise and state-wise assessments of key impacts of CSA interventions are presented below.

Madhya Pradesh

The prioritized CSA practices were demonstrated at the super champion, champion, and CSA farmers' fields in the project districts of the states over the last five years which has shown a significant increase in the crop yield, and income whereas a reduction in the emission over the baseline. The soybean and wheat yield data of more than 30000 farmers for the last five years were analysed to check the impact of the CSV program on productivity, income, resilience, and emission.

Soybean: The state has the largest area under soybean cultivation. An average of more than 2500 farmers were analysed to check the impact of CSA technologies on soybean production**.** Figure 11 shows the distribution pattern of soybean crop yield during baseline, and from 2017-18 until 2021-22 with the super champion, champion, and CSV farmers in Madhya Pradesh. The average yields of soybean in all districts significantly increased and distributions of yields (yield variations) during all the years were lower than baseline in the project area. Nevertheless, the results showed a significant increasing crop yield as well as reducing the yield variation among farmers due to the CSA interventions.

Figure 11 Distribution of soybean yields in Madhya Pradesh over the baseline (2016-17)



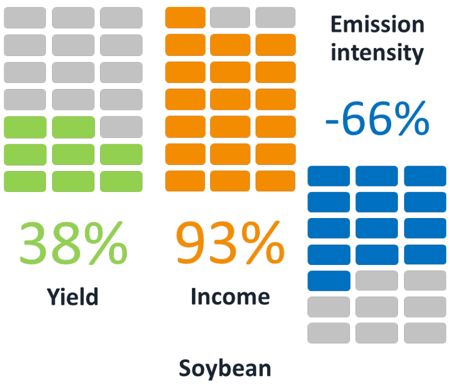
Changes observed in CSA indicators for soybean over time i.e., yield, income, and emission because of ***SGSK*** interventions in Madhya Pradesh are shown in Figure 12. The analysis builds over baseline and mid-line datasets carried out during the last six years of the project. The average change in yield and income of soybean was 38%, and 93% respectively over the baseline. A significant increase in soybean yield of 51%, 69%, 18%, and 50% were found during 2017-18, 2018-19, 2020-21, and 2021-22 respectively. Likewise, the average income was increased by 70% (2017-18),

Table 2 State and crop-wise number of data points analyzed from the project area for assessment of the impact of CSA interventions

	Baseline	2017-18	2018-19	2019-20	2020-21	2021-22	Total
Madhya Pradesh	556	597	805	10068	13587	4560	30173
Soybean	278	270	483	3582	4908	4560	
Wheat	278	327	322	6486	8679		
Maharashtra	84	103	84	121	36		428
Onion	84	103	84	121	36		
Rajasthan	505	865	3899	8264	10279		23812
Soybean	289	354	658	3829	4108		
Wheat	216	511	3241	4435	6171		

98% (2018-19), 32% (2019-20), and 82% (2020-21) over the baseline in the last five years. This indicates that CSA interventions are helping to improve crop yields as well as income in most farmers' fields in Madhya Pradesh. The CSV approach has resulted in a large reduction in emission intensity in Madhya Pradesh. The emission intensity at the time of baseline before the CSA interventions was 1.5 kg CO_2eq/kg crop yield which was reduced by 67% (0.52 kg CO_2eq/kg crop yield) during the last five years.

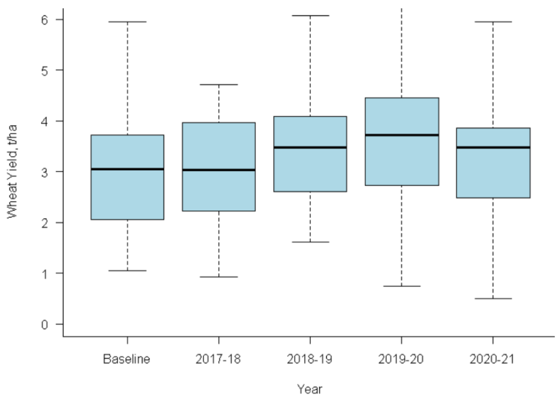
Figure 12 Percentage changes in yield, income, and emission intensity (kg CO_2eq/kg crop yield) (average change of six years from 2017 to 2022 over the baseline) for soybean crop over baseline in Madhya Pradesh



Wheat: Wheat is the major rabi crop across all districts of the state. Figure 13 shows the distribution pattern of wheat yield during baseline, and from 2017-18 until 2020-21 with the super champion, champion, and CSV farmers in Madhya Pradesh. The average yields of wheat in all districts significantly increased and distributions of yields (yield variations) during all four seasons were lower than baseline in the project area except in the year 2020-21. The results showed a significant increasing crop yield as well as reducing the yield variation among farmers due to the CSA interventions. One of the major CSA interventions was to change the seed varieties which helped the improvement of crop yield in the project area.

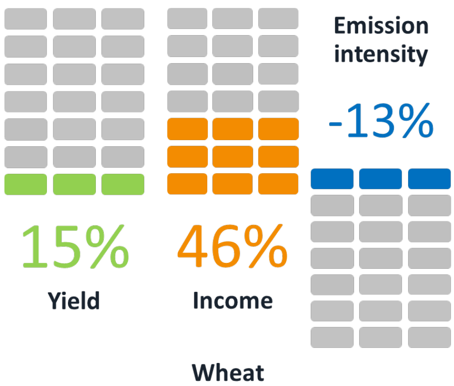
Changes observed in CSA indicators for wheat over time i.e., yield, income, and emission because of ***SGSK*** interventions in Madhya Pradesh are shown in Figure 14. The analysis builds over baseline and mid-line datasets carried out during the last five years of the project. The average change in yield and income of wheat was 15%, and 46% respectively over the baseline. A significant increase in wheat yield of 16%, 12%, 21%, and 13% was found during 2017-18, 2018-19, 2019-20, and 2020-21 respectively. Likewise, the average income was increased by 38% (2017-18), 47% (2018-19), 55% (2019-20), and 45% (2020-21) over the

Figure 13 Distribution of wheat yields over the baseline in Madhya Pradesh (2016-17)



baseline in the last five years. In addition, the effective use of nitrogen leads to an improvement in wheat yield. The average nitrogen use efficiency was found to be increased by 28% over the baseline during the last four seasons. This indicates that CSA interventions are helping to improve crop yields as well as income in most farmers' fields in Madhya Pradesh. Emission intensity in soybean cultivation was significantly reduced by 13% in all project villages in the state.

Figure 14 Percentage changes in yield, income, and emission intensity (kg CO_2eq/kg crop yield) (average change of five years from 2017 to 2021 over the baseline) for wheat crop over baseline in Madhya Pradesh

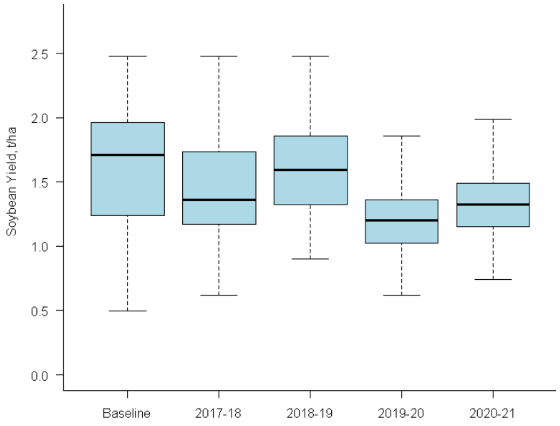


Rajasthan

The soybean and wheat yield data of more than 23000 farmers for the last five years were analysed to check the impact of the CSV program on productivity, income, resilience, and reduction in emission.

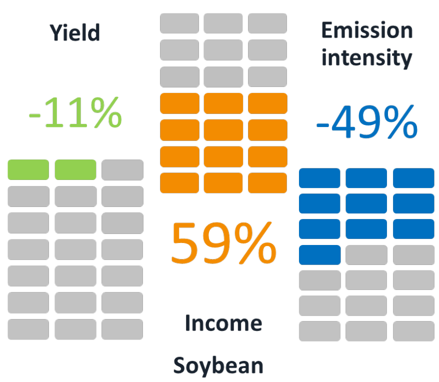
Soybean: Rajasthan is ranked third in terms of the largest area under soybean cultivation after Madhya Pradesh and Maharashtra. An average of more than 1800 farmers were analysed to check the impact of CSA technologies on soybean production in the state. Figure 15 shows the distribution pattern of soybean yield during baseline, and from 2017-18 until 2020-21 with the super champion, champion, and CSV farmers in Rajasthan. The soybean crop in the state was impacted due to the deficient rainfall which resulted in a decrease in soybean yield, nevertheless, the distributions of yields (yield variations) were lower than baseline in the project area expected during the year 2017-18.

Figure 15 Distribution of soybean yields over the baseline in Rajasthan (2016-17)



Changes observed in CSA indicators for soybean over time i.e., yield, income, and emission because of ***SGSK*** interventions in Rajasthan are shown in Figure 16. The analysis builds over baseline and mid-line datasets carried out during the last five years of the project. The average change in yield and income of soybean was -11%, and 59% respectively over the baseline. A minor decrease in soybean yield was observed because of high deficient rainfall during the monsoon season. Nevertheless, the average income of the farmer was increased over the baseline. This indicates that CSA interventions are helping the farmers to build resilience for the improvement in crop yields as well as income in Rajasthan. Likewise, in Madhya Pradesh, the CSV approach in Rajasthan has also resulted in a large reduction in emission intensity (CO_2 equivalent kg/

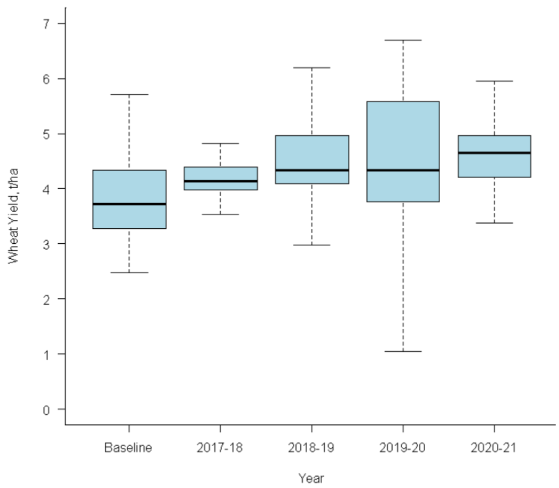
Figure 16 Percentage changes in yield, income, and emission intensity (kg CO2eq/kg crop yield) (average change of five years from 2017 to 2021 over the baseline) for soybean crops over base-line in Rajasthan



kg of soybean production). It was estimated that the emission intensity at the time of baseline before the CSA interventions was 0.9 kg CO_2eq/kg crop yield. The average emission intensity over the last four years was found to be 0.46 kg CO_2eq/kg crop yield. Thus, the project resulted in the reduction of emission intensity Emission intensity in soybean cultivation was significantly reduced by 49% in all project villages in the state.

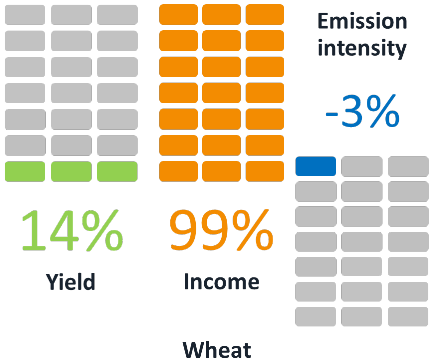
Wheat: Figure 17 shows the distribution pattern of wheat yield during baseline, and from 2017-18 until 2020-21 with the super champion, champion, and CSV farmers in Rajasthan. The average yields of wheat in all districts significantly increased and distributions of yields (yield variations) during all five seasons were found to mix representation i.e., lower than baseline in 2017-18 and 2020-21 in the project area. Many factors contributed to the improvement in the crop yield while one of the major CSA interventions was a varietal change in seed to help the improvement of crop yield in the project area.

Figure 17 Distribution of wheat yields over the baseline in Rajasthan (2016-17)



Changes observed in CSA indicators for wheat over time i.e., yield, income, and emission because of ***SGSK*** interventions in Rajasthan are shown in Figure 18. The analysis builds over baseline and mid-line datasets carried out during the last five years of the project. The average change in yield and income of wheat was 14%, and 99% respectively over the baseline. A significant increase in wheat yield of 8%, 15%, and 16%, was found during 2017-18, 2018-19, 2019-20, and 2020-21 respectively. Likewise, the average income was increased by 45% (2017-18), 199% (2018-19), 75% (2019-20), and 77% (2020-21) over the baseline in the last five years. This indicates that CSA interventions are helping to improve crop yields as well as income in most farmers' fields in Madhya Pradesh. Emission intensity in wheat cultivation was reduced by 3% in all project villages in the state. The use of nitrogen content fertilizers was increased which resulted in less reduction in the emission intensity over the baseline. It has been observed that the nitrogen use efficiency was reduced by 22% over the baseline.

Figure 18 Percentage changes in yield, income, and emission intensity (kg CO2eq/kg crop yield) (average change of four years from 2017 to 2021 over the baseline) for wheat crop over baseline in Rajasthan



Maharashtra

Onion is one of the major cash crops grown in Maharashtra. The short duration crop needs a specific portfolio of CSA interventions which were demonstrated at the super champion, champion, and CSA farmers' fields over the last five years which has shown a significant increase in the crop yield, and income over the baseline across all the project districts of the states. The onion yield data of more than 400 farmers for the last four years were analysed to check the impact of the CSV program on productivity, income, resilience, and reduction in emission.

Onion: Figure 19 shows the distribution pattern of onion yield during baseline, and from 2017-18 until 2020-21 with the super champion, champion, and CSV farmers in Maharashtra. The average yields of onion in all districts significantly increased and yield variations during all four seasons were vary with baseline in the project area. The results showed a significant increasing crop yield as well as reducing the yield variation among farmers due to the CSA interventions. The CSV practices contributed positively to increasing and stabilizing the income of onion growers in the state.

Changes observed in CSA indicators for onion crops over time i.e., yield, income, and emission because of ***SGSK*** interventions in Maharashtra are shown in Figure 20. The analysis builds over baseline and mid-line datasets carried out during the last five years of the project. The average change in yield and income of onion was 22%, and 38% respectively over the baseline. A significant increase in onion yield of 27%, 18%, 25%, and 19% was found during 2017-18, 2018-19, 2019-20, and 2020-21 respectively. Likewise, the average income was increased by 41% (2017-18), 110% (2019-20), and 26% (2020-21) over the baseline in the last five years. The average income in the year 2018-19 decreased by 24% because of a drastic reduction in the market prices of onion crops. The onion market rate during the baseline was Rs. 1607 per quintal while it dropped to around Rs. 717 per quintal in 2018-19. This shows the importance of considering market risk apart from increasing farm productivity and resilience. Overall, the CSA interventions are helping to improve crop yields as well as income in most farmers' fields in Maharashtra. Emission intensity in onion cultivation was significantly increased by 69% in all project villages in the state. It was estimated that the emission intensity at the time of baseline before the CSA interventions was 0.05 kg CO_2eq/kg crop yield. The average emission intensity over the last four years was found to be 0.064 kg CO_2eq/kg crop yield.

Figure 19 Distribution of onion yields over the baseline in Maharashtra (2016-17)

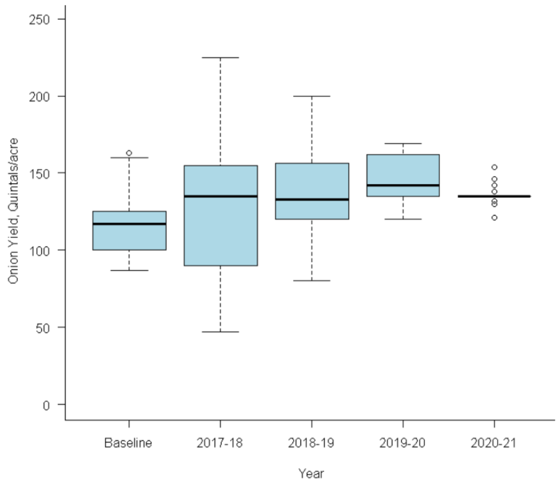
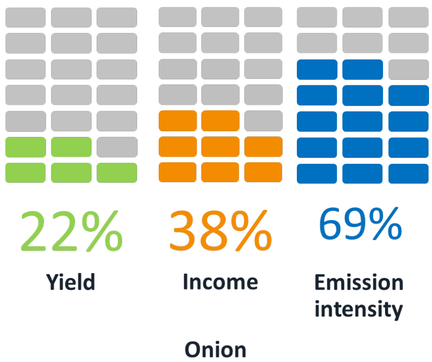


Figure 20 Percentage changes in yield, income, and emission intensity (kg CO2eq/kg crop yield) (average change of four years from 2017 to 2021 over the baseline) for onion crop over baseline in Maharashtra



Summary

The analysis presented above shows the salient findings of the BISA-ITC project "Increasing Adaptive Capacity of Farmers to Climate Change through Climate-Smart Villages in India" for the past five years in project sites located in Maharashtra, Madhya Pradesh, and Rajasthan. These findings are reported for key pillars of the Climate Smart Agriculture approach viz., adaptation (increase in yield and income) and mitigation (emission reduction). The analysis builds over baseline and mid-line datasets carried out during the earlier phase of the project. Significant average yield and income increase were observed over the baseline with some minor exceptions during extreme weather risks. High emission reduction was achieved through CSV practices in all the states except onion in Maharashtra. We also evaluated the resilience effect by analyzing the time series crop yields for the project farmers. The coefficient of variation (CV) of yield for five to six years after the project's inception was analyzed. The CV of yield for soybean and wheat in Madhya Pradesh was 20% and 3 %, respectively against district-level yield variability of 25% and 13% during the same period. For Rajasthan, the CV of yield for soybean and wheat was 12% and 3%, respectively against the district yield variability of 40% and 6% during the same period. The CSA interventions show initial signs of increased yield stability; however, the length of data is not sufficient to make a concluding remark on it.

The collection of the baseline data, crop input, and yield data for the 2005 villages in the 12 states are in the process which will be analyzed for the key pillars of the Climate Smart Agriculture approach viz., change in the agriculture production (increase in yield and income), adaptation (change in the agriculture input use) and mitigation (emission reduction).

ITC-BISA SGSK Stakeholder Consultation/Prioritizations Workshop

The SGSK Climate-Smart Villages program is being scaled up in fifteen states of ITC's outreached area. After selection of the project villages and collection of baseline information, the Bihar and Assam team of ITC Limited conducted the Stakeholder Consultation Workshop for the prioritization of CSA technologies on 3rd March and 23rd March 20201 respectively. The workshop aimed to create a platform for a diverse group of stakeholders like farmers, NGO representatives, technical institute representatives, government officials, and private sectors player to share their experiences on the ***SGSK*** approach and interventions that will enable the community to increase their resilience to climate change, conserve natural resources, and to strengthen capacities of farming communities for the better livelihood opportunities and enhance the agriculture productivity. BISA team participated in the consultation workshops and shared their experiences of the ITC-BISA partnership in the last six years and ***SGSK*** works across ITC's project area and the BISA-CIMMYT-CCAFS works in South Asia.

B) Development of Adaptation Strategies to Climate Change

One of the important aspects of the project was to develop the adaptation strategies for managing current and future climatic risks in agriculture for the three states i.e., Rajasthan, Madhya Pradesh, and Maharashtra. BISA-ITC together with all the relevant stakeholders prepared a guiding framework for developing adaptation strategies to manage current and future climate risks to agriculture in Maharashtra, Rajasthan, and Madhya Pradesh. The adaptation strategies were designed based on a participatory process and included stakeholders' from SAUs, the private sector, NGOs, farmers' groups, and policymakers. Participatory process and web-based survey capture stakeholders' views on prioritized location-specific climate-smart interventions, their implementation feasibility, and consideration of potential adoption barriers and key incentive mechanisms and institutions required to promote the CSA technologies. We have used a six-step approach which included preparation of a long list of CSA technologies, prioritization, and characterization of technologies, checking their implementation feasibility, reprioritizing the technologies based on their performance and feasibility index, and the development of crop and region-specific portfolio of CSA technologies. This hybrid approach, combining participatory prioritization and scientific analysis of data and literature, is used to identify crop and district-specific portfolios of technological interventions and climate services to strengthen CSA. Participatory prioritization of technologies for various agro-climatic regions is based on a multi-criteria decision-making framework. This was done by stakeholders including researchers of SAUs, the private sector, NGOs, farmers' groups, and policymakers based on their expert knowledge and judgment about their on-ground performance in terms of productivity, climate risk reduction, and mitigation potential. These are further assessed for their implementation feasibility in the state. A CSA index helped in identifying the top technologies that could be scaled out in different regions and for different crops to strengthen resilience.

Consultation Workshops

The development of the adaptation strategies involved a six-step approach which included preparation of a long list of CSA technologies, prioritization, characterization of technologies, checking their implementation feasibility, reprioritizing the technologies based on their performance and feasibility index, and development of crop and region-specific portfolio of CSA technologies. To collect the ground base information and prioritize the CSA technologies, virtual stakeholder workshops were organized for all three states where a web-based survey was introduced and asked the participants to fill up the survey questionnaire for the crop, livestock, and fishery from their respective areas. For the systematic collection of information, the web-based survey was divided into subsections like baseline, technology characterization, technology implementation feasibility, and technology suitability. More than 250 stakeholders including

Figure 21 Type of stakeholders by profession

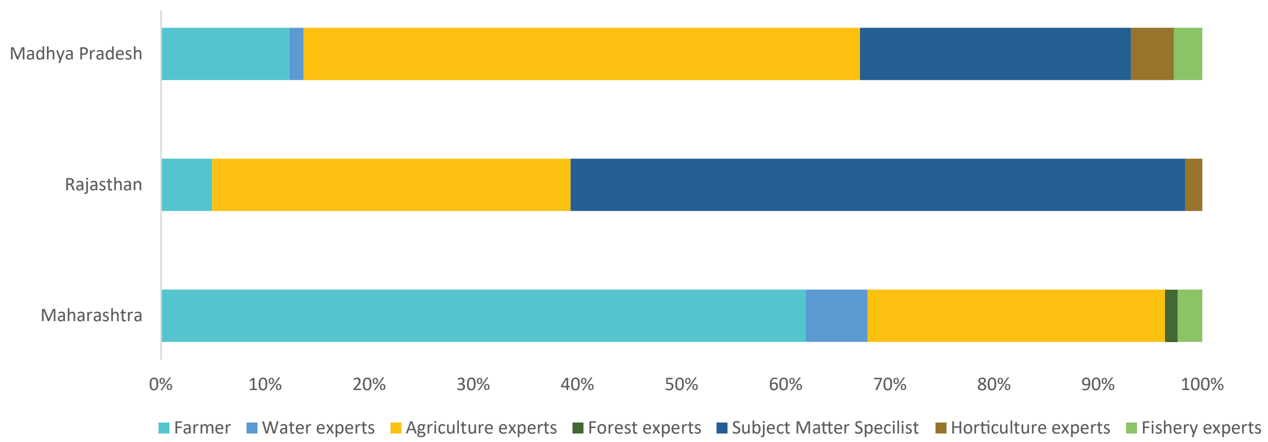


Figure 22 Details of stakeholders participated in the workshop

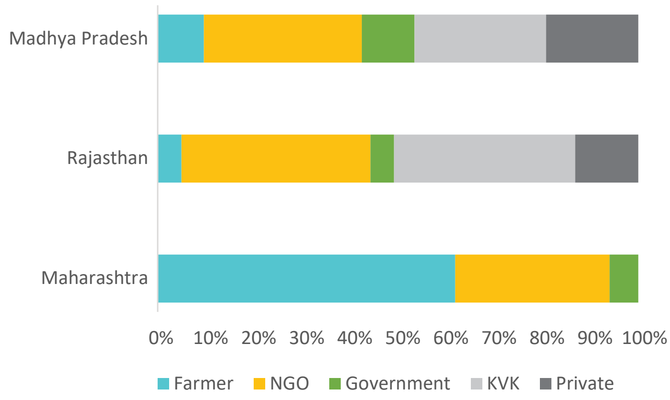
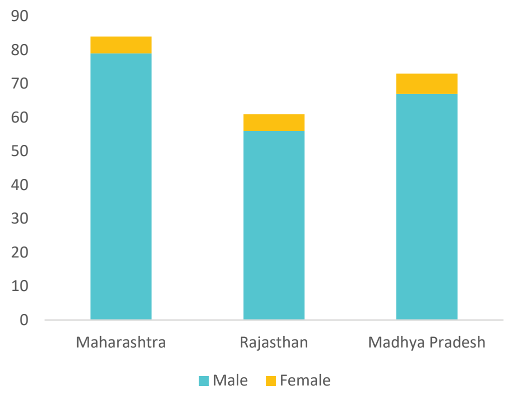


Figure 23 Women's participation in the workshop

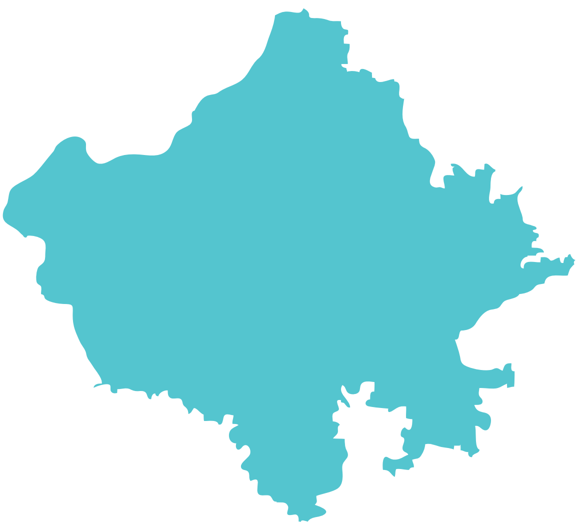


researchers of SAUs, the private sector, NGOs, farmers' groups, and policymakers attended the stakeholder workshop (Figure 21) and about 218 participants have filled up the web-based survey and submitted it online. Positive participation from the diverse group of experts like farmers, subject matter specialists from the KVKs, agriculture experts from NGOs, and government departments was found in the workshop (Figure 22) as well as in the online survey whereas very less participation of female experts was seen (Figure 23).

These participants' responses were further assessed for their implementation feasibility in the state considering cost, inclusivity, resource requirement (finance and machinery), farmers' knowledge and acceptability, extension service, and synergy with government plans. This hybrid approach, combining participatory prioritization and scientific analysis of data and literature, was used to identify crop and district-specific portfolios of technological interventions and climate services to strengthen CSA.

Adaptation Strategies for Rajasthan

State agriculture is highly vulnerable to climatic risks. The climate of Rajasthan is characterized by low and erratic rainfall, extreme temperatures, low humidity, and high wind velocity. While analyzing the last 102 years of climate data since 1901, 48 drought years of varied intensity were found. (Rathore, 2004). The intensity and frequency of drought in the last 30 years (1990 to 2019) in Rajasthan using a simplified drought index were analyzed by Rathore, 2004. The probability of witnessing drought is 42% whereas getting severe and very severe drought is also high (34%) in the state compared to the rest of India. Persistent long dry spells are often common; the maximum length of a dry spell for June to October varies from 34 days in eastern Rajasthan to 54 days in the west. Rajasthan experiences a maximum number of heatwaves in the country (Singh and Patwardhan, 2012). The state has witnessed statistically significant increasing trends in heatwaves of 3-day, 5-day, and 10-day duration. Heatwaves and hot days can lead to occurrences of terminal heat events for rabi crops. In Rajasthan, the northern wheat belt districts (Ganganagar and Hanumangarh) witness the longest heatwave duration from March to May. Heatwave duration is highest in



the northern part of Rajasthan while the number of hot days is highest in the eastern part from March to May. The impacts of concurrent droughts and heatwaves could be more serious compared to their occurrence, fortunately, the percentage changes in concurrent moderate droughts (SPI < -1.3) and heatwaves are decreasing in the state during 1981–2010 concerning the base period 1951–1980 (Sharma and Mujumdar, 2017).

A stakeholder survey was conducted to understand the perception of the local stakeholders (including farmers) on weather-related risks, their frequency, and their impact on major crops. The stakeholders were ranked top ten weather-related risks by crop/ season are drought, flood, hailstorm, excess rainfall, untimely rainfall, delayed monsoon, deficit rainfall, dry spells, high temperature, and low temperatures. The frequency of experiencing these events more frequently – every year or every two years. Such perception of farmers is in line with the measured weather data and their trends. In the livestock sector, high temperature is the prominent risk reported by the respondents followed by drought and low temperature. About 9% of respondents reported floods and 3% reported hailstorms as climate risks in Rajasthan for the livestock sector. Drought risks translate to fodder shortage; reduced grazing and pastures impacting both farmers having livestock as well as nomads.

CMIP6 projections indicate an increase in mean temperature of 2.05 ˚C (1.5 ˚C to 4.2 ˚C) by 2050 and 3.3 (1.5 ˚C to 7.5 ˚C) by 2080 in Rajasthan. This increase in temperature is on the slightly higher side compared to India's national average. The increase in temperature is more in the winter months. Regionally, Western Rajasthan has a higher increase in temperature than North-East and South Rajasthan. District-wise changes show the highest increase in temperature are found in Jaisalmer, Jodhpur, Bikaner, Barmer, Sri Ganganagar, Hanumangarh, and Churu districts. CMIP6 projections indicate an increase in annual rainfall of 12.98 % (5.25 to 32.19 %) by 2050 and 22.5% (0 to 70%) by 2080 in Rajasthan. The increase in rainfall is more in the winter months. Southwestern Rajasthan has a higher increase in precipitation. District-wise rainfall changes show the highest increase in Jaisalmer, Barmer, Jalor, Udaipur, Sirohi, Dungarpur, and Banswara districts.

In addition, the GHG emissions from Rajasthan have increased from 82 million tons of CO_2 EQ in 2005 to 138 million tons of CO_2 EQ in 2015. It accounts for around 5.6% of total emissions in India. The energy sector causes the highest emissions in the state, followed by Agriculture, Forestry, and Other Land Use (AFOLU) sectors. However, in terms of share in India's sectoral emissions, it is the Industrial Product and Process Use sector of Rajasthan that is responsible for around 13% of emissions from this sector at the all-India level. This is followed by AFOLU (9.7%). Rajasthan has the second-largest livestock population of 56.8 M in the country. The total methane emission from Indian livestock, which includes enteric fermentation and manure management, was ~20 Mt CO_2 EQ in 2015. Dairy buffalo and indigenous dairy cattle together contribute 60% of the total methane emission. Rajasthan contributed 9.1% of India's total livestock emissions.

Considering the climatic risk and its impact on agriculture and livelihood, Rajasthan state has developed multi-sector State Adaptation Plans for Climate Change in 2010. The recommendations suggested in the plan for agriculture were generic and lacked sub-regional actionable items. To address the gap in the existing adaptation plan, adaptation strategies for state agriculture have been developed. Therefore, a stakeholder consultation workshop was organized for the prioritization of CSA technologies in Rajasthan. The exercise of participatory prioritization of CSA technologies was done twice for the Rajasthan state. The top 21 technologies prioritized by the stakeholder consultation from a long list of more than 200 technologies are water-smart technologies like water management, micro-irrigation, BBF/ ridge, and furrow planting, a system of rice intensification, direct-seeded rice, seed, and breed smart technologies like improved crop varieties, fodder development, stress-tolerant and high-yielding breeds of livestock, carbon smart technologies like agroforestry, conservation agriculture practices, knowledge smart technologies like line sowing, pest and disease management, crop diversification, post-harvest management, farm mechanization, concentrated feeding in livestock and goat, co-benefits of ICT linked precision management of water and nitrogen, weather smart technologies like crop insurance, contingent crop planning/ ICTs, climate-smart housing for livestock, and nutrient smart technology like integrated plant nutrient management.

After prioritization of CSA technologies, we have determined the risk status of key Rajasthan crops by analyzing the historical district-level data for intensity and frequency of yield loss. Based on the risk category, we propose yield promoting, risk mitigation, risk coping, and risk transfer strategies that should be encouraged to strengthen resilience in the state. Table 3 below shows crop area distribution according to risk intensity and frequency category and corresponding adaptation strategies.

Table 3 Summary of crop risk matrix and adaptation strategies based on the risk exposure for Rajasthan

	Very low intensity		Low intensity		Medium intensity		Hight intensity
High frequency	**Area (%):** Bajra (3), Mustard (2), Minor pulses (0.3), Maize (26), Groundnut (6), Medicinal and Aromatic Plants (0.7), Urad (14), Rice (20), Vegetables (35) Sesamum (83), Chickpea (7) **Area: 1.0 M ha**	**Adaptation Strategy:** Location-specific adaptation/ risk reduction technologies; scale-up insurance coverage bundled with technologies; greater use of ICT-linked input management; added GHG co-benefits of interventions.	**Area (%):** Bajra (33), Gaur (70), Wheat (3), Mustard (5), Moong (82), Minor pulses (57), Moth (72), Soybean (87), Maize (33), Seed spices (32), Kharif sorghum (93), Cotton (100), Groundnut (12), Medicinal and Aromatic Plants (8), Urad (58), Rice (25), Vegetables (13), Fruits (17), Sesamum (13), Chickpea (29) **Area: 12.4 M ha**	**Adaptation Strategy:** Location-specific adaptation/risk reduction technologies; scale-up insurance coverage bundled with technologies; greater use of ICT-linked input management; added GHG co-benefits of interventions.	**Area (%):** Bajra (32), Gaur (23), Wheat (0.8), Moong (13), Minor pulses (8), Moth (21), Seed spices (9) Area: 3.06 M ha	**Adaptation Strategy:** Diversify to non-agriculture or livestock options; insurance is expensive and hence not suitable, expand individual and community social safety measures.	
Medium frequency	**Area (%):** Bajra (7), Gaur (0.3), Wheat (18), Mustard (52), Minor pulses (4), Soybean (13), Maize (10), Seed spices (10), Kharif sorghum (7), Groundnut (40), Medicinal and Aromatic Plants (70), Rice (14), Vegetables (2), Fruits (49), Chickpea (44) **Area: 3.76 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Bajra (6), Gaur (5), Moong (5), Minor pulses (29), Moth (7), Maize (19), Seed spices (2), Groundnut (3), Urad (28), Vegetables (4), Fruits (7), Chickpea (6) **Area: 2.25 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.			
Low frequency	**Area (%):** Bajra (11), Gaur (0.1), Wheat (43), Mustard (29), Minor pulses (1), Maize (12), Seed spices (8), Groundnut (2), Medicinal and Aromatic Plants (9), Rice (40), Vegetables (14), Chickpea (13) **Area: 3.09 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Seed spices (0.1), Medicinal and Aromatic Plants (2), Vegetables (0.7), Fruits (5) **Area: 0.013 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.			
Very low frequency	**Area (%):** Bajra (5), Wheat (36), Mustard (11), Minor pulses (0.4), Seed spices (39), Groundnut (37), Medicinal and Aromatic Plants (10), Rice (1), Vegetables (31), Fruits (22), Chickpea (1) **Area: 2.36 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.					

We have also investigated how the proposed strategies could be linked with the current development schemes of the Government to minimize the need for new resources. The analysis led to the following eight recommendations for building resilience in agricultural systems in Rajasthan.

1. ***Promote greater coverage of climate-smart technologies***. Several technologies such as improved crop varieties for stress tolerance, micro-irrigation systems, crop diversification, conservation agricultural practices, and agroforestry complemented with weather forecasts linked to agro. advisories at microscale and agriculture insurance can greatly help Rajasthan state in minimizing the negative impacts of climatic risks on agriculture systems. Adoption of most of the proposed interventions is in less than 40% area at present. Implementing a Climate-Smart Village approach, which integrates many of these technologies and maximizes synergies between them, will be very rewarding to build resilience in the agricultural systems of Rajasthan. The technologies were further targeted by using a classical risk analysis using historical yield loss intensity and frequency of various crops in all districts. The technology options for yield growth, adaptation/risk reduction, risk transfer, and GHG mitigation are proposed for scaling or crop-district combinations based on the risk status as summarized in the attached figure. These interventions can be scaled up further by aligning them with the current development schemes of the state.

2. ***Re-strategize the crop insurance program for increasing its effectiveness and efficiency.*** There is a need to reconsider crop insurance strategy in the state. Under the PMFBY scheme of highly subsidized crop insurance, Rajasthan today has coverage of less than 50 % farmers/area but must spend almost about 1800 crores per year as a premium. This is a large share of the state agriculture budget constraining other development schemes. In high-risk regions such as districts of Jaisalmer, Barmer, and Jalore, insurance is less remunerative because of high premiums. It will be useful to use the insurance subsidy for promoting the diversification of livestock or non-agri. options and to develop and scale innovative individual and community social safety nets. In medium-risk districts insurance should be bundled with yield growth and adaptation/risk reduction strategies such as those encouraging use of high-yielding seeds, irrigation, and fertilizer management strategies that can increase use efficiency. In low-risk regions, instead of a generic crop insurance scheme, it would be better to have only specific insurance products for emerging risks from hailstorms, frost, unseasonal rainfall, and floods.

3. ***Accelerate development, dissemination, and use of weather forecasts linked to value-added agro advisories.*** To manage increasing climate variability greater availability of demand-driven and downscaled weather information in the language and dialect understood by the people of the state will be important. The government of Rajasthan should consider developing long-term partnerships with weather services providers and private sector players for creating value-added agro advisories tailored for individual farmer situations and linked with real-time high-resolution weather forecasts.

4. ***Intensify development and deployment of climate risk-specific high yielding/stress-tolerant seeds/breeds.*** Given the high climatic risks in Rajasthan state, it is important to deploy the cultivation of seeds of varieties that are tolerant/resistant to drought/deficit rainfall situations in high-risk areas. Most farmers continue to use farm-saved seeds as indicated by a low seed replacement ratio (25-40%) and large yield gaps (almost 50%) in crops especially pulses, oilseeds, and seed spices. Encouraging the model seed village concept could be rewarding in quickly increasing the seed replacement ratio in the state.

5. ***Increase the water use efficiency in Rajasthan agriculture.*** Rajasthan has the maximum area under micro-irrigation, but the penetration rate is still lower in areas other than North Rajasthan. Most of the micro-irrigation coverage achieved in Rajasthan is through sprinkler systems under cereals and oilseeds. Micro-irrigation penetration needs to be increased across the state. Besides the use of sprinklers emphasis should be given to bringing horticulture and vegetables under more efficient drip irrigation systems. Micro-irrigation systems must be bundled with schemes such as solar irrigation pumps, farm ponds, diggi, etc. to maximize water use and economic returns.

6. ***Promote diversification of agriculture for increasing income and for strengthening resilience.*** Depending upon the climatic risk of the region, cropping history, and emerging market opportunities it is important to consider diversification to alternate agriculture systems. Jaisalmer, Barmer, and Jalore are in the high-risk

category for most crops. In such areas, it is useful to consider diversification of at least a part of the land to livestock, sheep and goatery, agroforestry, and options outside agriculture, if viable. Development of pastures and grazing lands, wherever possible, should be one of the priorities for Rajasthan state in addition to altering breed composition, and providing insurance to small ruminants against climatic stresses. Rajasthan produces a lot of seed spices (Ajwain, Coriander, Cumin, etc.), and medicinal plants such as Isabgol, and Guar gum. Crop diversification through seed spices and medicinal and aromatic plants as alternative crops can provide more economic returns to farmers of Rajasthan.

7. ***Need to develop international partnerships to manage the increasing risks of transboundary pests.*** Widespread desert locust attacks in Rajasthan and neighbouring Indian states in recent years have caused devastating losses and hence affected food and livelihood security. Similar problems occurred simultaneously in Pakistan, Afghanistan, the middle east, and eastern Africa. It is imperative for the concerned governments of the region to put in place an early warning system based on pest surveillance and forecasting methods.

8. ***Explore opportunities for reducing GHG emissions from the livestock sector.*** Rajasthan agriculture emits GHG emissions amounting to ~25 MT Co2 EQ. These emissions are predominantly from the livestock sector. Carbon smart technologies like biogas, green fodder supplements, feed management, etc. can be implemented to reduce GHG emissions from livestock-based production systems. However, considering that most livestock is a part of individual households and a large fraction of them are in medium to high-risk regions, it is not easy to strategize for GHG reduction. This may become possible if GHG reduction from livestock is monetized by the state governments or GHG reduction could be monitored, aggregated, reported, and verified for sale in carbon markets.

Adaptation Strategies for Maharashtra

Maharashtra has 52% of area comes under drought prone. Despite having a good average monsoon rainfall in the state, it faces climatic risks like drought, heavy floods in the coastal area, erratic rainfall, long dry spell, and high temperature during summer. The changes in the climate adversely affect the agriculture productivity, livestock productivity, and livelihood of the rural community. Recent studies suggest that out of 36 districts, 11 districts (Central Maharashtra Plateau Zone) of Maharashtra states are highly vulnerable, and 14 are moderately vulnerable (Central and Eastern Vidarbha Zone) whereas 9 districts are less vulnerable to climate change (Adhav et al., 2021). The intensity and frequency of drought in the last 30 years (1990 to 2019) in Maharashtra using a simplified drought index were analysed by Rathore, 2004. The central region, north-eastern region, and some spot in the western region of the state has shown the highest probability of occurrence of severe droughts.

Maharashtra experiences erratic and extreme rainfall during the Kharif season. The coefficient of variation of rainfall and rainy days during the Kharif are high compared to the rest of the country indicating a higher degree of uncertainty. Large variability in rainfall was observed in many districts, particularly in Pune, Ahmednagar, Satara, Nandurbar, Solapur, Osmanabad, and Hingoli districts. The coefficient of variation on rainy days is more in central Maharashtra and Marathwada region. This uncertainty is further compounded by the distribution issues. Several incidents of prevented sowing in Kharif because of early-season drought or crop failure are reported. The incidents of prolonged dry spells also follow a similar pattern of rainy days. The prolonged dry spells in rainfed areas result in either partial or total crop loss in the region resulting in highly volatile returns. Similarly, there is also a high risk of untimely and extreme rains are also cause of concern in the region. Changing climate is expected to further exacerbate these variabilities and reduction in agricultural production, affecting rural livelihoods.

We conducted a survey (n=96) to understand stakeholders' perceptions (including farmers) on weather-related risks and their impact on major crops in Maharashtra. Top-ten weather-related risks experienced by the respondents are drought, flood, hailstorm, excess rainfall, untimely rainfall, delayed monsoon, deficit rainfall, dry spells, high temperature, and low temperatures. In the livestock sector, high temperature is the prominent risk reported by the respondents (n=22) followed by drought and hailstorms. Several instances of loss of livestock animals because of floods and hailstorms are reported in Maharashtra. Surprisingly, about 8 % of respondents felt low temperature as a risk. About 18% of respondents reported hailstorms and 2% reported floods as climate risks in Maharashtra for the livestock sector. Drought risks often translate to fodder and water shortage resulting in increased demand for fodder banks or desperate selling of livestock.

CMIP6 projections indicate an increase in mean temperature of 1.9° C (1.2° C to 4.1° C) by 2050 and 3.6° C (1.2° C to 8.3° C) by 2090 in Maharashtra. Regionally, North-western, central part, and some sports of north-western Maharashtra have a higher increase in temperature than East and South Maharashtra. District-wise changes show the highest increase in temperature are found in Nandurbar, Dhule, Jalgaon, Nashik, Ahmednagar, Pune, Sangli, and Solapur districts. CMIP6 projections indicate an increase in annual rainfall of 16% (1 to 43.7 %) by 2050 and 21% (5.7 to 102%) by 2090 in Maharashtra. North-western, central, and southern parts of Maharashtra have a higher increase in precipitation. District-wise rainfall changes show a significant increase in Nandurbar, Dhule, Nashik, Jalgaon, Jalgaon, Beed, Osmanabad, Latur, Raigarh, Akola, Solapur, Washim, and Hingoli districts. Whereas the north-eastern part of Maharashtra and Kolhapur district of south Maharashtra has shown a decrease in rainfall.

To address the effect of changing climate on agriculture and livelihood, the Maharashtra State developed the State Action Plan on Climate Change in 2014, providing several strategic action items for the agriculture sector, aimed at reducing the sector's vulnerability to climate risks and building its resilience. It focused on building farming systems resilience through diversified cropping patterns, soil conservation, and value addition. While these recommendations are important, there is a need to determine more specific subregional actionable items. Therefore, the adaptation strategy for agriculture has been developed for the state. To find out the location-specific climate-smart agriculture technologies, a stakeholder consultation workshop was organized for the prioritization of CSA technologies in Maharashtra. The hybrid approach, like combining stakeholder consultation workshops for participatory prioritization and scientific analysis of data and literature, is used to identify crop and district-specific portfolios of technological interventions and climate services to strengthen CSA. These are further assessed for their implementation feasibility in the state. A CSA index helped in identifying the top 21 technologies that could be scaled out in different regions and for different crops to strengthen resilience are water-smart technologies like water management, micro-irrigation, solar pumps for irrigation, BBF/ ridge and furrow planting, direct-seeded rice, seed and breed smart technologies like improved crop varieties, fodder development, stress-tolerant and high-yielding breeds of livestock, carbon smart technologies like agroforestry, conservation agriculture practices, knowledge smart technologies like pest and disease management, crop diversification, post-harvest management, farm mechanization, concentrated feeding in livestock and goat, co-benefits of ICT linked precision management of water and nitrogen, weather smart technologies like crop and livestock insurance, contingent crop planning/ ICTs, climate-smart housing for livestock, and nutrient smart technology like integrated plant nutrient management.

After prioritization of CSA technologies, we have determined the production risk status of key crops by analysing the historical district-level data for intensity and frequency of yield loss. Based on the production risk category, we propose yield promoting, risk mitigation, risk coping, and risk transfer strategies that should be encouraged to strengthen resilience in agriculture systems in the state.

Table 4 Summary of crop risk matrix and adaptation strategies based on the risk exposure for Maharashtra

	Very low intensity		Low intensity		Medium intensity		Hight intensity
High frequency	**Area (%):** Oilseed (2), Cotton (10), Soybean (3), Rabi sorghum (1), Chickpea (8), Rice (22), Wheat (2), Minor pulses (5), Sugarcane (32), Groundnut (21), Linseed (10) **Area: 1.69 M ha**	**Adaptation Strategy:** Location specific adaptation/ risk reduction technologies; scale up insurance coverage bundled with technologies; greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Oilseed (80), Cotton (38), Soybean (81), Rabi sorghum (52), Chickpea (21), Rice (26), Pigeon pea (87), Wheat (27), Maize (19), Minor pulses (83), Sugarcane (19), Pearl millet (56), Kharif sorghum (91), Groundnut (38), Finger millet (42), Safflower (84), Sunflower (64), Sesamum (100), Linseed (71), Castor (54), Rapeseed and mustard (100) **Area: 14.2M ha**	**Adaptation Strategy:** Location specific adaptation/ risk reduction technologies; scale up insurance coverage bundled with technologies; greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Bajra (32), Gaur (23), Wheat (0.8), Moong (13), Minor pulses (8), Moth (21), Seed spices (9) **Area: 3.06 Mha**	**Adaptation Strategy:** Diversify to non-agriculture or livestock options; insurance expensive and hence not suitable, expand individual and community social safety measures.	
Medium frequency	**Area (%):** Oilseed (5), Cotton (25), Soybean (0.3), Rabi sorghum (5), Chickpea (32), Rice (25), Pigeon pea (2), Wheat (29), Maize (59), Minor pulses (10), Sugarcane (17), Pearl millet (25), Kharif sorghum (9), Groundnut (9), Finger millet (30), Safflower (17), Sunflower (3) **Area: 3.96 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Oilseed (7,), Cotton (13), Rabi sorghum (40), Chickpea (5), Pigeon pea (10), Wheat (9), Maize (16), Pearl millet (19), Groundnut (8), Sunflower (33) **Area: 2.72M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.			
Low frequency	**Area (%):** Oilseed (3), Cotton (5), Rabi sorghum (2), Chickpea (32), Rice (13), Wheat (28), Maize (1), Minor pulses (4), Sugarcane (17), Groundnut (23), Linseed (20) **Area: 1.73 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.					
Very low frequency	**Area (%):** Oilseed (2), Cotton (9), Chickpea (2), Rice (13), Wheat (5), Maize (4), Minor pulses (2), Sugarcane (15), Finger millet (28) **Area: 0.9 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.					

We have also investigated how the proposed strategies could be linked with the current development schemes of the Government to minimize the need for new resources. The analysis led to the following eight recommendations for building resilience in agricultural systems in Maharashtra.

1. ***Developing a real-time Early Warning System linked with ICT services for monitoring and mitigating agrarian distress.*** Maharashtra state regularly faces extreme weather variability and hence frequent episodes of crop yield losses as well as surplus production both leading to agrarian distress. Maharashtra government and the private sector have set up more than 2000 weather stations all over the state. This infrastructure, together with the increasing availability of downscaled satellite weather must be utilized efficiently and effectively to provide all stakeholders with demand-driven and downscaled weather information and value-added agro-advisories in the language and dialect understood by the people of the state. The current approach of the Maharashtra Project on Climate Resilient Agriculture (PoCRA) using hyper-local data in the Marathwada and Vidarbha region should be expanded to the whole of Maharashtra after a due third-party independent audit. Such ICT approaches and data should also be used to set up early warning systems of water deficiency, water surplus, crop production deficits, likely crop surplus production, and market prices to enable Government, farmers, industry, and other stakeholders to take timely appropriate preventive and corrective actions. The government of Maharashtra should consider developing a long-term partnership with private sector weather services and agro-advisory providers for evolving such early-warning systems.

2. ***Management of extremely heavy rainfall events and their impact on agriculture and the agricultural value chain.*** The recent past has witnessed several very heavy rainfall events all over Maharashtra which cause significant loss in agriculture production and livelihoods. Urgent attention is needed from all stakeholders to take proactive actions to manage such effects on the whole agricultural value chain including production, transport, storage, and marketing. Increased availability of spatial weather and infrastructure data, and big data analytics could greatly support such management by increased understanding of real-time demand and supply of commodities, and identification of optimal storage locations, transport routes, etc to match these.

3. ***Targeting insurance and risk financing.*** Under the PMFBY scheme of highly subsidized crop insurance, Maharashtra today has coverage of 14.6 million farmers covering 7.9 million hectares of land. The premium load for Maharashtra at today's coverage is about 6348 crores of rupees of which Maharashtra state share is about ~2700 crores rupees per year. To increase the efficiency and effectiveness of the insurance program a different strategy based on risk exposure is needed. In high-risk areas, such as soybean growing districts of the Aurangabad region, insurance is costly. The subsidy here would be better utilized by encouraging diversification and by developing and scaling innovative individual and community social safety nets. In the medium-risk category, the largest area in the state, it is useful to develop novel insurance products that can be bundled with yield growth and adaptation/risk reduction strategies such as those encouraging use of high-yielding seeds, irrigation, and fertilizer management strategies. In low- and very low-risk regions, an option for consideration for the state government is not to have a generic and comprehensive insurance scheme but rather to opt for only local, specific insurance products for emerging risks from a hailstorm, frost, unseasonal rainfall, and floods. Improved products targeted to cover climate risks experienced by livestock farmers and fishers in various agro ecologies are also required.

4. ***Shifting to long-term climate risk management planning and implementation using dynamic land use and contingency planning.*** Several steps are taken by the government to provide relief to farmers when exposed to climatic extremes, but these measures provide only short-term relief. A long-term scientific climate risk management plan including land use plan, water management, and contingency planning, linked to financial resources available, is the need of the hour. Implementing a Climate-Smart Village approach, which integrates many of these technologies and maximizes synergies between them, will be very rewarding to build resilience in the agricultural systems of Maharashtra. The portfolios of prioritized interventions for yield growth, adaptation/risk reduction, risk transfer, and GHG mitigation based on the risk profile of the crop district and its agriculture development status and crop acreage are listed in this report. The resources required for such a scaling-up exercise can largely be met by aligning the prioritized interventions with the current development schemes of the state/center such as PoCRA,

PMKSY-Har Khet Ko Pani, National Food Security Mission (NFSM), National Mission for Sustainable Agriculture (NMSA), Chief Minister Water Conservation Programme (CMWCP), Parampragat Krishi Vikas Yojana (PKVY), etc.

5. ***Managing water resources sustainably.*** Only 20% of Maharashtra's cultivated area is irrigated and hence efforts are needed to strengthen and streamline existing water resources and water harvesting. There is a need to develop near-real-time monitoring systems for small water bodies. This can be developed by combining remote sensing and mobile-based participatory monitoring like near-real-time crop monitoring systems recently launched by the Government of Maharashtra. The state has the maximum area under drip irrigation systems, but the overall penetration rate is still lower. Micro-irrigation systems should preferably be bundled with schemes promoting solar irrigation pumps and farm ponds to maximize water use efficiency, adaptation, and economic returns.

6. ***Developing cultivars and breeds for better climate risk management.*** Maharashtra faces several climate-induced stresses. There is a strong need to intensify the development and deployment of stress-tolerant seeds and breeds in medium to high-risk areas. The seed replacement ratio of the non-cash crops is very low, efforts are needed to deploy improved and stress-tolerant seeds. Encouraging the Seed Bank concept could be rewarding in quickly increasing seed replacement ratio as well as for providing inputs to breeding programs for bringing improved and stress-tolerant cultivars/breeds into the state.

7. ***Reducing carbon footprints from Maharashtra agriculture.*** Maharashtra agriculture emits GHG emissions amounting to ~31 MT CO_2 EQ largely from the livestock sector and to some extent from raab practices (residue burning of rice and sugarcane). This organized dairy sector should be incentivized to increase the adoption of carbon smart technologies like biogas, green fodder supplements, feed management, etc. to reduce GHG emissions. Similarly, the residue burning practice in sugarcane and paddy (raab) must be replaced by carbon smart practices such as residue incorporation, residue treatment using residue decomposers, and ex-situ management of residues. It is not easy to strategize for GHG reduction considering the predominance of smallholders in medium to high climatic risk regions. An option worth evaluation by the state is to monitor, aggregate, report, and verify GHG status and monetize this through either state subsidy or sale in carbon markets. Developing business models for gobar, as in Chhattisgarh, is an excellent example of such initiatives.

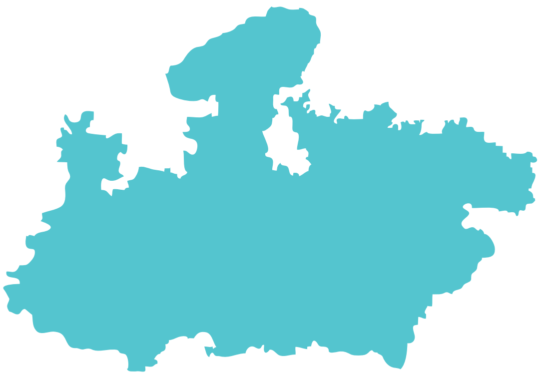
8. ***Managing climate-induced immigration/out-migration in agriculture/rural areas.*** Climatic extremes generally result in the outmigration of farmers and laborers from rural areas to large cities such as Mumbai and Pune. The recent Covid pandemic has shown that reverse migration from large cities to rural areas is also possible. In both cases, there is an urgent need to understand the pattern of migration and their links with climatic events to plan for on-farm employment, stress-relief measures, and maintain agriculture supply chains. Cell phones are now very common and practically every adult has one. Government agencies can query Call Data Records (CDR) of mobile phones safely and securely and obtain key insights related to socio-economic indicators and mobility matrices of populations over large geographical areas in the events of large climatic extreme events such as floods and cyclones. Such insights for example when combined with other data sources such as remote sensing-based land degradation identification and current/future climate forecasts, can help identify drivers of rural-urban migration, that can facilitate improved urban/rural planning, especially regarding food availability and quality.

Adaptation Strategies for Madhya Pradesh

Madhya Pradesh is highly vulnerable to the effect of climate change due to frequent drought, floods, long dry spells, and high temperatures during summer. There have been seven very severe and four severe drought years (out of 30 years analysed) of varied intensity since 1990 in the state by using a simplified drought index presented by Rathore, 2004. The north region, north-western region, and some spots of the central and eastern regions of the state show a high probability of very severe and severe droughts. At the state level, there is a 49% probability of witnessing drought. The probability of getting severe and very severe drought is also high (36%). The state has witnessed significant changes in its climate in the last 50 years. The key changes in the state of climate variables (Coefficient of variation of rainfall, mean rainy days, and maximum length of dry spell during kharif) were analysed in three time periods i.e., 1969 to 1983, 1984 to 1998, and 1999 to 2013. The rainfall variability has significantly increased in recent times all over the state. The maximum area of the state is under 30 to 40% coefficient of variation of kharif rainfall from 1999 to 2013. The number of rainy days is decreasing over time and the mean length of the dry spell increases with time.

We conducted a survey (n=73) to understand stakeholders' perceptions (including farmers) on weather-related risks and their impact on major crops in Madhya Pradesh. Top-ten weather-related risks experienced by the respondents are drought, flood, high temperature, low temperatures, untimely rainfall, delayed monsoon, deficit rainfall, dry spells, excess rainfall, and hailstorm. The climactic event like delayed onset monsoon, and excess rainfall which causes the waterlogging issues are highly experienced in Kharif crops. In the case of livestock, high temperature is the prominent climatic risk reported by the respondents (34%) followed by drought (32.3%) and low temperature. The rise in temperature increases the water requirement of livestock from 5 liters at 30° C to 10 liters at 35° C. Around 6.5 % of respondents felt floods and hailstorms as a risk for their livestock. In addition, the drought risks often translate to fodder and water shortage resulting in increased demand for fodder banks or desperate selling of livestock. In addition, the rise in temperature leads to the distribution of disease and pathogens which cause the losses of livestock in the state.

CMIP6 projections indicate an increase in mean temperature of 2.5° C (1.8° C to 4.7° C) by 2050 and 4.2° C (1.8° C to 9° C) by 2090 in Madhya Pradesh. Regionally, northern, and north-western parts have



a higher increase in temperature than Central, East, and South Madhya Pradesh. District-wise changes show the highest increase in temperature are likely in Sheopur, Morena, Bhind, Gwalior, Shivpuri, and Neemuch. CMIP6 projections indicate an increase in annual rainfall of 13% (1 to 28.7 %) by 2050 and 18% (5 to 67%) by 2090 in Madhya Pradesh. Western and southern parts of Madhya Pradesh have a higher increase in precipitation. District-wise rainfall changes show a significant increase in Barwani, Alirajpur, Dhar, Jhabua, Khargone, Burhanpur, Khandwa, Indore, and Dewas districts. Whereas the eastern part of Madhya Pradesh is likely to have decreased in rainfall.

The state GHG emission has increased from 99.9 million tons of CO_2 EQ in 2005 to 165.2 million-ton CO_2 EQ in 2015. Whereas the total GHG emission from agriculture, forestry, and other land use has been reduced by 3.62% i.e., from 2.70 million tons of CO_2 EQ in 2005 to 2.60 million tons of CO_2 EQ in 2015. The energy sector contributed the highest emission in the state followed by Agriculture, Forestry, and Other Land Use (AFOLU) sectors and the Industrial Processes and Product Use (IPPU) sector. Around 74% of emission is through the energy sector whereas Agriculture, Forestry, and Other Land Use (AFOLU) contributed approximately 15.76%. Among the AFOLU sector emissions, enteric fermentation accounts for 61.5% of emissions followed by emissions from agricultural soils (13.9%), rice cultivation (8%), manure management (6.5%), and croplands (3.9%).

The state experiences frequent climatic risk which affects the overall agriculture and livelihood of the farming community. To address such an issue, the state of Madhya Pradesh developed a state action plan on climate change in 2012 and provided several strategic action items for the agriculture sector, aimed at reducing the sector's vulnerability to climate risks and building its resilience. It focused on building farming systems resilience through promoting the soil and water conservation technologies, crop planning as per agro-climatic zone, dissemination of new and appropriate technologies developed by researchers and strengthening research, forest produce management, mechanization, and agriculture information management system. While these recommendations are important, there is a need to determine more specific subregional actionable items. Strategies to build resilience in agricultural systems will need to have a clear understanding of prioritized interventions that promote Climate-smart Agriculture (CSA), and address resources, policy, and institutional bottlenecks for their implementation. Therefore, a stakeholder consultation workshop was organized for the prioritization of CSA technologies for Madhya Pradesh. The exercise of participatory prioritization of CSA technologies was done twice for the Madhya Pradesh state. The top 21 technologies, prioritized by the above process, from a long list of more than 200 technologies are water-smart technologies like water management, micro-irrigation, solar pumps for irrigation, BBF/ ridge and furrow planting, direct-seeded rice, seed, and breed smart technologies like improved crop varieties, fodder development, stress-tolerant and high-yielding breeds of livestock, carbon smart technologies like agroforestry, conservation agriculture practices, biogas, knowledge smart technologies like pest and disease management, crop diversification, post-harvest management, farm mechanization, concentrated feeding in livestock and goat, co-benefits of ICT linked precision management of water and nitrogen, weather smart technologies like crop insurance, contingent crop planning/ ICTs, climate-smart housing for livestock, and nutrient smart technology like integrated plant nutrient management.

Likewise, for Rajasthan and Maharashtra, we have determined the production risk status of key crops by analyzing the historical district-level data for intensity and frequency of yield loss for Madhya Pradesh. Based on the production risk category, we propose yield promoting, risk mitigation, risk coping, and risk transfer strategies that should be encouraged to strengthen resilience in agriculture systems in the state.

Table 5 Summary of crop risk matrix and adaptation strategies based on the risk exposure for Madhya Pradesh

	Very low intensity		Low intensity		Medium intensity		Hight intensity
High frequency	**Area (%):** Oilseeds (11), Wheat (11), Soybean (3), Chickpea (15), Minor pulses (19), Rice (13), Maize (3), Rapeseed and Mustard (10.5), Pigeon pea (7), Cotton (4), Sesamum (16), Pearl millet (1.5), Kharif Sorghum (7), Groundnut (11), Linseed (9), Barley (18), CASTOR (51) **Area: 3.19 M ha**	**Adaptation Strategy:** Location-specific adaptation/ risk reduction technologies; scale-up insurance coverage bundled with technologies; greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Oilseeds (31), Soybean (59), Chickpea (10), Minor pulses (23), Rice (18), Rapeseed and Mustard (1.5), Pigeon pea (69), Cotton (23), Sesamum (34), Pearl millet (1.5), Kharif Sorghum (5), Groundnut (15), Linseed (5), Sugarcane (44), Barley (10), Castor (49) **Area: 8.5 M ha**	**Adaptation Strategy:** Location-specific adaptation/risk reduction technologies; scale-up insurance coverage bundled with technologies; greater use of ICT-linked input management; added GHG co-benefits of interventions.	**Area (%):** Rice (1) **Area: 0.005 M ha**	**Adaptation Strategy:** Diversify to non-agriculture or livestock options; insurance is expensive and hence not suitable, expand individual and community social safety measures.	
Medium frequency	**Area (%):** Oilseeds (31), Wheat (63), Soybean (19), Chickpea (26), Minor pulses (46), Rice (30), Maize (26), Rapeseed and Mustard (45), Pigeon pea (15), Cotton (0.2), Sesamum (10), Pearl millet (10), Kharif Sorghum (19), Groundnut (53), Linseed (46), Sugarcane (51), Barley (30) **Area: 7.35 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.	**Area (%):** Oilseeds (4), Chickpea (10), Minor pulses (1), Rice (8), Maize (70), Pigeon pea (3), Cotton (9), Pearl millet (4), Groundnut (1), Sugarcane (5) **Area: 0.9 M ha**	**Adaptation Strategy:** Focus on yield growth technologies- high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.			

	Very low intensity		Low intensity		Medium intensity		Hight intensity
Low frequency	**Area (%):** Oilseeds (20), Wheat (47), Soybean (18), Chickpea (29), Minor pulses (10), Rice (30), Maize (12), Rapeseed and Mustard (38), Pigeon pea (2), Cotton (63.5), Sesamum (40), Pearl millet (31), Kharif Sorghum (57), Groundnut (17), Linseed (40), Barley (7) **Area: 8.33 M ha**	**Adaptation Strategy:** Focus on yield growth technologies-high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.					
Very low frequency	**Area (%):** Oilseeds (3), Wheat (35), Soybean (1), Chickpea (10), Minor pulses (1) Rapeseed and Mustard (5), Pigeon pea (4), Cotton (0.3), Pearl millet (52), Kharif Sorghum (12), Groundnut (3), Barley (35) **Area: 2.97 M ha**	**Adaptation Strategy:** Focus on yield growth technologies-high yielding varieties, input intensification; optional insurance; Greater use of ICT linked input management; added GHG co-benefits of interventions.					

We have also investigated how the proposed strategies could be linked with the current development schemes of the Government to minimize the need for new resources. The analysis led to the following six recommendations for building resilience in agricultural systems in Madhya Pradesh.

1. ***Raise the bar for setting up Climate-smart Agricultural Villages in the state.*** A long-term scientific climate risk management plan including land use plan, water management, and contingency planning is the need of the hour. The Climate-Smart Village approach, which uses synergistic action of technologies, climate information services, and convergence to build resilience, is currently being used in many countries and several states of India could address this challenge. The state government indeed announced in 2016 its intent to establish 1,100 climate-smart agricultural villages (***SGSK***) across 11 agro-climatic zones. A commitment of funds to implement the proposed scheme will assist the state government in maintaining its impressive agricultural growth despite climatic risks. This report also highlights the portfolios of prioritized interventions that can be scaled up in different districts and major crop commodities for yield growth, adaptation/risk reduction, risk transfer, and GHG mitigation based on the risk profile of the crop district and its agriculture development status and crop acreage.

2. ***Scale-up weather-linked digital agriculture services for climate risk management.*** To manage increasing climate variability, making available demand-driven and downscaled weather information in the language and dialect understood by the people of the state is important. The state should make increasing use of satellite weather and vegetation data, which are likely to be a game-changer in this area for value-added agro advisories tailored for individual farmer situations and linked with weather forecasts. The government of MP should also consider developing a long-term partnership with private sector weather services providers for this. It is to be noted that the MP state was the first one in India to launch the e-choupal initiative with ITC Limited which resulted in significant benefits to its farmers.

3. ***Targeting crop insurance and risk financing for climate risk management while encouraging agricultural growth.*** Although the MP government has been investing more than 1500 crores rupees every year in premium subsidies of crop

insurance, the overall satisfaction with this scheme remains poor. It is high time to reconsider the viability and implementation of this scheme and its business value in terms of risk management. The state has about 13 M ha cropland in the low to medium risk category where it is useful to develop novel insurance products that can be bundled with yield growth and adaptation/risk reduction strategies such as those encouraging use of high yielding seeds, irrigation, and fertilizer management strategies. In very low-risk regions, which are almost 19 million hectares of cropland (70% of the total cropland) in the state, the state government should consider not having a generic and comprehensive insurance scheme rather than opt for only local, specific insurance products for emerging risks from a hailstorm, frost, unseasonal rainfall, and floods. This will perhaps also save a substantial portion of the current investment of the state in insurance subsidies while increasing satisfaction.

4. ***Accelerate water resources development program in irrigation-deficit regions.*** The state of MP has made impressive growth in developing irrigation potential during the last 15 years which has helped in accelerating overall agricultural growth. A scheme like the Gujarat government's Suryashakti Kisan Yojana (SKY), in which, farmers can use solar energy for irrigation purposes and can also sell the surplus power via the grid could further increase the irrigation potential. To increase the area under micro-irrigation an alternate subsidy delivery model of providing interest-free loans to the farmer for purchasing the drip system of his/her choice from anywhere should be considered. Bundling micro-irrigation systems with schemes such as solar irrigation pumps, farm ponds, etc. will also maximize water use and economic returns.

5. ***Developing stress-tolerant cultivars for better climate risk management.*** 'MP wheat' attracts a higher price in the market due to its chapati-making quality. Climate change would have some impact on its cooking quality and hence market demand and price. It is important to evaluate this soon and develop appropriate cultivars to ensure that the advantage of the 'MP wheat' in the market is maintained or enhanced. Drought and heat tolerant seeds need to be developed and deployed for all important crops of Madhya Pradesh. Encouraging Seed Villages (Beej Gram Yojana of the state) and greater involvement of farmer organizations could help in quickly increasing the seed replacement ratio in the state, a constraint for most crops.

6. ***Reducing carbon footprints from Madhya Pradesh agriculture.*** Considering the expanding livestock sector and its potential contribution to GHG emissions, it is important that GHG mitigation from the sector is paid adequate consideration. One option is the monetization of GHG mitigation by the state governments, or the facilitation of monitoring, aggregating, reporting, and verification for sale in carbon markets. The organized dairy sector also needs to be incentivized to increase the adoption of carbon smart technologies like biogas, green fodder supplements, feed management, etc. to reduce GHG emissions from livestock-based production systems. Developing business models for gobar, as in Chhattisgarh, could be an alternate efficient option to incentivize farmers and other producers to collect dung and for the state to process this for manure availability and to reduce GHG emissions.

C) Support for the Establishment of Model SGSKs

The project also provided technical support for the establishment of model ***SGSK*** in the ITC project area. The objective behind creating the model ***SGSK*** was to create knowledge hub villages where the possible portfolio of CSA technologies can be demonstrated in the farmer field. Considering the importance of model ***SGSK***, the systematic step-by-step process documents were developed that give the direction and idea on the development of the model climate-smart village. The guideline would be very helpful to the field team, technical people, and practitioners who want to develop the model of a climate-smart village.

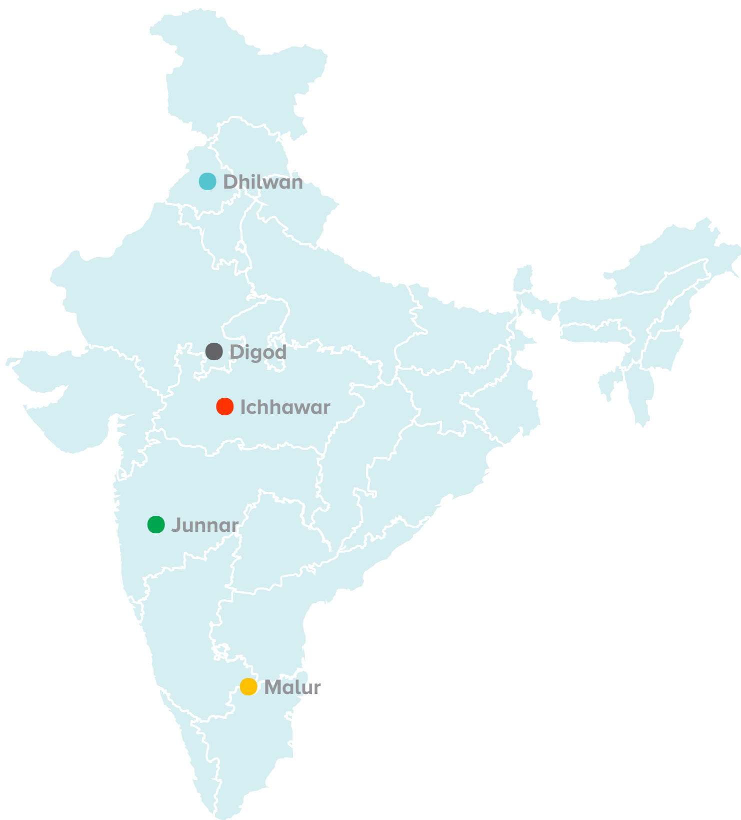
Details of model *SGSK* sites: Five model ***SGSK*** are being established (figure 24) at various agro-ecologies in ITC's outreach areas.

Nurpur Jattan model ***SGSK*** located in Dhilwan block of Kapurthala district of Punjab falls in the central plain zone which receives a total annual rainfall of 527 mm with a cropping intensity of around 205%. Kharif rice, maize, and wheat are the major crops grown in the district. The district's agriculture is often affected due to changes in the temperature like heat and cold waves frequently whereas the occasional occurrence of drought, flood, unseasonal rainfall, frost, and hailstorm.

The second model ***SGSK*** named Kacholiya is located at the sub-humid southern plain zone of Digod block of Kota district of Rajasthan. It receives a total annual rainfall of 732 mm with a cropping intensity of around 156%. The major crops grown in the district are soybean, rice, rapeseed, mustard, maize, and wheat are the major crops grow in the district. The district's agriculture is often affected by pest and disease outbreaks due to changes in the temperature like frequent heatwaves and the occasional occurrence of drought, cold waves, frost, and hailstorms.

The third model ***SGSK*** Dehkhedi is located at the Malwa Plateau Zone of Icchawar block of Sehore district of Madhya Pradesh. It receives a total annual rainfall of 1261 mm with a cropping intensity of around 158%. The major crops grown in the districts are soybean, rice, rapeseed and mustard, maize, and wheat. The district's agriculture is often affected by pest and disease outbreaks due to changes in the temperature like frequent heatwaves and the occasional occurrence of drought, cold waves, frost, and hailstorms.

Figure 24 Location of Model SGSK



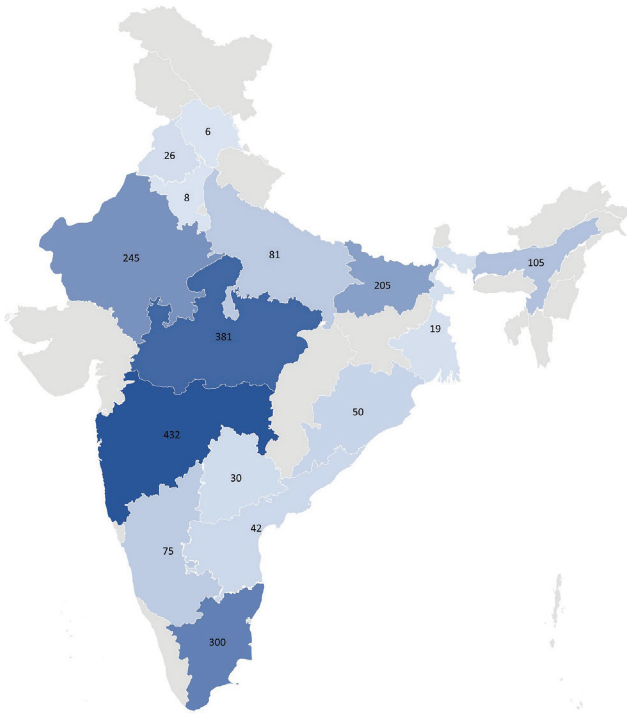
The fourth model ***SGSK*** Kalwadi is in the western Maharashtra plain zone of the Junnar block of the Pune district of Maharashtra. Kalwadi receives a total annual rainfall of 744 mm with a cropping intensity of around 121%. The major crops grown in the districts are sorghum, sugarcane, rice, pearl millet, groundnut, wheat, and chickpea. The district's agriculture and livestock are often affected due to the occasional occurrence of drought, long dry spells, and pest and disease outbreaks which cause a shortage of fodder for livestock.

The fifth model ***SGSK*** Yeshvantapura is in the eastern dry zone of the Malur block of the Kolar district of Karnataka. Yeshvantapura receives a total annual rainfall of 643 mm with a cropping intensity of around 103%. The major crops grown in the districts are ragi, groundnut, rice, and other pulses. The district's agriculture is often affected due to the frequent occurrence of drought, pest, and disease outbreaks as well as the occasional occurrence of cyclones.

Scaling of *SGSK* Model in other states of India

The project partnership started with implementing the ITC-BISA ***SGSK*** approach initially in three states (Madhya Pradesh, Maharashtra, and Rajasthan). Currently, the SGSK Climate-Smart Villages program is being scaled up in 15 states by ITC Limited and its partners. The scale of expansion can be gauged from the fact that in the first phase the climate-smart village initiative started with only 73 villages and is now being extended to 2005 villages and has plans to reach one million acres of farmland under the SGSK program by 2030. The state-wise details of existing/targeted ***SGSK*** as per the details provided by ITC's field team are shown in (figure 25). Table 3 shows further disaggregated information on several villages by state and district where the climate-smart village approach is being scaled. Initial three states (Madhya Pradesh, Maharashtra, and Rajasthan) where this started earlier have the maximum share (> 50%) of several villages reached or being reached in the CSV program.

Figure 25: SGSK Villages in different states where ITC is in the process of scaling up the SGSK approach



The rapid expansion has been already started, village selection, collection of baseline information, and prioritization of CSA interventions is in progress. For the newly added states, field teams of Punjab, Bihar, and Assam have already conducted the Stakeholder Consultation Workshop for the prioritization of CSA technologies.

With the rapid scaling of ***SGSK,*** the data collection must be made in the digital model. In the second phase, we adopted the GeoFarmer mobile app. for baseline data collection. The GeoFarmer app. was developed by CGIAR-CCAFS to serve as an effective and user-friendly ICT-based instrument that can be rapidly, reliably, and systematically deployed across the globe to collect the baseline and other data and track CSA adoption, output, and outcomes in the field. For each state, a GeoFarmer channel has been created. Each state channel can have different modules tailored to local agroecology. As of now, more than 7000 farmers' baseline information's have been collected through the GeoFarmer digital platform. Maharashtra has made impressive progress in collecting the baseline information of 1294 farmers followed by Uttar Pradesh (868), Bihar (862), Assam (778), and Rajasthan (735), Odisha (610), and Karnataka (605). The rest of the state like Tamil Nadu, Andhra Pradesh, West Bengal, and Punjab has collected the baseline information of 494, 350, 277, and 266 farmers respectively. Haryana, Telangana, and Himachal Pradesh teams are yet to start the collection of baseline information. In the case of Madhya Pradesh, the state team has collected the information of 37 farmers through the GeoFarmer app whereas the other farmer baseline information is available in excel format.

Table 6 State and district wise details of existing/targeted SGSK (preliminary work has started in these states as informed by ITC)

State	District	Number of villages	State total villages
Andhra Pradesh	Guntur	13	42
	Prakasam	22	
	West Godavari	7	
Assam	Darrang	50	105
	Kamrup Rural	55	
Bihar	Begusarai	11	205
	Lakhisarai	56	
	Munger	138	
Haryana	Gurgaon	3	8
	Mewat	5	
Himachal Pradesh	Solan	6	6
Karnataka	Bangalore Rural	45	75
	Kolar	30	
Madhya Pradesh	Agar	46	381
	Bhopal	45	
	Chhindwara	61	
	Indore	30	
	Mandsore	12	
	Ratlam	17	
	Sehore	112	
	Ujjain	46	
	Vidisha	12	
Maharashtra	Ahmednagar	65	432
	Amravati	89	
	Nashik	50	
	Pune	55	
	Pune	60	
	Sangli	101	
	Yavatmal	12	
Odisha	Ganjam	35	50
	Khordha	15	
Punjab	Kapurthala	26	26
Rajasthan	Baran	36	245
	Bikaner	11	
	Bundi	38	
	Jhalawar	104	
	Kota	50	
	Pali	6	
Tamil Nadu	Coimbatore	146	300
	Pudukottai	122	
	Theni	32	
Telangana	Bhadradri Kothagudem	30	30
Uttar Pradesh	Gorakhpur	54	81
	Saharanpur	27	
West Bengal	Howrah	19	19
		Grand Total	**2005**

Key Learnings and Way Forward

Over the last six years, the experience of implementing the SGSK led to several key insights. Below we list four key learnings and ways forward for strengthening the resilience of agriculture systems.

1. Scaling climate-smart agriculture is complex since it involves the development of location-specific practices and technologies and climate information services. Implementing this requires dealing with diverse partners such as farmers, industry, input suppliers, KVKs, government functionaries, and policy planners at different scales. This anyways must be addressed since the problem at hand is also large and complex. The ***SGSK*** approach provides an opportunity to build climate-resilient communities by integrating various stakeholders' knowledge and experience on CSA interventions, mobilizing the stakeholders through participatory design, prioritization of the CSA interventions, and linking cross-scale activities and players. The participatory project design and implementation process also ensure coherent linkage of the CSA process with stakeholders' needs and challenges. Results of CSA technologies and practices demonstration in the selected ITCs outreach villages in Madhya Pradesh, Rajasthan, and Maharashtra show that there is a large scope of CSA for improving crop yields and farmers' income, building resilient and reduction of emissions.

2. The state-level adaptation strategy developed under this project is an important step towards the vertical scaling of ***SGSK***. It is critical to integrate the results of the ***SGSK*** program with state and local government programs, schemes, and policies for the sustainability and long-term impact of the program. Development of farmers groups, strengthening existing Self-Help Groups (SHGs), development of service provision centers such as custom hiring and cattle development centers, promotion of community resource persons such as super champion and champion farmers, and linking farmers to the private sectors (seed suppliers, livestock services, ICT based agro-advisories, and farm machinery) are necessary. The state-level adaptation strategy developed under this project is an important step toward the vertical scaling of ***SGSK***. However, it must be noted that the learnings at the local farmer scale would remain critical to building upscaling strategies.

3. Knowledge and experience on new CSA innovations such as ICT-based weather and agro-advisory services, climate-resilient seeds/breeds, and agriculture insurance were limited by most stakeholders and therefore there is a need to build their capacity on these CSA interventions. Training and capacity building of the technical staff plays a crucial role in the transfer of climate-smart agriculture knowledge, technologies, and skills to the local farmers and farming communities, and other stakeholders. Right tools and effective communication are needed to facilitate the use of these complex approaches for resilient development.

4. There is a need to further understand the current barriers such as technical knowledge, cost of technologies, and incentive mechanisms that can facilitate ***SGSK*** reaching scale. In the process of further replicating this approach in other regions, it is important to pay due to emphasis on ***SGSK*** design protocols, which requires a detailed risk profiling of climatic, socio-economic, and edaphic factors, design, prioritization of interventions, and monitoring and evaluation of the program. The data collection, verification, and analysis must be made fully digital for the calculation of indicators at the farm and village scale for productivity, resilience, and GHG mitigation for internal and external viewers. Monitoring the ***SGSK*** at a large scale can be further facilitated by exploring the use of advanced analytics including remote sensing, crop models, and statistics.