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Full Length Research Article

Socio-economic Impacts of Climate Resilient Agricultural Innovations in Eastern UP and North Bihar

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Abstract

The north-eastern plains of Uttar Pradesh and north Bihar are similar in geographical characteristics and marked by low development indices owing to poverty and poor socio-economic conditions. Climate change and induced disasters are exacerbating the vulnerabilities of small-marginal-women farmers in the region due to increasing flood-waterlogging induced crop losses, increasing input costs and economic marginalization, low extension services, lesser capacity to deal with hydro-met shocks and stresses leading to increasing frustration in farming and distressed migration. Women farmers have to bear the responsibility as farm managers without needed access to extension services and resources. The effects on agriculture income resulting from climate change impacts are transmitted to poor socioeconomic conditions of farm households, in particular and landless farm households, in general. Having access to information on adaptation to climate change is essential for improving socioeconomic conditions of rural population. This paper deals with the science and technology interventions undertaken towards developing climate resilient agro-based livelihood systems in the region to enhance socio-economic empowerment of small-marginal and woman farmers. The interventions have been part of a support programme of the SEED Division of the Department of Science and Technology, Government of India, undertaken during 2018-2022.

***Key words*:** Climate change adaptation, Floods and water-logging, Agro-based livelihood system, Socio-economic, Gender-friendly technologies

The north eastern plains of Uttar Pradesh (Trans-Saryu region) and north Bihar share similar agro climatic conditions. The area is also marked by huge proportion of small-marginal farmers with a significant proportion of landless farmers, poor Human Development Index (HDI), high dependence on weather-based livelihood systems and small landholding sizes (84% having less than one hectare of land), rainfall intensities, humidity, temperatures are on a changing trend in the region thereby, affecting lives and livelihoods of people, especially the poor population [1]. Increased intensities of rain fall (in 24 hOUrs cycle), frequent drought like situations due to no rain fall spans during monsoon, uncertainties of flood peaks, sudden increase in temperature during spring, etc., are few examples how farmers are experiencing the climate change impacts in this region. Climate projections also confirm that such incidences will increase in the coming decades thus, posing increased challenges before small land holding farmers especially the women farmers without access of knowledge and information and rights over the resources [2]. The unexpected heavy rain, intermittent dry spells and changing temperature and humidity regimes affect the livelihoods of people who are dependent on agriculture or related activities. The *Kharif* crop invariably suffers heavy damage due to recurrent floods or long durations of water-logging in low-lying areas [3].

Historically, the region has had mild climate conditions; the winter of December- February is followed by the summer between March to May and the monsoon season from June to September. The summers are hot and winters are cold and dry. The south-west monsoon brings 80 percent of the rain here, although rain due to western disturbance and northeast monsoon also contribute small quantities toward the overall precipitation of the region [4]. The region records an average annual mean rainfall of 1156 mm. The average annual mean temperature is 25.57°C with the average annual mean maximum temperature around 31.97°C and the average annual mean minimum temperature is 19.17°C. However, in the last few years there has been an alteration in the temperature pattern, rainfall amount and moisture content in the air. During the last 30 years, decadal comparison of annual mean maximum and minimum temperature with summer and winter is showing an increasing trend. There has been an increase of 0.42 degree centigrade in the maximum and minimum temperature during 1990 and 2019 (Fig 1). The analysis of annual rainfall trend

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shows that between 1992 to 2021 the average annual rainfall increased from 1029 mm to 1357 mm but after 2009 the average annual rainfall is on a decreasing trend. During 2010 to 2019, the average rainfall decreased from 1357 to 1081 mm (Fig 2).

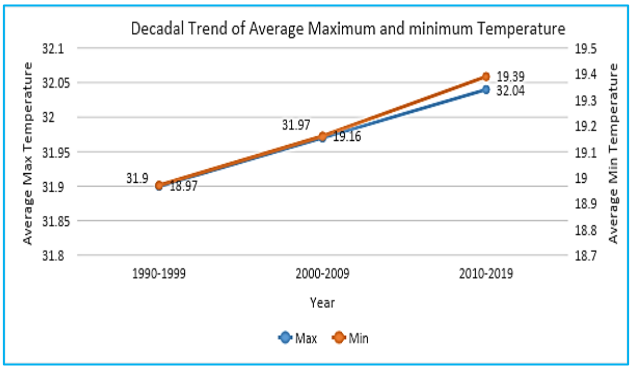

Fig 1 Decadal trend of average maximum and minimum temperature of Eastern U.P region

Analysis of seasonal rainfall variation shows an increase in rainfall during the pre-monsoon period i.e., in summer months, particularly in the month of May and June. However, during the monsoon period rainfall amounts are decreasing.

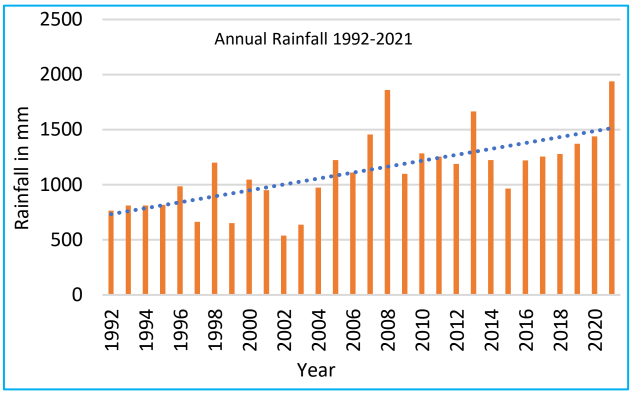

Fig 2 Annual trend of rainfall data of Eastern Uttar Pradesh

Socio-economic vulnerabilities of small-marginal and woman farmers

Climate change impacts are exacerbating the vulnerabilities of small-marginal-women farmers in the region due to increasing flood-waterlogging induced crop losses, increasing input costs and economic marginalization, low extension services and hence, lesser capacity to deal with hydro-met shocks and stresses leading to increasing frustration in farming and distressed migration. Women farmers have to bear the responsibility as farm managers without needed access to extension and resources (land ownership, decision making and so on).

In this dilapidated socioeconomic and technically backward area, changing climate thresholds and intensifying hydro-meteorological disasters have made this region more vulnerable and trapped the people into a prolonged vicious cycle of poverty and indebtedness. The effects on agriculture income resulting from climate change impacts are transmitted to poor socioeconomic conditions of farm households, in particular and landless farm households, in general. Having access to information on perception and adaptation to climate change is essential for improving socioeconomic conditions of rural population. This calls for an urgent attention to provide technological and programmatic support towards climate-resilient agro-based livelihood systems for these poor and marginalized farming communities.

This paper is based on the methods adopted for developing end-to-end packages for a resilient agriculture production system in flood-prone areas. The interventions have been part of the support programme of the Science for Equity Empowerment and Development (SEED) Division of the Department of Science and Technology, Government of India, undertaken during 2018-2022. The programme addressed agriculture and livelihood-related problems of small-marginal and women farmers for a resilient farm production system, resulting in increased productivity and reduced losses thereby enhancing net gains, while improving sustainability of the farm production system through environmental conservation measures. The programme also aimed to develop gender-friendly technologies to reduce the drudgery of women in agriculture, enhancing their ability to contribute in agro-based livelihoods. A total of 24 tools and technologies related to agriculture-based livelihoods were developed. The implementation of such techniques by the target farmers in their own fields helped develop live models for wider learning, dissemination and adoption by other farmers. Further, the technological innovations have also enhanced the socio-economic conditions of the targeted farmers, especially those of women farmers.

MATERIALS AND METHODS

Study area

The study area lies in district Gorakhpur, Uttar Pradesh and district West Champaran in Bihar (Fig 3). A total of 18 flood/water-logging affected villages were selected to work intensively with the small and marginal and woman farmers with 57% of the targeted communities belonging to socio-economically backward Scheduled Caste and Scheduled Tribes. The programme promoted technological innovations in agriculture and worked directly with 36 farmers (26 farmers from blocks Jungle Kaudiya and Campierganj, Gorakhpur and 10 farmers from block Nautam, West Champaran distrct) who developed "model farms" showcasing the innovations to enhance agricultural resilience.

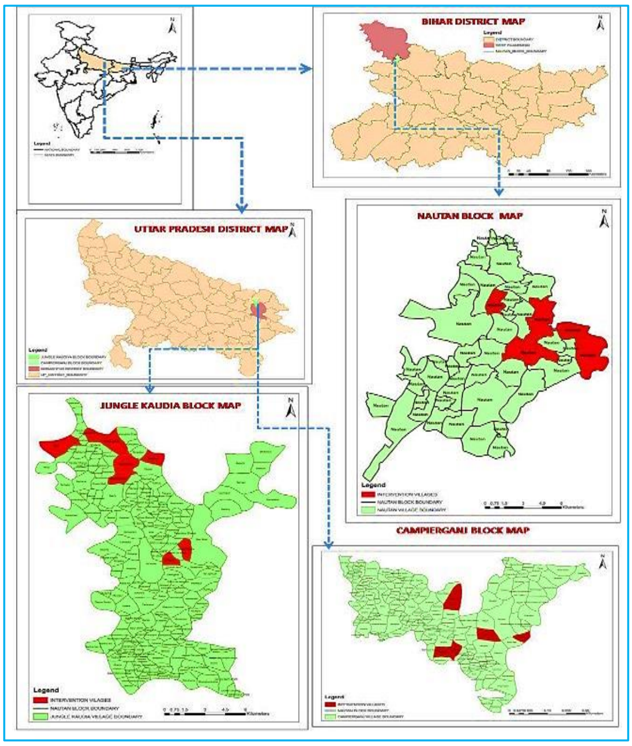

Fig 3 Study area

Science and technology interventions (STI) support for socio-economic empowerment

Science and technology innovations play a crucial role in small-scale farming and can significantly enhance the socio-economic empowerment of small and marginal farmers, especially woman farmers. In the Shared Learning Dialogues held with small-marginal and women farmers, it was realized that their socio-economic vulnerabilities need to be addressed through specific interventions that can enhance their resilience and empowerment. For such empowerment, the localized and customized science and technology innovations that can contribute to climate resilience in farming in flood affected areas along with its positive impact on the socio-economic status of the farmers were as below:

Increased agricultural productivity: Innovative techniques such as resilient crop varieties and seeds, inputs like bio-fertilizers, and bio-pesticides, innovations like multi-tier farming systems, raised nurseries and so on, which can enable small-marginal and woman farmers to reduce their input costs and crop losses, enhance net gains with increase crop yields and overall productivity.

Efficient resource management: Science and technology can facilitate the adoption of efficient irrigation systems (e.g., drip irrigation), water conservation and management techniques (e.g. mulching techniques) and energy-efficient equipment. This can help the farmers to make the most of scarce resources, such as water and energy, leading to increased agricultural sustainability and profitability.

Enhanced knowledge and capacity for better decision making: Localized weather and agro advisories through SMS based system can revolutionize access to agricultural information for small-marginal farmers. This access to regular weather forecasts, along with suggestions on cropping system through mobile can help farmers in taking informed decisions, planning better and responding to challenges effectively. Enhanced capacities of farmers have also given them a unique identity in their community who function as torch-bearers for other farmers.

Capacity building and social entrepreneurship: Science and technology-based training and capacity-building programs can empower farmers with the knowledge and skills to adopt resilient practices and technologies effectively. Training in climate resilient agricultural practices, establishing social entrepreneurship to strengthen livelihoods and financial literacy can enhance their ability to take control of their livelihoods. Increased access to services and institutional linkages with Agricultural Universities, Krishi Vigyan Kendras and other resource institutions can not only capacitate them for resilient and profitable farming but also enhance their social recognition.

By leveraging science and technology innovations, small-marginal and woman farmers can move away from subsistence farming and transition to more profitable and sustainable agricultural practices. These advancements not only enhance their productivity and income but also contribute to poverty reduction, food security, socio-economic empowerment and overall livelihood improvement.

A number of approaches have been taken in a scientific and technical manner under the following heads:

Problem identification and feasibility study

Prior to interventions, a brief survey was conducted for a detailed feasibility analysis of the field related problems among the communities of these marginal farmers and a baseline data has been created through focused group discussions during the year 2018-19. Based on the feasibility study, the main problems identified in the study area were: Mono-cropping pattern, lack of resilient seeds, cultivation in waterlogged areas, increase in input costs, crop losses, low farm productivity/income, degradation of the ecosystem, women's drudgery, non-accessibility to knowledge, lack of post-harvest technology limiting the return from perishable agro products, lack of market and institutional support etc.

Criteria of selection of science and technology solutions

- Flood and waterlogging situation, silted land
- Addressing limitations of small land holding
- Addressing needs and priorities of communities belonging socio-economically backward class (SC/ST)
- Low cost of technology
- Utilizing of local resources
- Potential to scale
- Potential to leverage fund from Govt. and other knowledge institutions

The process of developing S&T solutions and innovations was guided through the following principles:

- Synergy of local wisdom and scientific knowledge
- Trials, data acquisition, feedback and modifications in technology
- Training and orientation
- Farmer to farmer learning: Space for research and innovation
- Linkages: Market and other knowledge institutions.

RESULTS AND DISCUSSION

The technology and methods developed can be categorized into two parts – Direct interventions –largely focusing on farm-based innovations leading to socio-economic empowerment of farmers and the Contributory interventions – done at ecosystem and extension levels that supported in the process of enhancing resilience and empowerment. The below diagram depicts the technologies developed under broad thematic areas which were linked to farm level management, extension, post-harvest processes, addressing drudgery, soil fertility management and preparedness to deal with hydro-met induced shocks and stresses:

Direct interventions

Farm level

Multilayer farming with appropriate crop combinations

The technology, appropriate crop combinations with proper space and time management is a unique and situation-based solution to the small and marginal farmers in flood prone areas. It focuses on smart farm planning and appropriate crop combinations of vegetables with different root zones, maturity period, demand for solar energy (sunlight) and plant height. The inherent uniqueness and competitive advantages of the technology has not only paved a way for optimum land utilization but also opened up avenues for farmers to reduce input cost and increase the profit margin to an extent of more than double [5-6].

Portable and moveable nursey platform

For vegetable growing farmers, raising nurseries during summer for transplanting in winter is extremely difficult due to extensive waterlogging during monsoon period. The portable and movable nursery technology is a low tunnel type structure made with iron stand, wire and plastic sheets used for roof covering of the tunnel with a semi-circle shaped construction having low height. These tunnels facilitate the entrapment of carbon dioxide, thereby enhancing the photosynthetic activity of the plants and hence, stimulating healthy plant growth [7].

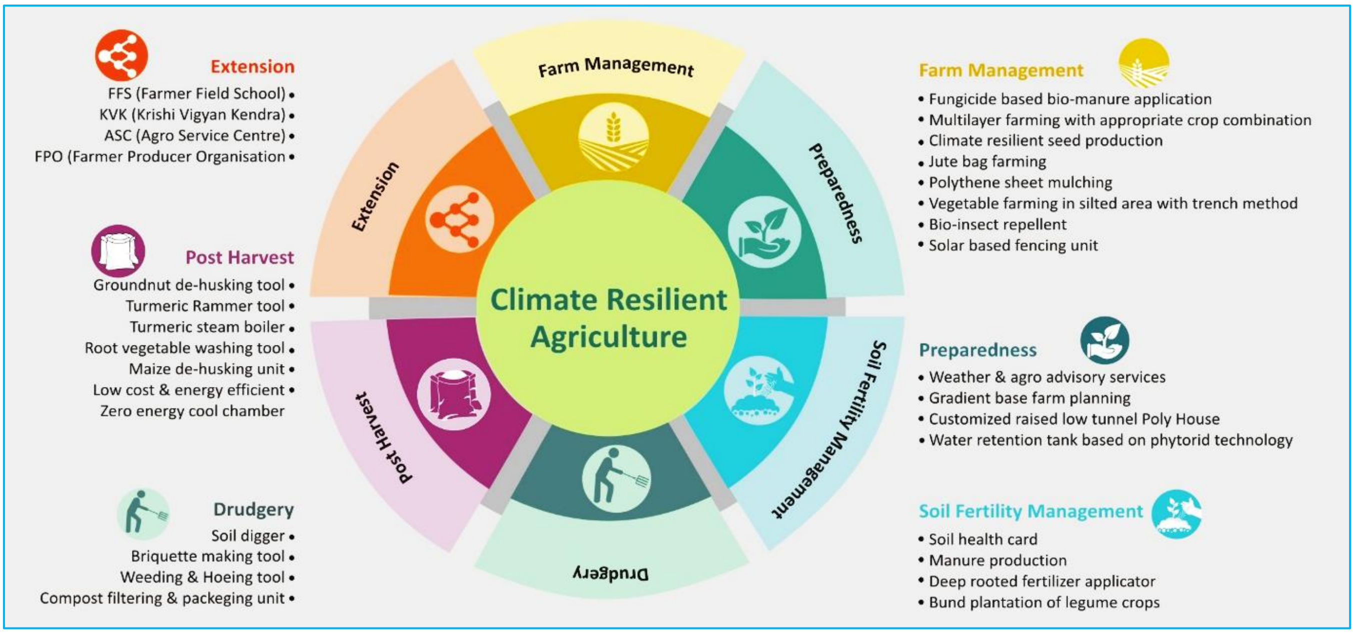

Fig 4 Climate resilient agriculture technologies

Eco-friendly bio insect repellent

The insect repellent solution is made up of locally available bio resources which is very effective especially on shoot borer, fruit borer, fruit fly, aphids, grasshopper and Gandhi bug in vegetable crops. It also has anti-fungal property and anti -microbial substances which act against soil borne pathogens viz. *Alternaria sp*., *Fusarium sp*. and *Pytheium*. Further, it is helpful in increasing chlorophyll content in leaves significantly.

Weeding and hoeing equipment

Weeding in crops is a major challenge for the farmers as it is time, labour and cost-intensive activity. The innovative weeding and hoeing tool is made with locally available resources, consisting of a cycle wheel with an iron frame handle. At the bottom of this frame, three V-shaped (bent inside) blades are attached with nut bolts. These blades are adjustable and can be replaced as per need or the distance between the two ridges in lined- sown crop. Cutting and uprooting of weeds in the field is easily possible through a push and pull type action with this tool. The capacity of this tool is 120 m^2/hr/person which means that with the help of this tool, a farmer, even a woman farmer, can easily complete weeding/ hoeing activity in one acre of land in just 2 days, as against 8-10 days of labour with the traditional tools [8-9].

Zero energy cool chamber for perishability management in vegetables

The perishability of vegetables and small shelf life especially green and leafy vegetables is one of the major problems for farmers causing losses and distressed sales. The waste percentage of vegetables goes up to 35% due to improper and poor post-harvest practices [10]. A low-cost on-farm storage system 'Zero Energy Brick Cooling Chamber' (ZEBCC) has been established to reduce the problem of short-term perishability of green and leafy vegetables particularly during summer which works on the principles of 'evaporative cooling technique'. The chamber is constructed using locally available raw materials such as bricks, sand, bamboo, dry grass and jute cloth etc.

Groundnut de-husker

Women in the region used to engage in removing the cover from the pods of groundnut which is a difficult, time-intensive and laborious task. An iron machine has been prepared at the local level, which can be easily operated by both men and women [11]. It takes only 15 minutes to de-husk 5 kg of groundnut.

Turmeric steam boiler

Boiling turmeric was the most laborious and costly task. Along with this, the smoke emanating from the burning of firewood and agricultural residues for a long time was also adversely affecting the health and the environment. Particularly the health of women who were staying in the smoky environment for a long time that caused eye, headache and breathing issues. It was time consuming as it took 4-5 days to dry the turmeric boiled in the pan. Turmeric steam boiler takes only 55 minutes to boil 35 kg of turmeric.

Contributory interventions

Ecosystem level

Phytorid technology for wastewater treatment

The low-cost drainage water treatment technique has been installed to improve the village ecosystem. It consists of a planted filter bed containing gravel, sand, soil and the system follows a natural way of biologically processing domestic effluents. This technology is a better solution for domestic waste water treatment, which improves drainage systems [12]. The treatment system has zero maintenance, and low operating costs because it considers the natural slope of the ground, so that water flows from one device to another without any external energy input such as a motor pump, etc.

Extension level

Disseminating technologies through community institutions and social entrepreneurship

Community institutions like Self Help Groups, Farmer Field Schools, Agro Service Centers and Farmer Producer Organizations, have proven to be effective mechanisms scaling up the technologies developed under the programme. Engaging woman farmers in social entrepreneurship activities such as processing, packaging and marketing of vermicompost, turmeric, bio-repellants and so on have made women self-reliant and improved their socio-economic identities [13].

Overall, the small-marginal farmers, especially women farmers were capacitated and empowered which has helped them to have a better livelihood with access to government programs and knowledge centers. They have established their identity as woman farmers and Trainer and gained respect in villages. They are also able to voice their concerns and priorities in village institutions like Gram Panchayat as well as claim their position in such institutions [14].

Socio-economic impact analysis

The climate resilient interventions in agriculture was continued for 5 years, and thereafter, it was deduced that along with farm-level resilience, the interventions have resulted in strong socio-economic impacts of small-marginal farmers, especially woman farmers.

The socio-economic impacts of the farmers were seen on the following 5 indicators:

Table 1 Linkages between S&T interventions and socio-economic impacts

Domain	Socio-economic indicator	S&T interventions – Socio economic impact linkage
Production	Input in productive decisions Autonomy in production	S&T enabled techniques like multi-layered farming, low tunnel poly-house, raised nursery, time management for climate resilient vegetable farming leading to enhanced crop intensity up to 148 percent helped small farmers to increase their production in a small piece of land. The farmer led development of such techniques helped in confidence building of farmers, especially women farmers, for better decision-making capacity with acquired capacity and knowledge enhancement, at different levels of farm production and livestock.
Resources	Ownership of assets Purchase, sale or transfer of assets Access to and decisions about farm inputs	The production of farm inputs by farmers themselves like bio-insect repellent, fungicide-based bio-manure, adapting deep urea applicator in local context helped farmers on one hand to reduce input cost and at the same time control over such resources. The community-based waterbody management and treatment of grey water through Phytorid based constructed wetlands also helped farmers to enhance their access and control over common property resources providing ecosystem services. This helped in enhancing participatory management of such resources for the common good of community.
Income	Control over use of income Increased productive assets Better education of children Reduced distressed migration	Increasing input costs in chemical intensive farming is a major challenge for small land holding farmers depriving them from better income leading to economic marginalization. Enhanced crop intensity (multi-layered farming, vegetable in silted area and groundnut integration), appropriate mechanisms for reducing losses (jute bag farming, time management, raised bed nursery, flood resilient seed production, solar fencing, polythene sheet mulching) and production and use of bio-inputs (bio-manure, bio- insect repellent etc.,) helped significant reduction in input costs and losses due to floods-waterlogging leading to better income. One example is techniques related to pest control where the total input cost reduced by 66.81% (i.e., From Rs. 1020.56 to Rs. 338.65) on an average. Enhanced income helped expenses on house repair/construction, education of children, buying livestock (mainly goats) and reduced dependency on high interest loans. With enhanced income and developed confidence women farmers were in better decision-making position at household and community level.
Leadership	Group membership Contesting in local elections Working as trainer/facilitator	Besides the engagement of small land holding and women farmers in appropriate technology development/adaptation in local context, the farmers led community institutions like farmer field schools (experience sharing and problem-solving platforms), agro-service centres (self-managed farm input centres), farmer producer organizations (sale of produce) whereas helped in scaling the developed tools and techniques, it also helped in developing farmer trainers and resource persons. A number of women farmers were recognized in the process. The established credibility helped in developing their leadership in the community. A number of such small farmers also contested in Panchayat election successfully.
Time	Workload Leisure	Techniques like weeding and hoeing tool, soil digger, ground nut de-husker, compost filtering tool etc., helped in significant reduction of work load and time saving. Such techniques especially helped women farmers in reducing drudgery, allocation of time to productive and domestic tasks and satisfaction with the time available for leisure activities.

Alkire *et al*. [15]

The post intervention assessment with farmers revealed that the technologies helped them to improve their status and credibility amongst community. The evolved confidence and morale of small and women farmers helped them for assertive actions, linkage with government services and institutions, leadership and control over common resources towards a sustained socio-economic empowerment. The enhanced scientific bent of mind and knowledge leadership contributed towards establishing recognized role as trainers and resource persons both within community and government [16-17].

CONCLUSION

The experiences gained from the programme confirms that there is great scope for agro-based livelihood in Eastern U.P and North Bihar region. In order to minimize the impact of changing climate conditions on the agro-based livelihood system of the small land holding farmers, it is needed that locally appropriate technology development is important, which can also enhance their socio-economic conditions. The linkage with relevant government schemes and programs helps in mobilizing resource linkage for resilient livelihoods. Linkage with research and knowledge center helps the farmers to access resilient mechanisms in strengthening farm-based livelihoods. Weather based agro-advisories in the local context have been quite helpful in strengthening the livelihood system. It is also important that mechanisms for farmer-farmer flow of information and exchange is facilitated so that farmers also contribute to developing and disseminating resilient practices. In the flood affected areas of Gorakhpur (UP) and West Champaran (Bihar), the scientific innovations and interventions in agriculture have shown a paradigm shift in the overall approach to farming, especially by the small and marginal and women farmers. The resilient farming techniques and technologies have resulted in reducing farm losses, decreasing input costs, thereby, enhancing overall gains in farming and improving their socio-economic conditions. The gain has not been only monetary, but the overall interest and inclination towards farming has enhanced in the small-marginal farming communities.

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