The Climate-Smart Village Approach for Building Resilient Agriculture in India

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1. The Issue

India is amongst the most vulnerable regions to climate change in the Inter-Government Panel on Climate Change (IPCC)'s Fifth Assessment Report released a year ago, and in other similar reports. Rise in average temperatures, changes in rainfall patterns, and increasing frequency of extreme weather events such as severe droughts and floods have been observed in different agro-ecological zones of India, which poses a major threat to India's food security. Despite impressive progress in food production in recent years, India remains home to almost 40% of the world's poor, 20% of the world's hungry and 40% of the world's malnourished children and women. The majority of poor and under-nourished live in rural areas and depend on agriculture for food and livelihoods. The impressive economic growth and remarkable increase in food production during last few decades have not contributed to alleviating poverty and reducing hunger in rural areas. Therefore, future growth strategies should include sustainable agricultural development.

Compounding food security and related livelihood related issues, is the significant amount of Green House Gas (GHG) emissions from the agricultural sector. Agriculture both affects and is in turn affected by climate change. The sector is responsible for a third of global GHG emissions, with India's contribution amounting to 18% (Sapkota et al. 2018). From another lens, the Indian population continues to grow. This, accompanied with rising per capita income, and urbanization will lead to an increase in demand for food grains and a gradual shift of expenditure from cereals to meat, milk, fish and other animal products. It is estimated that by 2050, our food grain requirements will be almost 50% more than the current demand. On the other hand, the large population and agricultural pressure on land has been very demanding on natural resources, especially water and land, and has resulted in their degradation over time. The additional food will have to be produced from the same or even shrinking land resources due to increasing competition for land from the non-agricultural sectors. The tasks of alleviating poverty and attaining food security at the household and sub-national/regional level are thus major challenges.

Several studies have shown that, unless we adapt now, India could lose 10-40% of crop production by the end of the century due to global warming, despite the beneficial aspects of increased CO2 (Aggarwal, 2009; Nelson et al., 2009; Knox et al., 2011). In fact, there is some evidence that changing climate has already impacted rice and apple yields. Projections indicate the possibility of losing of 4-5 million tons of wheat production with every rise of 1oC temperature throughout the growing period (Aggarwal, 2009). Recent simulation analysis has indicated that rainfed maize, sorghum and rice yields are likely to be adversely affected by the increase in temperature. The projected increase in drought and flood events could result in greater instability in food production and threaten the livelihood security of farmers.

Thus, the greatest challenge lies in attaining food security for the nations' bludgeoning population under a climate affected agricultural system while at the same time ensuring that food production follows a low emissions and sustainable trajectory. Through scientific innovation, partnerships and policy support, Indian agriculture needs to be infused with resilience while operating within the larger framework of achieving the Sustainable Development Goals of 'No Poverty', 'Zero Hunger', 'Climate Action', 'Partnerships for the goals' among others.

2. How is this being Addressed?

As a composite solution to advance climate-smart agricultural technologies and practices, CCAFS has developed the Climate-Smart Village (CSV) approach. Started in India in 2012 as an 'Agricultural Research for Development' (AR4D) approach, the CSVs are platforms, to test through participatory methods, technological and institutional options for dealing with climate change in agriculture (Aggarwal et al 2018). The CSV sites are generally a cluster of villages where such options are tested in collaboration with multiple stakeholders (farmers, researchers, local institutions etc.) to generate evidences on synergies as well as trade-offs between different options in terms of productivity, adaptation and mitigation. The options so chosen are geared towards attaining multiple benefits of: *resilient agricultural communities; higher yield potential and thereby higher farm incomes; enhanced livelihood opportunities; gender and social inclusion in agriculture strategies* among others.

2.1 Key Features of the CSV-AR4D Approach

- Sites for testing, through participatory methods, technological and institutional options.
- Sites where climate change in its broadest context is considered, but in relation to local realities: long-term adaptation, avoiding maladaptation, climate risk management and low emissions development.
- Embodies a holistic vision for climate change action – not a silver bullet approach.
- A platform for socially inclusive, multi-stakeholder collaborative work.
- Founded on the principle of bringing CSA to scale.
- Links global and local knowledge.

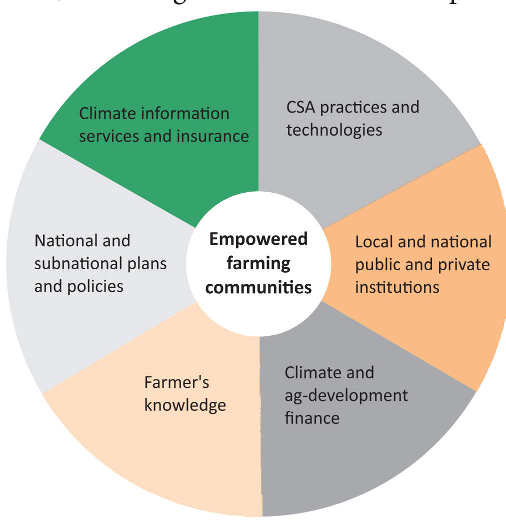

Figure 1: Components considered in a CSV-AR4D site

2.2 Steps in Developing Climate-smart Villages

In establishing a CSV AR4D site, the very first step is to build trust and partnerships amongst diverse stakeholders; and to get agreement and buy-in to a common approach (Aggarwal et al. 2018). Once partners have agreed on the establishment of a CSV site, the major steps include:

1. **Baseline assessment:** including climate risk analysis and gender and social inclusion analysis;
2. **CSV design:** Identification and prioritization of climate-smart technologies, practices and services based on biophysical, socio-economic, gender, policy and institutional context; also considering possible synergies and trade-offs amongst individual activities;
3. **Creating evidence:** Evaluation and development of portfolios of climate-smart interventions (e.g. providing value-added weather services to farmers, promoting weather-based insurance, building capacity in climate change adaptation and facilitating community partnerships for knowledge sharing);
4. **Scaling:** This involves scaling up through policies and institutions, and scaling out to large areas through farm-to-farm and ICT-based approaches (Figure 2).

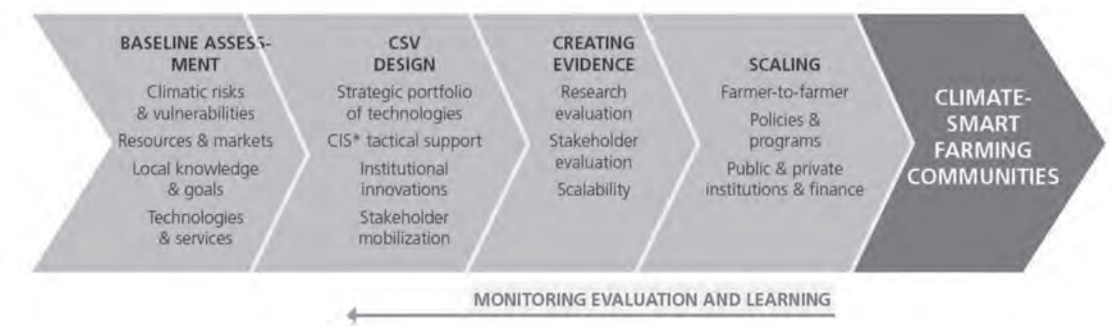

Figure 2: Steps for the implementation of the CSV AR4D approach. Implementation steps are based on stakeholder engagement and seldom follow a simple linear model.

The CSV approach usually results in a portfolio of CSA options and institutional and financial mechanisms which can be scaled up/out by the national/sub-national governments, NGOs and private sector actors in the region. A number of tools such as the Climate-Smart Agriculture Prioritization (CSAP) toolkit, choice-experiments for CSA prioritization, CCAFS Mitigation Options Tool (CCAFS- MOT) for emission measurement, Gender and Social Inclusion Toolbox, crop simulation models, and climate analogues, are used in the process. CSVs established in the states of Punjab, Haryana, Bihar, Odisha, Uttar Pradesh, Madhya Pradesh, Maharashtra, and Telangana have yielded models of CSA portfolios that can be scaled further and lessons drawn from it can be used by policy makers from local to global levels.

2.3 Climate-Smart Agricultural (CSA) Interventions in CSVs

The options tested as part of the CSV research agenda for dealing with climate change and variability include: weather-smart activities (weather forecasts, climate-informed agro-advisories, weather insurance, climate analogues as a tool for forward planning, strategies to avoid maladaptation), water-smart practices (aquifer recharge, rainwater harvesting, community management of water, laser-land leveling, micro-irrigation, raised-bed planting, solar pumps), seed/breed smart (adapted varieties and breeds, seed banks including community-based activities), carbon/nutrient-smart practices (agroforestry, minimum tillage, land use systems, livestock management, integrated nutrient management, biofuels) and institutional/market smart activities (cross-sectoral linkages; local institutions including learning platforms or farmer-to-farmer learning and capacity development), contingency planning, financial services, market information, gender equitable approaches, and off-farm risk management strategies.

There is no fixed package of CSA interventions to be tested however or a one-size-fits-all approach. Interventions selected differ based on the region, its agro-ecological characteristics, level of development, capacity, and interest of farmers and the local government.

3. How is the CSV Approach Scaled up?

Scaling mechanisms tested across the regions include:

- Horizontal scaling (Scaling out) of climate-smart options: CSVs provide demonstration sites for farmer-to-farmer learning (often via self-help groups or producer organizations) and/or enable local promotion of CSA options through local government plans, programs and policies or through private sector business models.
- Vertical scaling (Scaling up): CSV research and lessons learned provides evidence for the efficacy of practices, technologies, services, processes and institutional options and is thus able to: influence large-scale CSA investment

3.1 Case Study: Scaling the Climate-Smart Village Approach and Advancing Climate-smart Agriculture in Betul (Madhya Pradesh), Nalanda (Bihar) and Mathura (Uttar Pradesh)

A project collaboration has been made with the United States Agency for International Development to help scale the Climate-Smart Village approach and thereby advancing climate-smart agriculture (CSA) in Betul (Madhya Pradesh), Nalanda (Bihar) and Mathura (Uttar Pradesh). As part of the project implementation plan, 16 CSA technologies were implemented in 75 villages in the three aforesaid districts. As a result, more than 11,000 farmers were covered for adoption of CSA technologies, practices and services to build climate resilience in agriculture. Results of the model implementation highlighted improvements in resilience, reduction in greenhouse gas emissions and potential decrease in labour hours. Increased resilience was measured through increase in yields for all major crops across the three districts with simultaneous improvements in gross income. It also resulted in increase in nutrient use efficiency by more than 100% for all crops. Average emission intensity reduced by more than 20% overall as a result of multiple interventions including Integrated Nutrient Management, Solar irrigation and Biogas. Additionally, gender integration in the form of improved incomes and reduction in labour by more than 1,000 days also indicated improvement in adaptive capacity for women farmers.

4. The CSA Technology Transfer Model within the CSV Framework

The CSA technology adoption model (Figure 3) aims to highlight the process of building climate resilience of a large number of farmers in a systematic and sustainable manner. The model promotes the adoption of CSA technology and services through multiple activities centred on the hub and spoke model. The hub and spokes are supported by the various elements of the enabling environment, which continuously interact with the key actors of the model, the Super Champion, Champion and CSA farmers. At the same time, the model also encourages incorporating the impacts of technology adoption to make the model more relevant for scaling out.

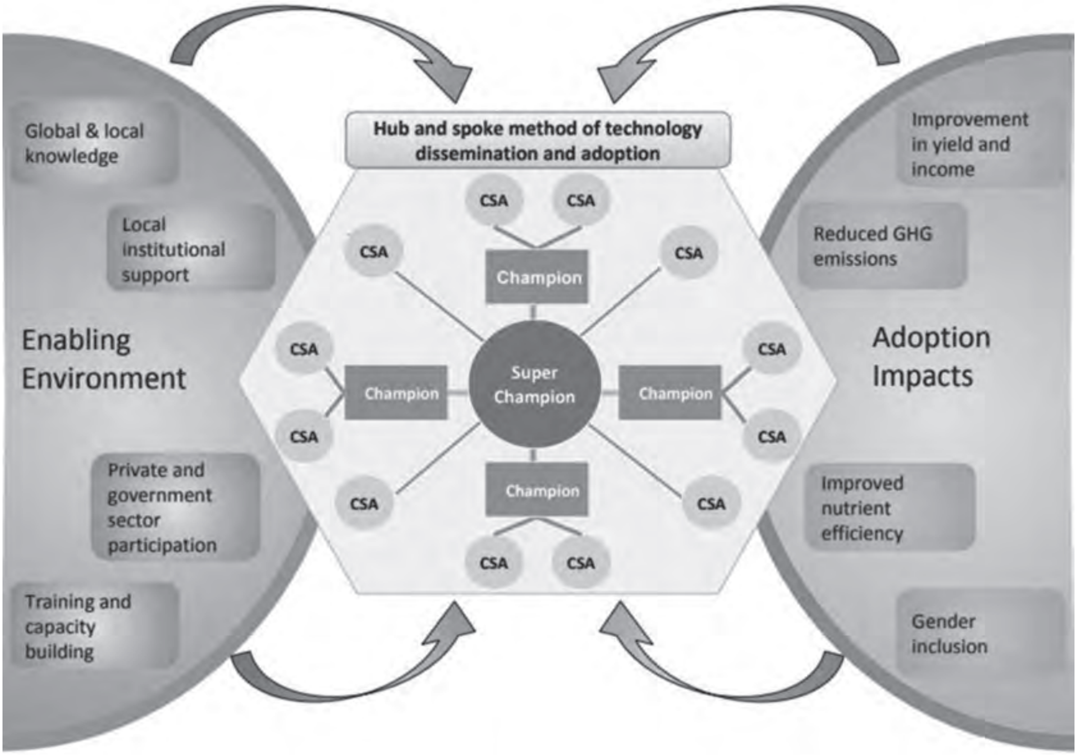

Figure 3: A schematic illustration of the CSA technology adoption, highlighting the inputs to and the results of technology dissemination and adoption through the model for building climate resilience.

4.1 Technology Transfer by Farmer Type

The hub and spoke model: The hub and spoke is the focus of the model that involves the key participants of the process, the farmers. There are two levels of hubs, the Super Champion and the Champion farmers. The Super Champion is the main hub who acts as influential supporters as well as promoters of CSA technology for Champion as well as the CSA farmers. The Champion farmers are another level of hub with whom CSA farmers can be connected. The Super Champion farmers are implementing a portfolio of 15 CSA technologies related to agriculture and livestock, while the Champion farmers are implementing a list of 9 CSA technologies, practices and services. Each of the 75 villages includes 1 Super Champion, 14 Champion and 135 CSA farmers. These farmers were selected based on their willingness and ability to participate and contribute financially to the process of technology adoption. The hubs are the focus of all technology linked implementation, which as a result also becomes the testing grounds for learning and adoption of best practices by other farmers.

A number of participatory activities such as farmer field visits and farmer fairs facilitate the working of the hub and spoke model. Champion, and CSA farmers are regularly taken to the demo fields of Super-Champion farmers to understand the climate-smart interventions on the field and the difference in outputs between the demo and regular plots. Similarly, during farmer fairs, the participants are exposed to the different types of climate-smart technologies and practices that the Super Champion and Champions are implementing. They are also shown some of the demo plots to understand the benefits of changing the traditional cropping practices. This ensures the spread of knowledge and the initiation of interactive learning among the farmers.

Enabling Environment

The enabling environment consists of all the activities, support systems and mechanisms that continuously feed the hub and spoke system of the model. These also act as enabling factors for CSA technology adoption and play an important role to keep the model sustainable in the long run. The components of the enabling environment are:

i. **Global and local knowledge:** The process of selecting a locally relevant portfolio for technology adoption involves bringing in existing global CSA related knowledge to the fields and then testing it using participatory processes to shortlist the most favourable options. Therefore, a list of 34 CSA technologies, practices and services was developed based on a global literature review of past studies and in consultation with researchers and local stakeholders in the region. The local cropping pattern and climatic risks prevailing in the three districts were considered during the process. Subsequently, a CSA prioritization exercise was conducted with the local stakeholder including the villagers, local NGO partners and local farmer organizations, to finalise the list of CSA interventions.

   In addition, a baseline was conducted across the three districts of 1,125 farmers to understand the locally prevailing conditions with respect to the climate risks, current farm productivity, demographic characteristics, and farmers experience with CSA technology adoption. This information is also considered as the base for assessing the results of CSA technology adoption.

ii. **Local institutional support:** Local institutions support the CSA technology adoption process by keeping all stakeholders connected with each other. These are primarily community based approaches that support collective action and decision making to promote climate change adaptation. Three types of institutions have been formed to enable technology access to the farmers in the hub and spoke. These include the Village Climate Management Committee (VCMC), Custom Hiring Center and Cattle Development Center.

   The Village Climate Management Committees (VCMC) have been formed in every village to drive the implementation of CSA interventions at the local level. The members of this institution comprise of the Super Champion and Champion farmers. As a group, they are responsible for ensuring technology access to all kinds of farmers and therefore act as a link between the farmers and the external agencies such as the private sectors and government. The VCMCs act as a self-governing mechanism by tracking activities and ensuring compliance of all farmers with respect to their financial contributions, capacity building and awareness raising related to CSA technologies and practices.

The institution of Custom Hiring Centers (CHC) have been established with the objective of ensuring technology transfer to the local community through an institutional and business oriented approach. Managed by women farmers, these institutions also contribute to gender integration and empowerment in the farm community. Given the small landholdings of farmers combined with a minimal investment capacity for new technologies, the CHC promotes a technology hiring mechanism to overcome affordability barriers. Therefore, by making CSA technologies available at a rental cost, the CHCs are enabling farmers to overcome the technology access issue, facilitating efficient use of inputs, promoting use of CSA to farmers in and around their locality, and earning a source of income for its members. A total of 11 such institutions are currently running in the three districts.

Livestock in the study areas is characterized as low yielding cattle having a poor rate of conception, poor quality germplasm, and inadequate animal health care. Further, climate stresses such as drought, heat stress and excess rainfall further affect the health and productivity of the animals. Therefore, Cattle Development Centers, one each in the three districts have been established to promote improved breeds of cattle, provide better healthcare for the animals and build capacity of farmers to better manage their livestock to reduce adverse climatic impacts on them. Youth participation is encouraged for managing the activities of the institution and promote the use of CDC interventions to farmers in their villages. These institutions are directly linked with the local research centers to update them about the latest technologies, practices and breeds in the field.

iii. **Private and government sector participation:** Private and government sector partnership forms a key role in providing the CSA technologies, services and related practical knowledge. Across the three districts, several private players are supplying the different technologies and services through the NGO partner, ensuring access to new technologies for all farmers. For instance, IFFCO Kissan Sanchar Limited is providing ICT based weather, agro-advisory and market information in the villages through voice messages and SMSs to the farmers. Similarly, farmers are linked with government's agriculture insurance scheme to help them mitigate climate impacts on crops.

Additionally, the CSA technology adoption related activities are undertaken in coordination with multiple government departments and agencies. As a result, there is convergence of these activities with those of other government schemes and programs. This is enabling the spread of CSA technologies and practices to other farmers beyond the selected 75 villages. In two of the study districts, these convergence activities have been able to cover more than 6,000 additional farmer households as part of their on-going schemes related to CSA.

iv. **Training and capacity building:** To ensure continuous interactions of the hub and spoke process with the enabling environment requires continuous efforts for training and capacity building of all stakeholder, especially the farmers. Regular trainings are required for efficient and effective adoption of CSA technologies and practices. The training mainly includes implementation of CSA package of practices in the farmers' field, time and method of CSA technology application, preparation and importance of organic fertilizers, pesticides and vermicompost, as well as livestock related activities. Trainings on use of weather information and agro-advisory services and enrolment in the agriculture insurance program are also provided.

5. Impact Estimation

The impacts of CSA technology adoption have been measured in three major forms: increased resilience through improvement in yield, income and nutrient use efficiency, reduced greenhouse gas (GHG) emissions and reduction in labour hours for women farmers. All these are expected to enable farmers to sustainably improve agricultural production by developing their adaptive capacity and resilience to climate risks.

Improvement in yields, income and nutrient use efficiency

A midline survey was conducted in the three districts to collect yield data post technology adoption. The surveys covered two cropping seasons, Rabi and Kharif. The improvements in yields and income have been calculated as an increase from the baseline levels. Similarly, a livestock survey was conducted in two of the three project districts to evaluate the impact of climate-smart livestock interventions on animal milk yields. Data was collected from all farmers who are receiving livestock based interventions. The sample size was 225 and 90 in Mathura and Nalanda district, respectively. Given the majority usage of nitrogen rich fertilizers in the study districts, the nutrient use efficiency has been calculated by diving the crop yields with the nitrogen content of fertilizers.

Reduced greenhouse gas emission

Three CSA technologies and practices have been identified as a source for reducing greenhouse gas emission levels. These include nutrient management, bio-gas and solar pumps. Emissions from integrated nutrient management have been calculated using the CCAFS MOT tool (Feliciano et al., 2017). Emission reduction from biogas have been estimated in two forms, from the use of surplus cow-dung produced by cattle, as well reduction in firewood burning as fuel. Primary and secondary data sources have been used for these estimations. The emission from fuel wood is based on the following formula (IPCC, 2006):

$$\text{Emissions}_{\text{GHG, fuel}} = \text{Fuel Consumption}_{\text{Fuel}} \times \text{Emission Factor}_{\text{GHG, fuel}}$$

Where, Emissions $_{\text{GHG, fuel}}$ = emissions of a given GHG by type of fuel (kg GHG), Fuel Consumption $_{\text{fuel}}$ = amount of fuel combusted (TJ), Emission Factor $_{\text{GHG, fuel}}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

The emission reduction potential from solar pumps has been estimated for its replacement with diesel and electric pump using secondary data.

Gender Inclusion

Gender inclusion is an essential part of building resilience of farmer communities. All three districts are characterized by different social structure and therefore women's role in agriculture as well as their level of participation in public forums and interventions differs across the districts. Benefits of the technology adoption model for women farmers has been measured in terms of improvement in incomes, and reduction in labour hours.

6. Results: Impacts of Technology Adoption

6.1 Improving Resilience through Increased Yields, Income and Nutrient use Efficiency

Increase in crop yields and income

Figure 4 highlights the improvement in overall yields and income for the major Kharif crop of Rice and Bajra in two of the study districts. Average Rice yields in Nalanda improved by 101% increasing farmer's gross income by 113%. Major technologies adopted during the season included System of Rice Intensification including line sowing and improved seeds, which prevented crop falling due to strong monsoon winds. Similarly, in Mathura, the crop yield growth post technology adoption was 24% more than the baseline with a consequent increase in gross income of 30%. A change of sowing practice from broadcasting to line sowing combined with improved seeds prevented Bajra yield loss during excess rainfall in the district in Kharif 2018. Additionally, a smaller range in the midline highlights more farmers benefitting from improved Rice and Bajra yields and income.

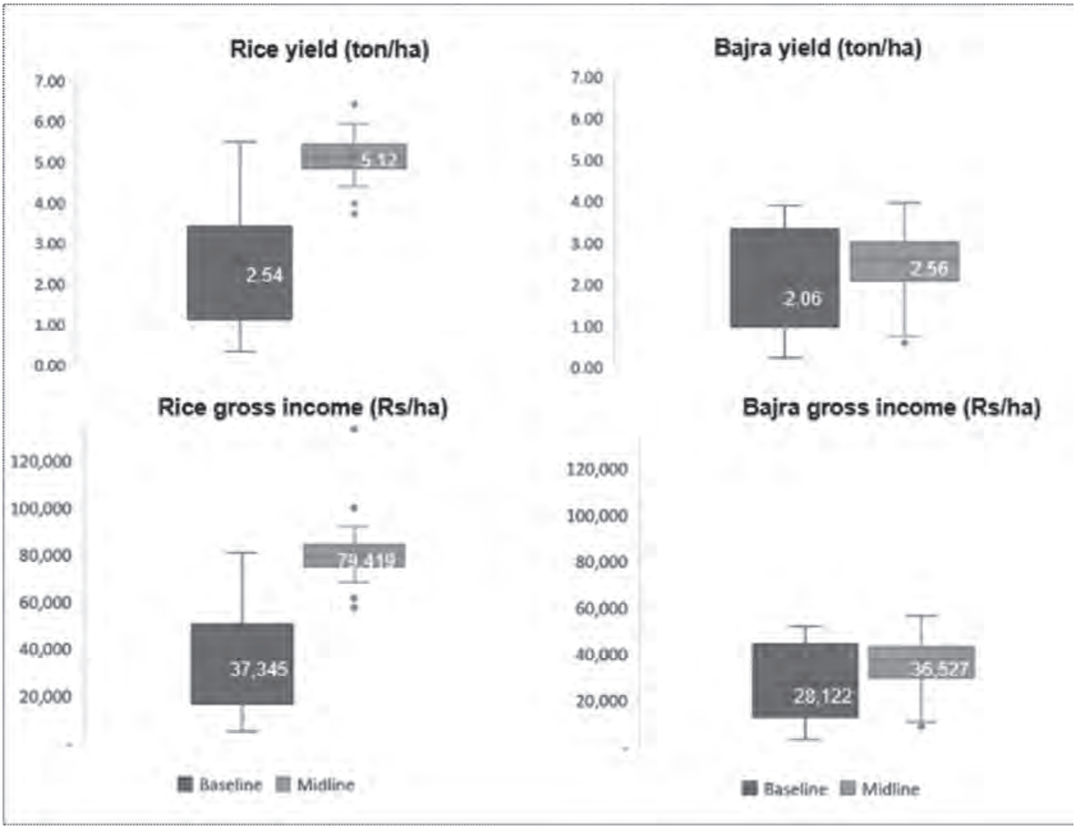

Figure 4: Change in yields and income of Kharif crops, Rice and Bajra, in Nalanda and Mathura districts respectively, as a result of technology adoption

Wheat is the major Rabi crops for the three districts. Cold waves in Betul and excess rainfall in Mathura during the harvesting stage of Wheat are mostly responsible for the loss in yield in the two districts. Similarly, in Nalanda, a delay in sowing of Wheat crop usually results in damage due to increased pest infestation. Therefore, the use of early maturing seed variety in Betul and adoption of line sowing method combined with contingent crop planning and agro-advisory based information in Mathura, has resulted in yield improvements by 39% in Betul and 68% in Mathura. Simultaneously, gross incomes increased by 48% and 78% in Betul and Mathura, respectively (Figure 5). In Nalanda, the use of Zero Tillage to enable timely crop sowing has helped in avoiding the expected damage and enabled a yield and gross income increase of 16% and 24% respectively. For Wheat crop as well, there are more number of farmers benefitting from improved yields and income in the baseline than in the midline, as highlighted by a shorter range of yields and income per hectare in all the districts.

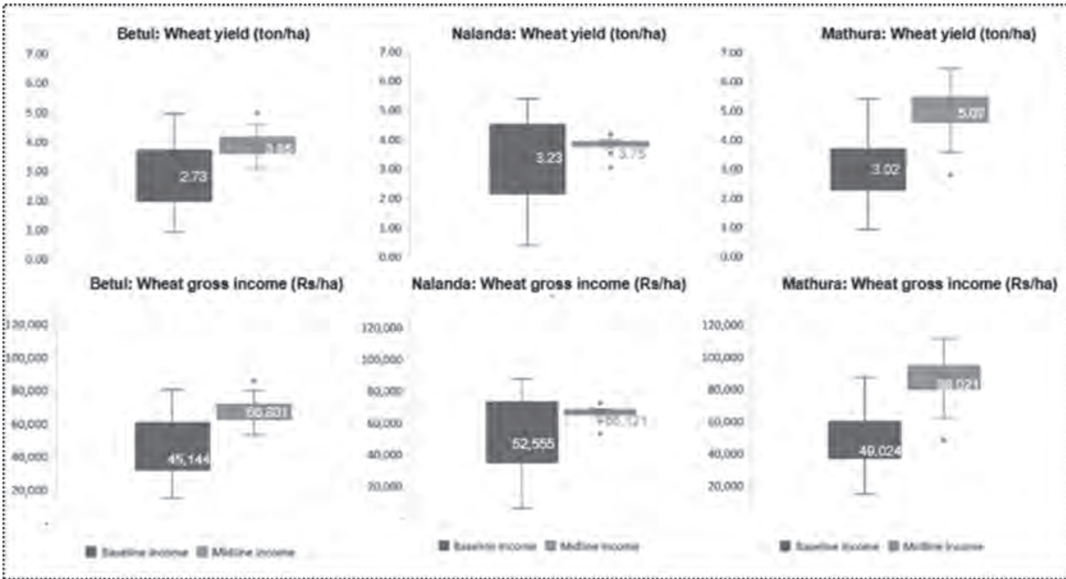

Figure 5: Change in yields and income of Rabi crop (Wheat) in all the three districts, as a result of technology adoption.

Increase in livestock yields

Promotion of several CSA livestock based practices and technologies through the Cattle Development Centers in two districts has helped in improving milk yields of the existing cattle breeds as seen in Table 2. Major CSA technologies include improved cattle breed (through Artificial Insemination), preventive animal health care, climate-smart housing for livestock and infertility camps among others. Over 1,000 farmers have opted for better breeds of animals through Artificial Insemination. Of the 1,570 animals inseminated, the success rate for pregnancy diagnostics has been 62% on an average, while 55% of those diagnosed have confirmed pregnancy. These new calves are expected to be more productive and less vulnerable to the climate stresses.

Table 2: Increase in milk yields of current cattle

Increase in milk yields	Mathura			Nalanda		
	Litres/day (before model)	Litres/ day (after model)	Change in yield (Litres/day)	Litres/day (before model)	Litres/ day (after model)	Change in yield
Cow	10.5	12.2	1.7	9.4	12.1	2.7
Buffalo	10.1	11.8	1.7	6.1	11.2	5.1

Increase in nutrient use efficiency

There is excess use of fertilizers including Urea and DAP across all the three districts which has been controlled through the CSA practice of soil management (Table 3). Additionally, capacity building and soil testing have been the major supporting activities to reduce the fertilizer inputs. As a result, nutrient use efficiency, specifically for nitrogen, has improved significantly across districts. Reduction in fertilizer input with a simultaneous increase in yield outputs have been the major driving factor for this improvement.

Table 3: Change in nitrogen use efficiency per ton per hectare of crop produced

Crop	Reduction in fertilizer (t/ha) from baseline	Increase in yield from baseline (t/ha)	Nitrogen use efficiency – baseline (yield output/ nitrogen input)	Nitrogen use efficiency – midline (yield output/ nitrogen input)	% improvement in nitrogen use efficiency per hectare
WHEAT					
Betul	-0.2	1.1	17.8	45.6	156.9%
Mathura	-0.3	2.1	15.5	53.5	245.4%
Nalanda	-0.5	0.5	6.6	13.8	109.5%
RICE					
Nalanda	0.6	2.6	6.4	53.0	724.0%
GRAM					
Betul	0.2	-0.4	14.8	45.7	210.0%
BAJRA					
Mathura	0.1	0.5	19.9	53.7	170.2%

6.2 Reducing Greenhouse Gas Emissions

Reduction in emissions through Nutrient Management

The CSA practice of Integrated Nutrient Management was adopted in all districts to manage the soil quality by reducing the use of emission intensive inorganic fertilizers such as Urea. The excess usage of these fertilizers was reduced by partially replacing them with organic fertilizer such as vermicompost. This resulted in more than 37% reduction on an average in overall CO2 emission per ton of crop production as seen in Table 4. This reduction has been the maximum for rice crop where the fertilizer usage was reduced by 0.6 tons per hectare, the highest among all crops and districts.

Table 4: Reduction in emission intensity

Crop details	Emission intensity – Baseline (Kg CO2 per Kg production)	Emission intensity – Midline (Kg CO2 per Kg production)	% change
WHEAT			
Betul	0.57	0.35	-39%
Mathura	0.52	0.28	-46%
Nalanda	1.01	0.55	-45%
RICE			
Nalanda	4.35	1.76	-59%
GRAM			
Betul	0.59	0.56	-6%
BAJRA			
Mathura	0.28	0.2	-29%

Reduction in emission through Manure Management

Livestock manure also contributes to greenhouse gas (GHG) emissions and its effective management can help in reducing these emissions. The CSA technology of biogas is helping reduce methane emissions through the use of surplus cow-dung produced by cattle, as well reducing firewood burning as fuel in the study districts. Table 5 explains the estimated amount of GHG reduction through the use of Biogas in project districts. There are a total of 26 Biogas units, each of 2 cubic meter capacity in the three districts, with 6 being used to replace firewood as a cooking fuel.

Table 5: Estimated reduction in GHG emissions from usage of biogas

Estimated GHG reduction from using cow dung	Details
Amount of cow dung used per Biogas	25 Kg/Day
Dung produced per animal	10 Kg/Day
Number of animals required to produce dung	2.50
Emissions per animal per year	1.6 tons of CO2 eq.
Yearly emissions by animal per Biogas	4.00
Total number of Biogas in project areas	34
Total annual GHG (methane) emission saving from project Biogas	136 tons of CO2 eq./year
Total estimated GHG reduction from replacing firewood	Details
Firewood usage before Biogas	1.760 Ton/Year
Firewood usage after Biogas	0.208 Ton/ Year
Firewood usage reduction	1.552 Ton/ Year
Number of Biogas replacing firewood	6
Total firewood saved	9.31 Ton/ Year
Amount of fuel combusted	0.015 TJ/Ton
Emission factor for wood	112 Kg CO2/TJ
Total estimated GHG (CO2) emission saving from firewood replacement	15.6 tons of CO2/ year

Reduction in emission through Energy Management

Clean energy fuels such as solar are helping farmers replace the fossil fuel and other high emission energy sources. In one of the study districts, Betul, solar pumps of 1HP each have been introduced through the Custom Hiring Centers to provide farmers with access to clean energy irrigation sources, primarily for wheat crop in which less winter rainfall results in water scarcity impacting crop yields. The estimated GHG emission reduction potential of these pumps is 0.93 tons of CO2 Equivalent (Table 6). This technology, therefore, when scaled out, has the potential to fulfil the farmers' water requirements in adverse climate conditions while contributing to emission reductions at the same time.

Table 6: Estimated reduction in emissions from usage of solar energy

Emission reduction by using solar pumps	Details
Total Number of pumps in Betul	4
Total estimated area covered by the pumps	81 Ha
Estimated GHG reduction by replacing diesel pumps	Details
Irrigation from diesel pump	175 mm
Ground water depth	10 mm
Irrigation pump efficiency	30%
Diesel requirement	35 litres.
Emissions from diesel irrigation per pump	0.10 ton of CO2 Eq.
Total estimated emissions replaced from diesel irrigation	0.40 of CO2 Eq.
Estimated GHG reduction by replacing electric pumps	Details
Irrigation from electric pump	175 mm
Ground water depth	10 mm
Irrigation pump efficiency	30%
Electric units consumption	147 KwH.
Emissions from electric irrigation per pump	0.13 ton of CO2 Eq.
Total estimated emissions replaced from electric irrigation	0.53 ton of CO2 Eq.

6.3 Gender Inclusion in Technology Impacts

Increase in income

The institution of Custom Hiring Center, serves as a source of income for women farmers. The regular flow of income through renting technologies helps women build their adaptive capacity to deal with weather risks in agriculture and encourage them to be equal contributors to improved productivity. During the Kharif season in 2018, 3 of the CHCs have earned more than INR 5000 by renting out more than 6 types of CSA technologies.

Reduction in labour hours

CSA technologies including Direct-Seeded Rice (DSR) and Biogas are playing a key role in reducing the labour contribution of women in agriculture and related activities. While DSR eliminates the activity of transplanting rice, a task primarily performed by women farmers, the use of Biogas for cooking eliminates the need for firewood collection as fuel and also reduces the time taken to make cow dung cakes by women. Estimations show that there is a potential of reducing 1,800 labour days for women farmers in the study areas of Nalanda and Betul. At the same time, biogas plants can reduce more than 1,500 hours of firewood collection time for farmers in Betul district.