Innovations in Extension Approaches for Scaling Up of Climate Smart Agricultural Technologies

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Jointly Published By

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Programme Coordination

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This e-book is a compilation of resource material obtained from various subject experts for ICAR-CRIDA & MANAGE collaborative online training program on "**Innovations in Extension Approaches for Scaling Up of Climate Smart Agricultural Technologies"** conducted from September 23-27, 2024. This e-book is designed for researchers, academicians, extension workers and scholars engaged in natural resource management, rainfed agriculture etc.

Published for Dr. Sagar Hanuman Singh, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr. Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication

Foreword

ICAR-Central Research Institute for Dryland Agriculture is a premier national research institute under the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, New Delhi with a mandate to carry out basic and applied research in rainfed farming. ICAR-CRIDA is also working closely with different stakeholders towards the development of climate resilient agriculture in India.

India is highly vulnerable to climate change, with rising temperatures, erratic monsoons, and an increasing frequency of extreme weather events such as droughts, floods, and cyclones, which threaten agricultural productivity and rural livelihoods. Rainfed agriculture, covering nearly 55% of the net sown area, is particularly at risk due to shifting rainfall patterns and water scarcity. To address these challenges, scaling up climate-resilient technologies is crucial, including the adoption of drought- and flood-tolerant crop varieties, water-smart agriculture, integrated farming systems, agroforestry, and conservation agriculture. ICAR-CRIDA is implementing the ICAR flagship program, National Innovations on Climate Resilient Agriculture (NICRA), which plays a crucial role at the national level in developing adaptation and mitigation strategies for agriculture and allied sectors. These strategies are being demonstrated in over 150 villages representing key climate vulnerabilities. Efforts are also underway to scale up these technologies through the National Mission for Sustainable Agriculture (NMSA). Additionally, ICAR-CRIDA has developed approximately 650 district agricultural contingency plans in collaboration with all agricultural universities, several ICAR institutes, Krishi Vigyan Kendras (KVKs), and other key stakeholders across various agricultural sectors.

In this scenario, It is a pleasure to note that, ICAR-CRIDA, Hyderabad and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on and coming up with a joint publication as e-book on **“Innovations in Extension Approaches for scaling up of climate smart agricultural technologies”** as an outcome of this training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for various stakeholders across the country. I extend my best wishes for the success of the program. I would like to compliment the efforts of Course Directors from ICAR-CRIDA and MANAGE for this valuable publication.

Dr. V.K Singh
Director,
ICAR-CRIDA, Hyderabad

Foreword

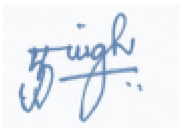
Climate change is no longer a distant threat, it is a current reality affecting millions of farming households. India ranks among the most climate-vulnerable countries globally, with its agriculture sector experiencing increasingly erratic monsoons, prolonged dry spells,unseasonal rainfall, floods, cyclones, and rising temperatures. Rainfed regions, covering about 55% of the net sown area and supporting a large share of small and marginal farmers, are particularly at risk. Ensuring their resilience is not only critical for food and nutritional security but also for the socio-economic stability of rural India.

ICAR-Central Research Institute for Dryland Agriculture (ICAR-CRIDA) has been a national leader in addressing these challenges through pioneering research and development works. National Institute of Agricultural Extension Management (MANAGE), on its part, has consistently focused on capacity building and policy support for agricultural extension systems. Through its national and international training programs, policy advocacy, knowledge platforms, and institutional development activities.

Collaborative training program of ICAR-CRIDA and MANAGE, culminating to bring about an e-book titled "Innovations in Extension Approaches for Scaling up of Climate Smart Agricultural Technologies." I am glad to see that this publication reflects the innovations, scalable models and participatory extension approaches that have shown promise in real-world field conditions.

This timely initiative reflects the shared commitment of both institutions to building the capacities of extension professionals and promoting sustainable, climate-resilient agriculture across India.

I congratulate the Course Directors and faculty teams from ICAR-CRIDA and MANAGE for bringing out this e - Publication.



(Dr.S.H.Singh)
Director General, MANAGE

Preface

This e-book is an outcome of collaborative online training program on **"Innovations in Extension Approaches for scaling up of climate smart agricultural technologies"** jointly organized by ICAR-CRIDA & MANAGE, Hyderabad during September 23-27, 2024. It is a result of collective efforts, experience, knowledge and wisdom of several authors. This book is intended for research scholars, extension professionals and department officials who are the key players in the technology transfer. Bringing views of experts from different fields of agriculture through this training programme suffice opportunities for cross-learnings among trainees.

Scaling approaches in agriculture are crucial for ensuring the widespread adoption of innovative technologies, enhancing productivity, and building resilience against climate change and other challenges. As agriculture plays a vital role in food security, rural livelihoods, and economic growth, scaling up proven technologies and best practices can bridge the gap between research innovations and on-ground implementation. In line with the theme of this training, experts from ICAR-CRIDA, MANAGE, ICAR-ATARI, and NGOs such as Digital Green have been invited to provide a common platform for officials engaged in agriculture and allied sectors to deepen their understanding of the subject. We would like to acknowledge the cooperation and support received from all the authors and staff at ICAR-CRIDA and MANAGE, whose contributions have been instrumental in the timely publication of this book.

This book covers key topics such as climate-resilient agriculture, extension strategies for scaling up (ATARI Zone III experiences), AI and chatbots for climate-smart agricultural technology (experiences from Digital Green), extension strategies for upscaling millet crops, carbon offsets in agriculture and their potential for carbon credits, scaling strategies for adopting contingency plans for climate risk mitigation, digital tools for scaling agricultural extension models, gender issues in agriculture, and other relevant themes.

We hope this book serves as a valuable reference for various stakeholders working in this sector, and we welcome suggestions for future improvements.

September, 2024 Editors

Content

Chapter 1

Towards Vikasit Bharat through Climate Resilient Agriculture in India

V.K Singh[1], Jagriti Rohit[2] , Suvana Sukumaran[2]
[1]*Director and* [2]*Scientist ICAR-CRIDA, Hyderabad*

'Viksit Bharat 2047' is an ambitious initiative by the Government of India, aimed at transforming the nation into a fully developed country by 2047. This vision marks the centenary of India's independence and serves as a roadmap to establish India as a strong, self-reliant, and prosperous global leader. The initiative envisions building a robust, inclusive, and sustainable agricultural system focused on enhancing productivity, improving the income of farmers and agricultural workers, and ensuring food and nutritional security. This transformation is crucial for achieving equitable economic growth and reducing rural poverty. Climate change stands as one of the most pressing ecological, economic, and social challenges today, largely driven by greenhouse gas (GHG) emissions resulting from human activities. Agriculture and food production systems are particularly susceptible to the impacts of climate change, which pose significant risks to food and water security and impede efforts to meet the Sustainable Development Goals (SDGs). Extreme weather events—such as erratic rainfall, floods, droughts, and heatwaves—have a profound effect on food security, especially in rural communities. Given that nearly half of India's workforce is involved in agriculture, it is vital to enhance farmers' incomes to promote inclusive and sustainable growth, particularly in light of the widespread occurrence of small landholdings and the sector's limited contribution to the overall GDP. From 1991-92 to 2023-24 (based on second advance estimates), India's overall GDP has grown at a long-term rate of 6.1%, while agricultural GDP has lagged behind at just 3.3%. The majority of Indian farmers fall into the small and marginal category, which restricts their access to technology and resources, making them especially vulnerable to the challenges presented by climate change. The IPCC AR-5 report forecasts a decline in crop production by 10-40% between 2080 and 2100 due to climate change. Crop simulation models indicate that rainfed rice yields in India could decrease by 20% by 2050 and 47% by 2080, while irrigated rice yields may drop by 3.5% and 5%, respectively. Nevertheless, effective mitigation strategies could potentially increase irrigated and rainfed rice yields by about 17% and 20%. Additionally, wheat yields are projected to decline by 19.3% by 2050 and by up to 40% by 2080, with a temperature increase of just 1°C possibly leading to a reduction in production by 6 million tons. By adapting farming practices—such as adjusting sowing times, utilizing climate-resilient crop varieties, and optimizing fertilizer and irrigation management—yields could improve by over 10%. Kharif maize yields may also see declines of 18-23% by 2050 and 2080; however, with suitable adaptation measures, a yield increases of around 10% is feasible by 2050. Beyond reducing agricultural productivity, climate change also impacts the nutritional quality of crops. To address these pressing challenges, it is crucial to transition towards climate-smart agriculture. Implementing climate-resilient farming techniques can help maintain productivity while protecting the agricultural sector from climate-related risks.

Climate Resilient Agriculture

The Intergovernmental Panel on Climate Change (IPCC) defines resilience as the capacity of a system and its components to anticipate, absorb, adjust, or effectively recover from hazardous events. This encompasses maintaining, restoring, or enhancing its essential structures and functions. For Climate-Resilient Agriculture (CRA) to yield long-term positive outcomes, it must prioritize overall sustainability. CRA, which incorporates both adaptation and mitigation strategies, is essential for achieving sustainable development in an evolving climate. It entails the integration of adaptation, mitigation, and various agricultural practices to bolster the system's capacity to handle climate-related disruptions, allowing it to endure damage and recover swiftly. Acknowledging this need, the Indian Council of Agricultural Research (ICAR) has initiated a significant project called the National Innovation in Climate Resilient Agriculture (NICRA). This project examines the effects of climate change on agriculture across crops, livestock, horticulture, and fisheries while also focusing on developing and promoting climate-resilient agricultural technologies for vulnerable regions in India. In collaboration with various ICAR institutes, the Indian National Agricultural Research System (NARS) has created several advanced crop varieties designed to withstand abiotic stresses such as heat, flooding, and submergence. These varieties assist farmers in mitigating risks associated with extreme weather events. The adoption of climate-resilient crop varieties, combined with effective adaptation and mitigation strategies, can significantly reduce yield losses under adverse climatic conditions. As part of the NICRA initiative, 22 climate-resilient crop varieties and hybrids—including rice, maize, lentils, mung beans, and tomatoes—have been developed to endure climatic stresses. Additionally, efforts have been made to enhance heat tolerance in wheat, improve submergence tolerance and nitrogen use efficiency in rice, strengthen drought resistance in maize, and increase the adaptability of black gram to heat, drought, and photothermal variations. These initiatives aim to empower farmers by promoting agricultural sustainability in the face of climate change. Over the past decade (2014-2024), ICAR has introduced 2,593 crop varieties, with 2,177 demonstrating resistance to one or more biotic and abiotic stresses.

Crop Diversification and Natural Resource Management

Crop diversification is an effective approach to reducing carbon emissions, with potential reductions ranging from 32% to 315% (Yang et al., 2014). The primary goal of diversification is to expand crop production while reducing risks, making it a crucial strategy for adapting to climate change. In India, this shift is reflected in the transition from traditional, less profitable crops to high-value alternatives. This method is particularly beneficial for rainfed areas, as it reduces vulnerability to drought and ensures a more stable yield under climate-resilient agricultural practices. Incorporating pulses as cash crops, cover crops, or intercrops plays a vital role in reducing nitrogen fertilizer dependency at different crop cycle stages. Additionally, high-value crops such as spices and horticultural crops enhance profitability and long-term sustainability. Various state-specific cropping systems have been identified, and efforts are being made to implement them effectively. Integrated Farming System (IFS) models are being diversified by incorporating horticulture and agroforestry components, making agriculture more resilient to climate change. Given their sustainability and profitability, these diversified farming models have been integrated into several state-level agricultural programs.

The distribution and intensity of rainfall are increasing, leading to significant reductions in agricultural production. Therefore, it is crucial to collect rainwater at the place where it falls. To achieve this, various water harvesting structures have been developed. Location-specific technologies for rainwater harvesting, such as farm ponds, percolation tanks, and check dams, have been developed. Groundwater recharge technologies include open well and tube well recharge models, which have been developed and expanded. The collected water has been utilized to expand the agricultural area and improve crop rotation, leading to increased yield and profitability. Both in-situ and ex-situ water harvesting structures have facilitated the efficient use of collected water, resulting in higher yields and net profit despite reduced rainfall.

Apart from water, soil health management is also crucial for sustainable agriculture. The objective of soil health management is to promote crop- and location-specific sustainable practices, including residue management, organic farming, nutrient management, balanced fertilizer use, and reducing soil erosion and degradation. Conservation treatments have improved soil aggregation and water stability. Balanced fertilization and integrated nutrient management systems are key to sustainable crop production, as they aid in carbon sequestration in soil, enhance structural stability, and improve crop yields.

Climate-Friendly Measures and Their Impact

As a result of implementing climate-resilient measures, greenhouse gas (GHG) emissions (CO2, CH4, and N2O) from various production systems (annual and/or perennial crops, irrigated rice, inputs, livestock, forestry, and land-use changes) in seven villages of Gujarat and Rajasthan were assessed and converted into equivalent values (tons of CO2 equivalent). The findings indicated negative values, suggesting that these regions have reduced GHG emissions and now act as carbon sinks rather than sources.

Sustainable Technologies to Prevent Crop Residue Burning

Several sustainable and effective technologies are available for managing crop residues instead of burning them. The baler machine converts residues into bales for use as fuel in biomass-based energy plants. The straw chopper-cum-shredder chops the residue and incorporates it into the soil, facilitating zero tillage sowing. The straw management system in paddy combine harvesters helps evenly distribute rice straw in fields.

Rotavators and reversible moldboard plows help incorporate crop residues into the soil, enhancing its fertility. Additionally, crop residues can be used as livestock fodder, bedding material, and soil mulch in orchards. These technologies not only ensure environmental conservation but also improve soil health, conserve biodiversity, and contribute to energy production. By adopting these technologies, farmers can achieve economic benefits while becoming part of a sustainable agricultural system.

Climate-Resilient Villages (CRVs)

According to the Intergovernmental Panel on Climate Change (IPCC) protocol, an assessment of climate risk and agricultural vulnerability has been conducted at the district level for 651 agriculture-dominated districts. Among the 310 districts identified as vulnerable, 109 districts were classified as 'very highly' sensitive, while 201 districts were categorized as 'extremely' sensitive. District Agriculture Contingency Plans (DACP) have been prepared for these 651 districts to tackle weather-related anomalies and recommend location-specific climate-resilient crops, varieties, and management practices for use by state agricultural departments.

To enhance farmers' adaptation to climate change, the concept of "Climate-Resilient Villages" (CRVs) has been introduced under the NICRA (National Innovations on Climate Resilient Agriculture) project. Demonstrations of location-specific climate-resilient technologies have been conducted in 448 CRVs across 151 climate-sensitive districts in 28 states and union territories. Through its NICRA project, ICAR raises awareness among farmers about the impact of climate change on agriculture. Capacity-building programs are being conducted to educate farmers on various aspects of climate change to facilitate the widespread adoption of climate-resilient technologies.

Livestock and Fisheries

Climate change is negatively impacting livestock and fisheries, but these challenges can be mitigated by adopting climate-resilient strategies. Indigenous livestock breeds possess traits such as heat shock proteins, air coat color, and wool-like hair, which provide heat stress tolerance. These traits can be utilized in future breeding programs to develop breeds capable of withstanding high temperatures.

Additionally, various feed supplements have been identified and successfully tested to reduce heat stress in livestock. Studies on pre-fed feeding have shown that it not only reduces stress levels in animals but also decreases methane emissions. The inclusion of chromium propionate and mineral supplements (such as copper, magnesium, calcium, and zinc) in animal feed and fodder has significantly improved heat stress tolerance in livestock. Furthermore, custom-designed shelter systems, such as structural modifications, help protect animals from heat stress.

By adopting these advanced measures and strategies, livestock production can be made sustainable and climate-resilient, thereby improving both farmers' livelihoods and animal health. Given the impacts of climate change, significant steps have also been taken to enhance resilience and adaptation in the fisheries sector. Climate change is altering fish breeding cycles, leading to changes in breeding periods and seasonal shifts. Extensive studies have been conducted to understand these changes and develop appropriate strategies accordingly. The blue carbon potential of mangroves and marine algae has been assessed, as these ecosystems have a high capacity for carbon sequestration. Additionally, the cultivation of climate-resilient marine algae has been promoted, enhancing carbon sequestration potential and mitigating climate change impacts. Recirculatory Aquaculture Systems (RAS) have been developed on a pilot scale for cold-water fish species under controlled environments with minimal water use. This system represents a significant initiative for climate-resilient aquaculture. These measures in the fisheries sector will not only help mitigate the effects of climate change but also strengthen sustainable development and rural livelihoods.

Initiatives for Scaling Up Climate-Resilient Agriculture

Under the Maharashtra Climate-Resilient Agriculture Project (PoCRA), 5,000 villages have been included. This project, initiated with World Bank support at a cost of $649 million, aims to protect farmers from climate change impacts and make agriculture more sustainable. To promote climate-smart agriculture in South Asia, the Consortium for Scaling Up Climate Smart Agriculture (C-SUCSeS) has been launched. Led by C-CAFS, this initiative has been implemented in eight SAARC member countries with financial assistance of $1.5 million from the Asian Development Bank (ADB).

Additionally, climate-resilient agricultural initiatives have been introduced in Telangana, Bihar, Odisha, and Tamil Nadu to enhance climate resilience in agriculture and secure farmers' livelihoods. These efforts are not only stabilizing agricultural production but also mitigating the effects of climate change.

Conclusion

To achieve the goal of a "Viksit Bharat 2047," it is imperative to make the agricultural sector more resilient and adaptable to climate change. Assessing the impact of climate change at the sub-district level and formulating location-specific solutions should be a priority. Additionally, developing climate-resilient indicators at the farmer and village levels will ensure stability and progress.

Under the vision of a developed India, climate-resilient agriculture should be integrated with advanced research and modern technology. Novel solutions to combat climate change can be achieved through system approach modeling, artificial intelligence (AI), precision agriculture (PA), and plant phenomics. GHG flux towers should be installed to monitor and control greenhouse gas emissions.

The nationwide implementation of agricultural contingency plans and the large-scale adoption of climate-resilient technologies—such as improved crop varieties, water management, and crop residue management—will strengthen sustainable development. Expanding climate-resilient villages in vulnerable districts will stabilize rural economies.

This initiative will not only protect rural communities from climate change impacts but also ensure food and nutritional security. By integrating technologies developed under projects like NICRA, these villages can be established as climate-resilient models. Climate-resilient agriculture is a key pillar in realizing the vision of Developed India 2047. It will not only reduce greenhouse gas emissions but also empower rural communities and promote sustainable development. Now is the time to make the agricultural sector more resilient, sustainable, and inclusive to ensure that India emerges as a developed nation by 2047.

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Chapter 2

Scaling Approaches: Concept and Applications in Agricultural Extension

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Scaling Up: Expanding Impact and Reach

Introduction

Scaling is a multifaceted concept with various interpretations. However, there's a general agreement on three key dimensions: scaling out, scaling up, and scaling deep. Each dimension represents a unique approach to expanding the impact of successful interventions. Scaling is a learning process.

Defining the Dimensions of Scaling

Scaling Out: Horizontal Expansion

Scaling out refers to the geographical spread of successful technologies and knowledge to a wider audience, specifically targeting similar stakeholder groups. It's a horizontal expansion characterized by quantitative processes.

- **Key Processes:** Replication, expansion, extension, adoption, dissemination, technology transfer, mainstreaming, rollout, and multiplication (Wigboldus and Leeuwis, 2013).

Scaling Up: Vertical Expansion and Institutionalization

Scaling up takes a vertical approach, extending the reach of successful technologies and knowledge beyond the initial intervention area. This involves engaging additional stakeholders and institutions at various levels (e.g., from village to county, district, region, and national levels).

- **Key Processes:** Transition, institutionalization, transformation, integration, incorporation, and development (Wigboldus and Leeuwis, 2013).

Scaling Deep: Transforming Values and Relationships

Scaling deep addresses the need for lasting change by focusing on transforming people's values, cultural practices, and relationships. It recognizes that durable change is achieved only "when peoples' hearts and minds, their values and cultural practices and the quality of relationships they have are transformed" (Moore *et al*., 2015).

Scaling Up: A Definition

"Scaling up means expanding, replicating, adapting and sustaining successful policies, programs or projects in geographic space and over time to reach a greater number of rural poor."

Dimensions of scaling out and up (Gundel et al., 2001)

- Quantitative scaling up is the geographical spread to more people and communities within the same sector or functional area. It is also referred to as horizontal scaling up or scaling out. It occurs when a programme expands its size by replication in various places or by increasing its beneficiary base in a given location

- Functional scaling up is expansion by increasing the scope of activity. For instance, a programme initially specialised in agricultural development may add nutrition, health, or literacy activities.

- Political scaling up refers to expansion through efforts to influence the political process and work with other stakeholder groups, with state agencies, parliamentarians and political parties among others. He mentioned that through political scaling up, individual organisations can achieve greater influence, protect their efforts from countervailing political interests and affect political and institutional change that sustains scaled up interventions.
- Organisational (or institutional) scaling up means the expansion of the organisation implementing the intervention, or the involvement of other existing institutions, or the creation of a new institution. This can involve both horizontal and vertical organisational expansion, the former involving similar institutions while the latter means going up the ladder from community to local to regional to national (and in some cases even supra-national) institutions.

Approaches to Scaling: A Learning Process

The early work on scaling was undertaken by David Korten (1980). Korten's model portrays scaling as an integral part of the learning process. The learning process approach proceeds through three successive stages, each of them involves a different learning task. It also highlights that some of the trade-offs may be made during the process.

- **Stage 1 – Effectiveness:** Developing a solution that works. Focus is on a high degree of fit with beneficiary needs.
- **Stage 2 – Efficiency:** Finding a way to deliver the solution at an affordable cost. Focus shifts to reducing input requirements per output unit. At this stage, some loss in effectiveness might happen in exchange for efficiency.
- **Stage 3 – Expansion (where scaling occurs):** Developing a way to deliver the solution at a larger scale. At this stage, both effectiveness and efficiency might suffer due to trade-offs with expansion requirements. They will be maintained at an acceptable level.

The Innovation, Learning, and Scaling Up Phases

Scaling is part of the triad “innovation – learning – scaling up” (Linn et al. 2010). This presents scaling as part of a dynamic and interactive process, which includes three phases: innovation, learning and scaling up.

1. **Innovation Phase:** During the innovation phase a new idea, model or approach is embedded in a pilot intervention or project, which by itself has limited impact. We adopt a broad definition of innovation. It involves implementing or demonstrating new ideas or practices, including:
    - Technical innovations (e.g., new seeds, growing techniques)
    - Process innovations (e.g., mobilizing communities or pedagogical techniques for teaching farmers)
    - Delivery techniques (e.g., getting information or access to marginalized communities)
    - Institutional innovations (e.g., creating alternatives to missing markets in supply of inputs, marketing, delivery and sale of outputs, access to technology)
    - Policy innovations (e.g., assuring appropriate legal and regulatory frameworks for land ownership and use, for natural resource management, financial intermediation)
2. **Learning Phase:** During the learning phase, the experience with the design and implementation of the pilot is monitored and evaluated, and a knowledge management process ensures that the lessons learned enter into the IFAD internal knowledge base and through dissemination contributing to the external knowledge base.
3. **Scaling Up Phase:** In the scaling up phase, the original idea, model or approach is brought to scale, generated by the pilot phase and on external knowledge, where appropriate.

Characteristics of Scalable Technologies

Scaling agricultural technologies will require a good understanding of the nature of technologies itself; technology is defined as the sum of knowledge of received information, which allows things to be done.

Mediators of Technology Scaling and Strategies

- Technology scaling through Agricultural Innovation Platform
- Technology scaling through sustainable intensification practices
- Facilitation of value addition and agribusiness incubator
- Facilitation of markets and access to knowledge and information
- Facilitation of capacity building on skills for scaling of technologies
- Monitoring and evaluation of technology scaling
- Facilitation of funds for scaling of technology

Case Studies and Examples

GI Tag for Tandur Red Gram

The Tandur red gram, a local variety of pigeon pea, was granted the prestigious Geographical Indication (GI) tag in December 2022, marking a significant milestone for Telangana as the state's first agricultural commodity to receive this distinction. Renowned for its high protein content, Tandur red gram is primarily grown in the rain-fed tracts of Tandur and neighboring regions, with its unique quality traits attributed to the fertile deep black soil rich in Attapulgite clay mineral and limestone deposits. The application for the GI tag was filed by the Yalal Farmers Producers Company Ltd with the support of Prof. Jayashankar Telangana State Agricultural University (PJTSAU), which provided crucial guidance and technical data. Post-registration, the prices of tur dal in Tandur have risen by 39%, as farmers can now command premium rates for their GI-tagged produce. However, many farmers remain unaware of the tag's significance, highlighting the need for greater awareness and support infrastructure to fully leverage the economic benefits and enhanced market access offered by this prestigious status.

Strategies to Scale Up Drones

- Financial assistance @ 100% of the cost of drone up to a maximum of Rs. 10 lakhs per drone is provided for purchase of drones for their demonstration by institutes under Indian Council of Agricultural Research, Farm Machinery Training & Testing Institutes, KrishiVigyanKendras (KVKs), State Agriculture Universities (SAUs), State and other Central Government Agricultural Institutions/Departments and Public Sector Undertakings (PSUs) of Government of India engaged in agricultural activities.
- The Farmers Producers Organizations (FPOs) are provided grants up to 75% of the cost of agriculture drone for its demonstrations on the farmers' fields. A contingency expenditure of Rs.6000 per hectare is provided to these implementing agencies that do not want to purchase drones but will hire drones for demonstrations from Custom Hiring Centres (CHCs), Hi-tech Hubs, Drone Manufacturers and Start-Ups.
- In order to make available drone services to farmers on rental basis, financial assistance @ 40% up to a maximum of Rs. 4.00 lakhs are provided for purchase of drones by CHCs under Cooperative Society of Farmers, FPOs and Rural entrepreneurs. Agriculture graduates establishing CHCs are eligible to receive financial assistance @ 50% of the cost of drone up to a maximum of Rs.5.00 lakhs per drone.
- For purchase of drones on individual ownership basis, the Small and Marginal, Scheduled Caste/Scheduled Tribe, Women and North Eastern State farmers are provided financial assistance @ 50% of the cost up to a maximum of Rs. 5.00 lakhs and other farmers @ 40% up to a maximum of Rs. 4.00 lakhs.
- **NAMO Drone Didi Scheme:** Launched in November 2023 with an outlay of Rs. 1,261 crores to empower women Self Help Groups (SHGs) by providing them drones on subsidised price along with free of cost training to fly drones.

A subsidy of 80% of drone cost or a maximum of Rs. 8 Lakh is provided under this scheme with a nominal interest of 3% payable on the loan. Women SHGs can rent the drone to farmers for spraying of pesticides or fertilizers in agriculture fields and can earn a minimum additional income of Rs. 1 Lakh per year. The scheme aims to equip

15,000 SHGs with drones for rental services to farmers for applying fertilisers and pesticides.

Carbon Credit Market

Carbon Credit Market in India

The carbon credit market in India is increasingly being driven by the private sector, with companies like Grow Indigo and Boomitra playing significant roles. Grow Indigo, a joint venture between Mahyco and Indigo Ag, has been instrumental in enrolling farmers in carbon credit programs, particularly in regions like Haryana, Punjab, and Maharashtra. These programs incentivize farmers to adopt sustainable practices such as direct-seeded rice (DSR) and zero-tillage farming, which reduce greenhouse gas emissions and enhance soil carbon sequestration (Financial Express, 2024). Farmers for Forests (F4F), a non-profit organization, is also contributing to the carbon credit landscape by focusing on forestry sector innovations. F4F aims to sequester carbon, support farmers, and create green jobs through partnerships with rural communities (Farmers for Forests, 2019). The Government of India has initiated the Carbon Credits Trading Scheme (CCTS) and developed a framework for the carbon market. This framework is part of India's broader strategy to achieve net-zero carbon emissions by 2070. In Uttar Pradesh, farmers are set to benefit from this initiative by earning carbon credits through the planting of fast-growing trees like Poplar, Melia, Dubia, and Semal. These credits will be purchased every five years at a rate of $6 per credit, providing a financial incentive for sustainable forestry practices (Invest UP, 2023). While carbon farming offers opportunities for farmers to earn additional income, challenges persist. A recent study highlighted that many farmers in Haryana and Madhya Pradesh reported receiving minimal monetary benefits from carbon projects, despite their potential to reduce emissions (Mongabay, 2025). Ensuring equitable distribution of benefits and addressing social exclusion remain critical issues in the development of India's carbon credit market

Scaling Up Disruptive Technologies for Agricultural Productivity in Kenya

World Bank projects in Kenya supported the government to implement digital technology innovations to improve agricultural productivity. Kenya’s Ministry of

Agriculture, Livestock, Fisheries, and Co-operatives developed a Big Data Platform and the Kenya Agricultural Observatory Platform (KAOP) at the Kenya Agriculture Livestock and Research Organization (KALRO) and linked 1.1 million farmers to these platforms.

These platforms provided comprehensive data, information, and agronomic advisories to enable national and county-level agricultural institutions, farmers, and other stakeholders to access high-resolution geospatial agro-meteorological data and customized advice. In partnership with the World Bank, the Ministry launched the One Million Farmer Platform and facilitated a partnership between county governments and agricultural technology (AgTech) startups, transforming last-mile service delivery

Extension approaches

Pluralistic Extension

Pluralistic extension involves a diverse range of stakeholders and service providers to address the complex needs of farmers. This approach recognizes the inherent diversity of farming systems and seeks to provide demand-driven services by engaging multiple actors, including government bodies, NGOs, private sector companies, farmers' associations, and research institutions (Agriallis, 2023; ICAR, 2019). The pluralistic model offers extensive knowledge databases, customized approaches, and networking opportunities, enhancing the resilience of farming communities (Agriallis, 2023).

However, challenges such as coordination, quality assurance, and equity concerns must be addressed to ensure effective implementation (Agriallis, 2023).

Participatory Extension Methods

Participatory extension methods involve active engagement with farmers in the planning, implementation, and evaluation of agricultural projects. This approach emphasizes collaboration and mutual learning between farmers and extension agents, ensuring that solutions are tailored to local needs and contexts (FAO, 2013). Participatory methods foster a sense of ownership among farmers, leading to higher adoption rates of new technologies and practices.

Small Group Approach like SHGs

The small group approach, exemplified by Self-Help Groups (SHGs), focuses on organizing farmers into small, cohesive units. SHGs facilitate peer-to-peer learning, mutual support, and collective decision-making, which can enhance the adoption of new agricultural practices and technologies (World Bank, 2019). This approach is particularly effective in empowering marginalized communities and improving their access to resources and markets.

Commodity-Based Approach like Millet-Based FPOs

Commodity-based approaches involve organizing farmers around specific crops, such as millets, through Farmer Producer Organizations (FPOs). These organizations help farmers improve their bargaining power, access better markets, and enhance their profitability by focusing on value addition and market linkages (ICAR, 2020). FPOs also facilitate the dissemination of specialized knowledge and technologies related to the targeted commodity.

ICT-Led Approach like Digital Green and Big Haat

ICT-led approaches leverage digital platforms to disseminate agricultural information and advisory services. Platforms like Digital Green and Big Haat use digital tools to provide farmers with real-time advice, market information, and access to inputs and services (Digital Green, 2024). This approach enhances the efficiency and reach of extension services, allowing for personalized advice and feedback loops that improve farming practices.

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Chapter 3

Impact Assessment of Climate Resilient Technologies (CRT): Data and Methods

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Introduction

Socio-economic impact assessment (SEIA) in the context of agricultural climate technologies evaluates how these technologies affect social and economic factors in farming communities, economies, and society as a whole. The aim is to understand the broader impacts of implementing climate-smart agricultural practices, technologies, and interventions on livelihoods, food security, community welfare, and local economies. t helps assess whether the technology is economically viable for farmers, especially in resource-poor or vulnerable communities. This is crucial for ensuring that these technologies are accessible and beneficial to smallholder farmers. By assessing the technology's effectiveness in reducing vulnerabilities and enhancing resilience, SEIA supports climate adaptation strategies in agriculture.

Impact Assessment

What is Impact Assessment?

Impact assessment is an evidence-based process used to evaluate the effects of technology, projects, or interventions, focusing on economic, social, and environmental outcomes. It involves systematically analyzing the intervention and its contributions to results. Essentially, it looks at the cause-and-effect relationship between inputs and the resulting changes.

Data and methods

The assessment considers whether the intervention is:

- Technically feasible
- Economically viable
- Socially acceptable
- Environmentally safe

Types of Impact Assessment:

1. **Economic Impact Assessment**
    - Adoption studies
    - Economic analyses (returns on investment)
2. **Social and Environmental Impact Assessment**
    - Effects on poverty, gender issues, food security, etc.
    - Effects on pollution, sustainability, and natural resource use, etc.

Impact assessments can be conducted from two perspectives: after the research is completed (ex-post) or during the planning phase (ex-ante). Ex-ante assessments help prioritize future research projects, while ex-post assessments provide insights on the outcomes of completed projects.

Steps in Impact Assessment:

1. Choose the technology or intervention to be evaluated.
2. Determine the type of assessment (economic, social, environmental, etc.).
3. Identify the needs, issues, and questions to address.
4. Define the level of assessment (e.g., farm, regional, national).
5. Select the methods for impact assessment.
6. Design data collection and analysis strategies.
7. Conduct field tests of assessment instruments and adjust if necessary.
8. Collect data.
9. Analyze the data.
10. Present the findings and recommendations.

Methods of Socio-Economic Impact Assessment:

Surveys and Questionnaires

These are commonly used to gather data directly from farmers and other stakeholders about their experiences with agricultural technologies, such as changes in income, productivity, and household welfare.

Cost-Benefit Analysis (CBA)

This method compares the costs of implementing a climate technology to the benefits it provides. It helps assess whether the economic returns justify the investments in the technology, considering long-term impacts.

Participatory Rural Appraisal (PRA)

This method involves communities in the assessment process, allowing farmers to share their perspectives and knowledge. It helps to identify community-level social impacts, including changes in social structures or gender roles.

Value Chain Analysis

This approach evaluates how agricultural climate technologies affect the entire value chain—from production to marketing and consumption. It helps to assess economic impacts at different levels, such as improved productivity, reduced losses, or increased market access.

Impact Pathway Analysis

This method focuses on the cause-and-effect relationships between the technology implementation and its impacts on socio-economic factors. It helps track how specific technologies influence agricultural productivity, income levels, food security, and other aspects of rural livelihoods.

Scenario Modeling and Simulation

Using models, this method simulates the potential outcomes of adopting climate technologies under different conditions and scenarios. It can provide projections of long-term socio-economic benefits or risks.

Impact assessment of CRTs: A case study

Difference in Difference approach (DID)

DID regression model is a powerful tool to estimate causal effects, especially in observational studies where randomization is not possible. By comparing the differences in outcomes before and after an intervention across a treatment group and a control group, it helps to identify the causal impact of a policy or treatment. Proper implementation requires careful consideration of the parallel trends assumption, which assumes that in the absence of the treatment, the treatment and control groups would have followed the same trend over time.

The major challenge is using a more reliable methodology for better evaluation. Comparative study between the treated and non-treated groups is a technical way while before and after intervention comparison is also another way. Impact evaluations rely on control or comparison groups, as well as other econometric techniques. One tool which control for factors or events called confounders that are correlated with the outcomes but are not caused by the project is the DID estimate. The DID method is one of the recent improvements in development studies and in many economic evaluation studies

Key Components of the DID Model:

1. Treatment Group: The group that is exposed to the intervention or policy change.
2. Control Group: The group that is not exposed to the intervention but is otherwise similar to the treatment group.
3. Pre-Treatment Period: The period before the intervention occurs.
4. Post-Treatment Period: The period after the intervention has been implemented.

In its simplest form, the DID model can be expressed using the following equation:

The outcome Yi is modelled by the following equation

$$Y = \beta 0 + \beta 1 * [Time] + \beta 2 * [Intervention] + \beta 3 * [Time * Intervention] + \varepsilon$$

$\beta 0$ = constant term (C0)
$\beta 1$ = Time tend in the control group (C1-C0)
$\beta 2$ = Difference between two groups pre-intervention (T0-C0)
$\beta 3$ = true effect of treatment [(T1- C1) – (T0 - C0)]
εi is a random, unobserved "error" term

The DID model parameters

Particulars	**Treatment Farmers**	**Control Farmers**	**Difference Across Groups**

After	T1	C1	T1-C1
Before	T0	C0	T0-C0
Difference across time	T1-T0	C1-C0	Double difference (T1-C1) -(T0-C0)

The study was conducted in one of the most vulnerable districts in the country that is Nalgonda in Telangana state of south India. The data are collected for two groups for two periods. And one of the them is the treatment group and other group is the control group. The treated group receives treatment in one period while the control group receives no treatment during both periods. The average gain over time in the control group is extracted from the gain over time in the treated group. This double differencing methods, removes biases arising from permanent differences between those groups, as well as time differences in the treatment group which can be due to time trend.

At household level, data on socio-economic profile, land endowments, cropping pattern, composition of household income, employment before and after NICRA intervention and during drought period was collected. The crop and livestock production data, climate resilient interventions adopted, and constraints faced by famers were also collected

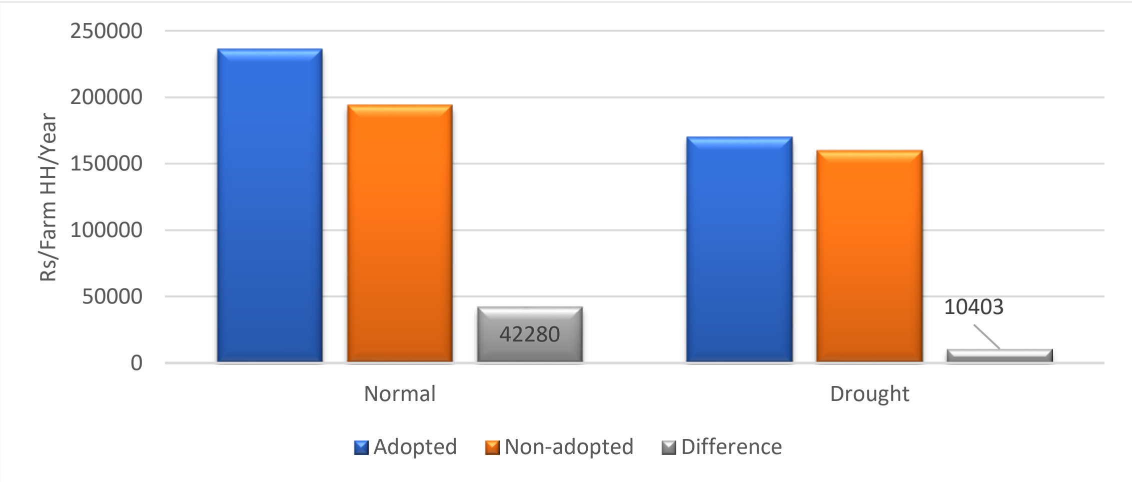

Figure 1: The first difference between normal and drought year obtained is depicted in the figure

There are visible impacts of drought that cannot be ignored and at the same time they can be avoided or reduced by adopting better technologies. The farm household in if adopts climate resilient technologies can save an average income of Rs.31, 877/FHH. It is evident that during a drought year the control village farmer had a loss of his investment in agriculture and his family income reduced significantly

Conclusion:

socio-economic impact assessment of agricultural climate technologies is essential for understanding their broader implications on farmers, communities, and economies. It informs decision-making, ensures sustainability, and promotes equitable benefits across all segments of society. It allows for the continuous monitoring and evaluation of technology adoption, helping stakeholders track progress and make adjustments to improve outcomes over time. This helps ensure the successful implementation of climate-smart practices.

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Chapter 4

Strategies for Livestock Technology Dissemination in Rainfed Areas

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In India, crop-livestock mixed farming is traditional and the combination of livestock with crop production is an effective risk aversion mechanism, developed out of generations of experience of farmers in rainfed areas. The system is a very good example of efficient resource usage, where all the products of the farming operations, local material, household waste, etc., with little dependence on outside resources. This is an appropriate and sustainable approach for remote rural areas, where access to outside resources or services is difficult. The system illustrates very well how rural families can match production with resources and available (or unavailable) services and linkages. In semi-arid regions, the combination of trees, cereal crops, leguminous pulses and oilseeds along with a mix of livestock (cows, buffalo and goats) is common. The farmers prefer varieties of crops which are appropriate for local conditions and provide better quality crop residues. They choose trees which provide leaves as well as flowers and pods for feeding animals. They have identified bushes which have protein-rich leaves. They are aware of aquatic plants, mangroves, salt bushes and weeds which can be fed to a different type of animals with beneficial results.

What is participatory extension management?

Participation means that the poor people themselves are involved in identifying the problems they face, determining ways to overcome them, designing realistic plans to achieve these goals, and carrying them out. Solutions devised and fulfilled by the people in need are far more likely to prove successful than those imposed from outside. Participation occupies a central place in development thinking and practice. Governments, funding agencies, donors, and civil society actors including NGOs and multilateral agencies like the World Bank and the International Monetary Fund have all arrived at a near consensus that development cannot be sustainable and long-lasting unless people's participation is made central to the development process. While there is a virtual unanimity about the need for people's participation in development, there is a wide spectrum of views on the concept of participation and the ways of achieving it. The way participation is defined largely depends upon the context and background in which participation is applied.

Guidelines for Participatory Methods in Livestock Management

1. The most important thing for PRA is to establish rapport with the villagers and make it a safe place for them to talk freely and openly with one another. The ideal approach to meet this requirement is for the research team to live and dine among locals during the duration of the study. The group needs to pay attention and be involved in regular life.

2. "Do It Yourself" (DIY): The crew should try to do what the villagers are doing when it comes to livestock management, like feeding, grooming, milking, chaffing fodder, and so on. In addition to facilitating rapport building, this offers useful suggestions and an understanding of the intricacies of the tasks at hand.

3. Before beginning, it is important to inform and discuss with officials, including development workers, concerned Sarpanches, and villages. District and civic officials at the highest levels must reach a consensus on the village. It will be easier to oversee and carry out the project if the site is easily accessible.

4. Collecting Secondary Data: Researchers, NGOs, departmental reports, and documentaries are good places to find secondary data, such as information found in reports, newspapers, leaflets, brochures, library sources, folklore, and other classified materials. It is recommended to collect community data prior to conducting the real diagnosis in the field. The residents of the village can utilize the data collected and analyzed by the interdisciplinary team as a foundation for their Action Plans. Data collected from these sources can also be utilized to back up claims made in the semi-structured interviews.

5. Educating Trainers: In order to effectively train other extension workers and farmers, it is crucial to train a core team of facilitators.

6. A diagnosis is a thorough evaluation of a specific issue. The PRA diagnostic process looks at the opportunities, challenges, practices, and reasons of the villagers' problems. Secondary data (mentioned previously), mapping, transect, Venn diagram, semi-structured interviews, and other similar technologies are used to gather this vital information.

Various Methods of Involvement

1. The term "rapid rural appraisal" (RRA) refers to a method whereby a multidisciplinary team conducts an on-site, methodical, and semi-structured activity to rapidly and efficiently gather fresh information and test hypotheses on rural life and rural resources.

2. With the use of Participatory Rural Appraisal (PRA), farmers are able to assess their living situations, discuss the results, and formulate plans for the future. Transferring control of the procedures and activities to the farmers is analogous to doing so. A community that is ready to change its circumstances can look to the scientist to catalyze, facilitate, and convene processes within that group.

3. When it comes to participatory learning methods (PALM), some of the areas where it has been effectively implemented include: participatory impact monitoring and assessment of development programs; participatory planning of natural resource development at the village level; and integrated rural development programs that address health care, livelihoods, and gender issues.

4. Successful applications of agro-ecosystem analysis (AEA) span all tiers of agricultural ecosystems. It is recommended to study at the local level.

5. Successful applications of Participatory Action Research (PAR) include adult education, community development, and rural groups. However, PAR has proved most useful in helping grassroots movements to concretize and mobilize their goals.

6. Encouraging Active Participation in Assessment, Monitoring, and Evaluation

7. Systematic Study of Farming (FSR)

8. The PRAP Program—Participatory Rural Assessment and Planning

Extension for Livestock

As part of their Livestock Extension services, they help stakeholders develop their skills through technology transfer and by enhancing a variety of infrastructure and support services. Farmers can enhance their livestock farming methods and techniques, production efficiency and revenue, and quality of life with the help of the extension service's instructional programs. The goal of the Extension program is to help farmers pinpoint the source of their production issues, conduct thorough analyses, and become more cognizant of the opportunities for improvement. Those who are apprehensive or uninformed about new methods and technologies that can boost output and revenue should be encouraged by it. Real extension service for the poor and semi-literate livestock keepers entails guiding them step-by-step until they embrace best practices and become an integral part of the value chain, allowing them to reap the greatest benefits.

By raising awareness, exposing them to new knowledge, and facilitating information flow among farmers, extension officers, and other stakeholders, effective livestock extension would assist farmers in identifying production and marketing restrictions. Capacity building should be implemented to assist farmers in maximizing the utilization of support services and technology. Connectivity to databases housing data on agricultural advances, new technology, and market-related metrics including supply and demand as well as pricing should be set up. The primary goal of livestock extension is to support Producers' Organizations, which will help to improve output and profitability by providing a platform for the value chain and ensuring that all relevant stakeholders are involved.

Present Scenario of Livestock Extension Services

The State Animal Husbandry Department is the main extension agency, however they are mostly involved in treatment and breeding, not extension. As a result, they only provide a restricted set of services. Extension receives only 0.4–1% of the budget, with the majority going unused. Institutions for Veterinary Education and Research, Dairy Federations, and People's Organizations fail to coordinate their efforts in any significant way. Top-down programs fail to address the concerns of farmers and ranchers in the areas where livestock are raised. A small, immobile workforce makes it difficult to build meaningful relationships with farmers, especially women who do the bulk of animal husbandry's manual labour (80%).

Extension policy for livestock

1. Agricultural extension programs tend to cover a lot of ground, but animal husbandry extension has to be area and demographic specific, taking into account things like household income and livestock quality.
2. The development of value chains ought to be the primary focus of extension programs, with measurable outcomes and objectives in place.
3. Improving efficiency and production through an efficient public-private collaboration requires reforming the links between different organizations involved in cattle husbandry and their coordination.

A participatory approach to improve livestock productivity

All important stakeholders should be encouraged to actively participate in this process by learning and taking action. Different from the conventional top-down or bottom-up approaches, the process seeks to institutionalize a need-based approach. By including producers, this method seeks to solve problems pertaining to the entire cooperative system, such as raising milk production and quality standards, empowering female members, bolstering village societies, and boosting feed and other natural resources. In order to make inputs distribution and extension services more accessible, efficient, and successful for farmers, this method plans to use para-extension personnel stationed in the area. In order to address issues like raising farmers' consciousness and engagement, bettering natural resources, etc., it encourages collaboration and partnership with research and development groups. All parties involved should be part of an ongoing process rather than a one-time exercise.

Making plans for intervention and carrying them out

Using participatory techniques, we can learn more about rural livestock business systems overall, how producers (especially women) see things, what limits there are to increasing productivity, and which methods and tools work best to remove those limits.

It has also brought attention to the fact that producers require planning, training, and information dissemination based on an evaluation of their information, skill, and knowledge needs.

Livestock management's response to participatory extension management

The adoption of an extension management process has a significant influence on farmers because it raises awareness among key stakeholders (extension officers, supervisors, and farmers themselves) about upcoming issues and the necessary approaches to overcome them. The relevant staff members at all levels will have a new perspective and attitude toward one another, and their skills in the relevant domains will have improved. In addition to helping us understand why farmers aren't making greater use of the services and inputs we offer, this method will highlight the limitations and issues that farmers rank high on their list of priorities. This allows for more efficient, effective, and need-based delivery of technical inputs and extension services.

Who manages extension?

Besides national or regional governments, extension services can be run by NGOs, by cooperatives, by universities or research institutes and by the commercial sector. In India, some extension is provided through the system of dairy cooperatives, which reaches from village-level primary societies to a national federation and has 8 million members. Primary societies are successfully delivering information both on business management and on technical aspects of dairy production such as the use of green fodder and concentrates.

Agencies involved in Animal Husbandry Extension are:

Public Extension Services, like State Government Animal Husbandry Departments, Agriculture Extension Dept: ATMA Programme, Panchayat Raj Institutions, Agricultural/Animal Sciences Universities, Krishi Vigyan Kendras and ICAR Extension Centres. Private Extension Services, like Farmers' Cooperatives/Federations, Producer Groups/Companies, Processing/Marketing Agencies, Self Help Groups, Paravets/Private Vets, NGOs, Input suppliers: Seeds, feeds, tools, vaccines and medicines, micro-finance groups. Mass Media and Information Technology Centres, like

Print media, Newsletters, Radio, Television, Private cable networks, Electronic network: mobile, email/internet, private portals, Local wireless loops, Farm Advisory Centres, Information shops

Livestock production and management-related major ongoing extension programs include

1. Animal hospitals and clinics run by the state's department of animal husbandry
2. Treatment and data collecting take up a disproportionate amount of time in the animal husbandry extension program.
3. Cooperatives for Dairy Products
4. Production of crops is the primary emphasis of the Agricultural Technology Management Agency (ATMA).
5. Krishi Vigyan Kendras: Inadequate veterinary knowledge and resources
6. Colleges for Veterinary Medicine and Agriculture: Ignoring the Issues at Hand
7. Organizations that provide input, such as NGOs, frequently lack credibility and connections.

How can it be effective in improving livestock productivity?

To increase livestock production, it seems to be extremely important to keep farmers in updated information regarding various production processes and marketing practices. Inadequate access of developing-country farmers to relevant livestock information/technology has an effect on all livestock subsectors and different stages of livestock production. The livestock technology dissemination, therefore, is very important for improved smallholder farmer livestock production and consequently increased family income (Pankaj *et al.*, 2014). The strategy for revamping animal husbandry extension are:

1. Farmers' Group based approach for backward and forward linkages.
2. Technology backup by reorienting Livestock Development Officers, KVKs and ATMAs, and strengthening their linkage with Research Institutions and Agri / Vet. Universities.

3. Increased involvement of private service providers, NGOs and self-employed professionals and Synergy between public and private sector service providers.
4. Explore Additional/Alternative Agencies for Extension Delivery.
5. Knowledge and Information management and dissemination.
6. Human Resources Development including Gender mainstreaming.
7. Coordination among various stakeholders, development and facilitating agencies in particular to strengthen the value chains.

Examples of success stories of participatory extension management for improving livestock productivity

The following models were helpful in the dissemination of fodder technologies to small and marginal farmers in the field as well improve fodder production (Pankaj *et* al., 2015) and ultimately the livestock productivity in rural India:

i). Participatory Action Research (PAR) model adapted to improve farmers technological capabilities in fodder production: A Participatory action research (PAR) model is well suited to cater the location-specific need of the farmers (Rao *et al*., 2012).

ii). Need-based capacity building model: which includes Organization of need-based training and capacity building programs on to improve knowledge and skill on improved fodder production technologies, like Intensive rainfed/ irrigated fodder production systems, fodder production systems through alley cropping, non-conventional fodder production systems, hydroponic fodder production systems, year-round forage production systems, etc.

iii). Common Interest Group (CIG) model for mitigating fodder scarcity: Development of Institutions like Common Interest Group (CIG) were able to mitigate fodder scarcity as membership of a co-operative or commodity association increases access to productive resources such as seed, information and training (Rao *et al*., 2012). Later on, a revolving fund may also be developed for fodder development through CIG which will increase the risk-bearing capacity of small and marginal farmers.

iv). Entrepreneurship model for imparting skills to SHG women:

- Production of quality seed by appropriate selection of promising varieties/hybrids.
- Establishment and management of a feed mixture plant by women groups.
- Motivate female farmers for Indigenous Technical Knowledge (ITKs)

v). Forage seed distribution model: Dairy farmers who have undertaken forage production are not able to optimize the yields and maximize the returns due to several reasons. These include poor quality soils, inadequate fertilizer application, moisture scarcity, improper timing of sowing and inadequate facilities to transport and store the forage until it is fed to livestock.

vi). Contingency plan model: Development of Contingency plan (Srinivasa Rao *et al*., 2010) to mitigate drought and sustain fodder production at village level

- Early season drought: Short duration (50-60 days) fodder crops like sorghum Pusa chari CSH- 14, bajra (Co 8, TNSC1).
- Midseason drought: cultivate winter crops like berseem, Lucerne and in wastelands cultivate Anjan, *Stylosanthes scabra,* etc.,
- Late season drought: Avoid multi-cut varieties, cultivate less water required lucerne varieties.

vii**). Wallpapers**: Poster, display board to create awareness among general people and other stakeholders. It can be also disseminated using a Public Address System (PAS) for crucial climatic circumstances or agro-advisory services. Basically used in dissemination of urgent information like cyclone, natural climatizes etc.

viii). **Demonstration Effect Approach**: Very useful for progressive farmers. Framers were learning by seeing to others.

ix). Educational and Methods approaches: These approaches focused on education of farmers and use of various methods- exposure visits, field days, radio and television programs, film shows (cinema), leaflets and posters. These approaches resulted in improved farming practices, productivity and production.

x). Training and Visit Approaches: Capacity building of trainers who works in field is important motive of this method. Trained person can be better training to farmers and other stakeholders.

xi). Mass Media Campaigns: Extension functionary can reach to large number of audience in very short period of time. The main purpose of this method is to create awareness among stakeholders.

xii). ICT supported farmers : Use of smart phones, videos, radios etc. was done to address the climate change issue by creating awareness among the farmers about the availability of different adaptation and mitigation strategies. It also helps in coordination and monitoring.

xiii). Farmers Field Schools (FFS): It is a non-formal, participatory extension technique that prioritizes farmers and their needs via experience learning. Farmers can discuss and learn from their observations, allowing them to gain new practical knowledge and skills, as well as improve their individual and collective decision-making.

xiv). Climate-Smart Villages (CSVs): The concept of climate resilient village (CRV) – i. to provide stability to farm productivity and household incomes and resilience through livelihood diversification in the face of extreme climatic events like droughts, cyclones, floods, hailstorms, heat wave, frost, and seawater inundation. ii. Development of CRVs warrants establishment of a host of enabling mechanisms to mobilize and empower communities in the decision-making process to manage and recover from climate risks.

Conclusion

Instead of looking at the livestock industry in a vacuum, a more comprehensive and systems-based approach is required for sustainable growth. This approach must include the development of natural resources. Therefore, the relevant organization should be ready to collaborate with other research and development groups in order to overcome limitations or address issues by using their skills and knowledge.

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Chapter 5

Risk and Vulnerability assessment for adaptation planning

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Introduction

Climate change has emerged as a potent threat to sustainability of food security and agriculture. The Coupled Model Inter-comparison Project (CMIP) 5 projections for India show that the average climate is likely to be warmer by 1.7 to 2.0^{0} C for 2030s and by 3.3 – 4.8^{0} C for 2080s compared to the pre-industrial times. The precipitation is likely to increase by 5 to 6 per cent and 6 to 14 per cent, for 2030s and 2080, respectively. Agriculture, being a biological production process, is obviously affected by climate and hence the projected change in climate will have implications to sustainability of agricultural production and of livelihoods of those dependent on agriculture. Indian agriculture, dominated by small holders with low adaptive capacity, is vulnerable to adverse impacts of climate change. Intensified adaptation efforts are needed in spite of the Paris Agreement arrived at COP 21 to limit warming to 1.5^{0}C. Adaptation requires resources in terms of investments and interventions. However, considering climate and climate change are spatially variable, not all regions are equally impacted by climate change and vary with their capacities to adapt and shocks to adapt to. A well planned and better targeted adaptation is critical to building resilience to agriculture and to farmers' livelihoods. Assessment of risk and vulnerability informs policy and programme planning towards this. Since district is the basic unit of administration in India, risk and vulnerability assessment at the district level will be of more policy relevance. This policy brief presents the summary of such district level assessment of risk and vulnerability to climate change as detailed in Rama Rao *et al*., (2019).

Vulnerability – meaning and concepts

'Vulnerability' has emerged as a cross-cutting multidisciplinary theme of research in the current context, characterized by rapid changes in environmental, economic and social systems (O'Brien et al., 2004). The dictionary meaning of the word 'vulnerable' means propensity to be harmed. However, the word vulnerability has been used and vulnerability was assessed without actually being defined in many different contexts. Vulnerability is an *ex ante* concept in that what is likely to happen in future is the focus of analysis and thus the analysis has to lead to making decisions as to what is to be done in the present. Further, vulnerability of *what* to *what* are to be clearly defined along with the preference criteria for evaluation (Ionescu et al., 2009).

Vulnerability and its assessment received attention in three important areas of research: disaster management, economic development and climate change. The disaster management literature sees vulnerability as susceptibility to a climatic disaster and is often concerned with the location of the system or entity. On the other hand, the vulnerability research in the broader area of economic development is concerned with vulnerability to, poverty for example, wherein the interest is to assess whether or not an economic decision making unit becomes worse off (in terms of outcomes) in the event of a climatic or non-climatic shock given its characteristics. Vulnerability is viewed both as a component of poverty as well as a determinant of poverty in the literature on poverty.

Vulnerability is sometimes seen as a threshold value or tipping point which can be described as a degree of acceptable damage (Joakim et al., 2015). The shifting of the threshold or tipping points is seen as the responses to moderate or deal with vulnerability. Though there is a vast literature on the theoretical development in the conceptualization and analysis of vulnerability, this discussion is limited to vulnerability and assessment in the context of climate change only.

Evolution of vulnerability assessment

Vulnerability assessment is generally done in a number of different contexts and in view of different stakeholders. However, three important contexts for vulnerability assessment can be identified. These three contexts have different goals, varying information needs and thus will lead to different policy implications. These three contexts are related to fixing long term mitigation targets, identification of vulnerable regions for providing international assistance and for recommending adaptation measures for different regions or sectors. The evolution of vulnerability assessment in terms of focus, frameworks and methods broadly reflect these three decision contexts. The assessments concerned with mitigation aspects focus on biophysical impacts of climate change and are usually referred to as impact assessments. Following such impact assessments are the first and second generation vulnerability assessments that increasingly recognized the importance of non-climatic factors in determining vulnerability. These vulnerability assessments are then followed by what are referred to as adaptation policy assessments whose purpose is to identify adaptation strategies and are more policy oriented. These assessments clearly recognize the 'facilitation' and 'implementing' aspects of both mitigation and adaptation and differentiate between adaptive capacity and adaptation. The key characteristics of these four broad classes of vulnerability assessment are summarized in table 1.

Table 1. Key features of different stages of climate change vulnerability assessments

	Impact Assessment	**First generation VA**	**Second generation VA**	**Adaptation Policy Assessment**
Focus	Mitigation policy	Mitigation policy	International assistance	Adaptation policy
Analytical approach	Positive	Mainly positive	Mainly positive	Normative

Main result	Potential impacts	Pre-adaptation vulnerability	Post-adaptation vulnerability	Adaptation strategies
Time horizon	Long term	Long term	Mid to long term	Short to long term
Consideration of non-climatic factors	Little	Partial	Full	Full
Integration of natural and social sciences	Low	Low to medium	Medium to high	High
Stakeholder consultation	Low	Low	Medium	High
Typical question	What are biophysical impacts of CC?	What socioeconomic impacts are likely to result from CC?	How vulnerable are systems or entities to CC after after feasible adaptation?	What adaptation options can be recommended to reduce vulnerability?

Source: Fussel and Klein (2006)

Approaches to vulnerability assessment

'Outcome vulnerability is conceptualized as 'end point' analysis where in the impact of climate change is examined on productivity or production of a particular crop or animal species either through simulation modeling or through physical experimentation. This is also referred to as biophysical impact assessment or first generation vulnerability assessment. Such assessments 'superimpose future climate scenarios on an otherwise constant world to estimate the potential impacts of anthropogenic climate change on a climate-sensitive system' (Fussel and Klein, 2006). The emphasis gradually shifted to derive policy lessons from vulnerability assessment as the purpose of such assessment was to identify strategies that reduce vulnerability of the systems or populations concerned.

The socio-economic approach to vulnerability assessment proposes that the attributes of the system or entity of interest predispose it to the adverse impacts of an external shock (climate change or variability) (Adger and Kelly, 1999) and thus it is referred to as 'starting point analysis'. In this case, vulnerability is regarded as a pre-existing condition (Alexandra Jurgilvech et al., 2017) in terms of health, education, wealth, etc. of the individuals and the differential endowments of individuals are responsible for varying vulnerability. The integrated approach combines both these approaches integrating bio-physical and socio-economic dimensions of vulnerability. As the vulnerability assessments evolved, more non-climatic data became a part of such assessments.

Current vulnerability analyses the current risks to the system of interest whereas *future vulnerability* assessments are concerned with future risks. Vulnerability assessment is considered static or dynamic whether the temporal changes in the predisposing conditions and/or risk are considered in the analysis.

Conceptualization of impacts and vulnerability

Figure 1 depicts hypothetical trajectories for the level of climate-related impacts (caused by anthropogenic climate change as well as natural variability) on a climate-sensitive system. The lowest trajectory denotes the (unrealistic) reference case of an undisturbed climate where variations in the level of impacts over time are solely caused by changes in non-climatic factors. The illustrative trajectory shows an initial increase in climate-related impacts (e.g., due to population growth) followed by a substantial decrease later (e.g., due to economic development). The other trajectories present the impacts associated with a single climate change scenario for four different assumptions regarding adaptation. They include (in descending order of impacts) the 'dumb farmer', who does not react to changing climate conditions at all; the 'typical farmer', who adjusts management practices in reaction to persistent climate changes only; the 'smart farmer', who uses available information on expected climate conditions to adjust to them proactively; and the 'clairvoyant farmer', who has perfect foresight of future climate conditions and faces no restrictions in implementing adaptation measures. Depending on the level of adaptation assumed, assessment results may fall anywhere in the range spanned by the 'dumb farmer' and the 'clairvoyant farmer' trajectories in Figure 1.

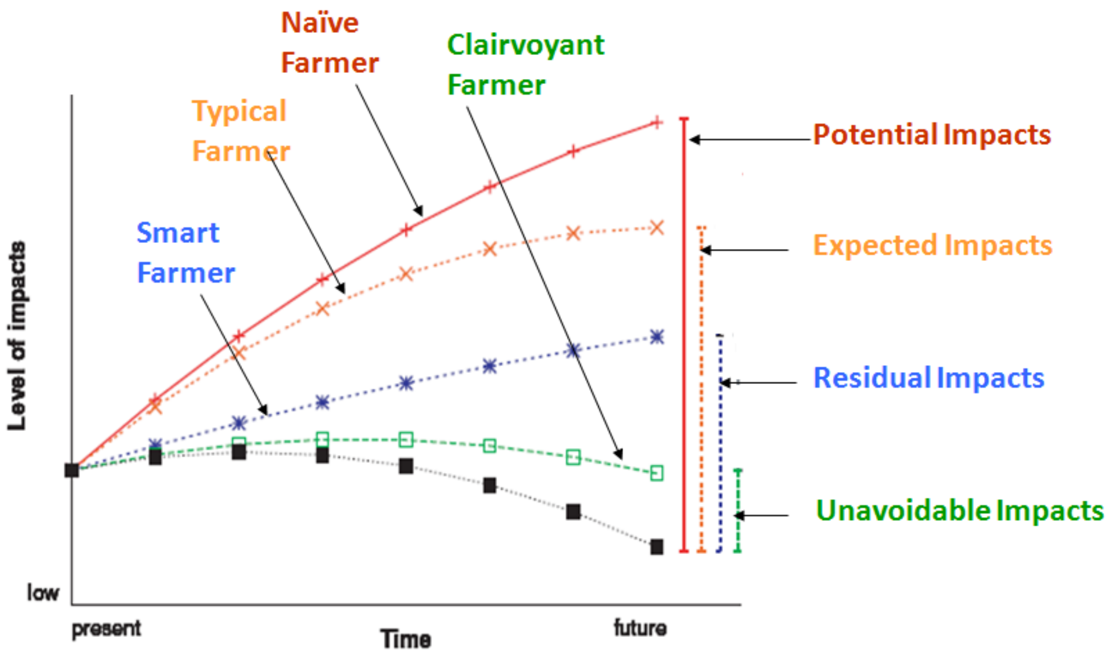

Fig 1. Conceptualization of impacts and vulnerability (Source: Fussel and Kelin, 2006)

The IPCC-AR4 framework of vulnerability assessment

There were a plethora of studies on climate change vulnerability starting in 2000s as the national governments and international community are increasingly concerned about dealing with climate change. Though there are varying conceptualizations and definitions of vulnerability in the context of climate change, the one given by the IPCC is adopted in a large number of studies (Schneider et al., 2007). IPCC in its 3rd and 4th Assessment Reports define vulnerability a "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al., 2001, 2001, 2007). This conceptualization views vulnerability as a residual impact of climate change: the sensitivity and exposure together determine the potential impact which will be moderated by adaptation. Adaptation is the manifestation of adaptive capacity.

Sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli". It is determined by demographic and environmental conditions of the region concerned. Exposure is defined as "the nature and degree to which a system is exposed to significant climatic variations". Thus, exposure relates to climate stress upon a particular unit of analysis (Gbetibouo and Ringler 2009). "A more complete measure of exposure to future climate change would require consideration of projected changes in climate in each analysis unit" (Eriyagama et al., 2012). Adaptive capacity is "the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. It is considered to be "a function of wealth, technology, education, information, skills, infrastructure, access to resources, stability and management capabilities" (McCarthy et al., 2001).

In this framework, adaptive capacity is largely consistent with socioeconomic approach and sensitivity with biophysical approach and both are internal dimensions. The component of exposure is viewed as an external dimension. While higher exposure and sensitivity mean higher vulnerability, higher adaptive capacity implies lower vulnerability and hence is inversely related to vulnerability. Although lack of standard methods for combining the biophysical and socioeconomic dimensions is a limitation to this approach, it can be helpful in making policy decisions (Deressa et al., 2008).

This definition and framework of vulnerability is depicted in Figure 2.

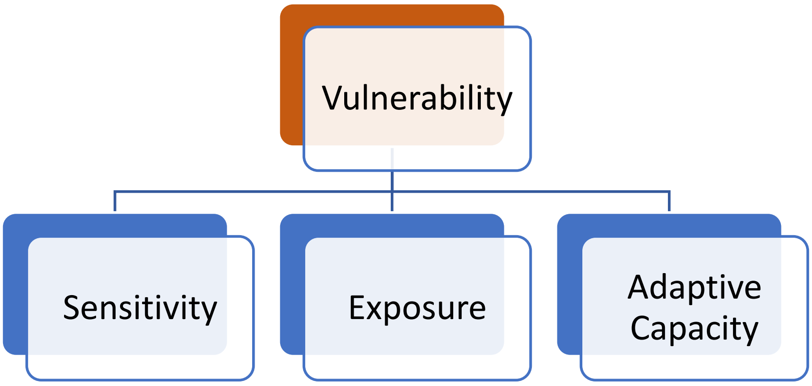

Fig 2. Components of vulnerability

3.1 Change of vulnerability assessment framework by IPCC with AR-5

The literature on vulnerability and its assessment is continually evolving drawing on works in different fields. The dynamic trait of vulnerability and its components is not adequately addressed in the Third and Fourth Assessment Reports of the IPCC. The recent literature suggests that the risks due to climate change are also a result of complex interactions among social and ecological systems and the hazards arising out of climate change rather than being externally generated alone. Various facets of these interactions have to be carefully differentiated to understand risk to inform policy making for risk management. The AR 5 framework (Fig 3) emphasizes these aspects as well as that the very components of vulnerability and risk will also interact with the contextual factors of development pathways and the climate systems (Oppenheimer, et al., 2014). Also, inclusion of 'exposure' as a component of vulnerability as in AR 4framework, may trigger decisions that may potentially lead to maladaptation given the uncertainty associated with climate projections.

3.2 Vulnerability – a component of risk assessment

The AR5 proposes a different framework where in vulnerability is placed as one of the determinants of risk, the other two being 'exposure' and 'hazard'. The definitions given by AR 5 for risk and its components (Oppenheimer, et al., 2014) are given below:

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risk.

Impacts: (Consequences, Outcomes) Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

Risk = (Probability of Events or Trends) × Consequences

Risk results from the interaction of vulnerability, exposure, and hazard.

The AR4 and AR5 definitions and frameworks view the terms vulnerability and exposure differently. Exposure in the AR 4 terminology is related to climate related shocks that a system is exposed to whereas the AR 5 describes it being related to the individuals, systems, etc. being exposed to the 'hazard' which is a concept introduced in AR 5 framework. Vulnerability, as per AR5, is more a predisposition to an external shock and whether it will lead to risk depends on whether the vulnerable system is located (exposure) in a place where the 'hazards' are likely to occur. Thus, a highly vulnerable system may not suffer risk due to climate change or a less vulnerable system may face risk if it is placed where severe hazard incidence is possible. Thus, the relationship between these three components of risk are more explicit and policy relevant. The AR5 vulnerability framework is closer to the disaster management conceptualization which is considered more appropriate in the context of climate change.

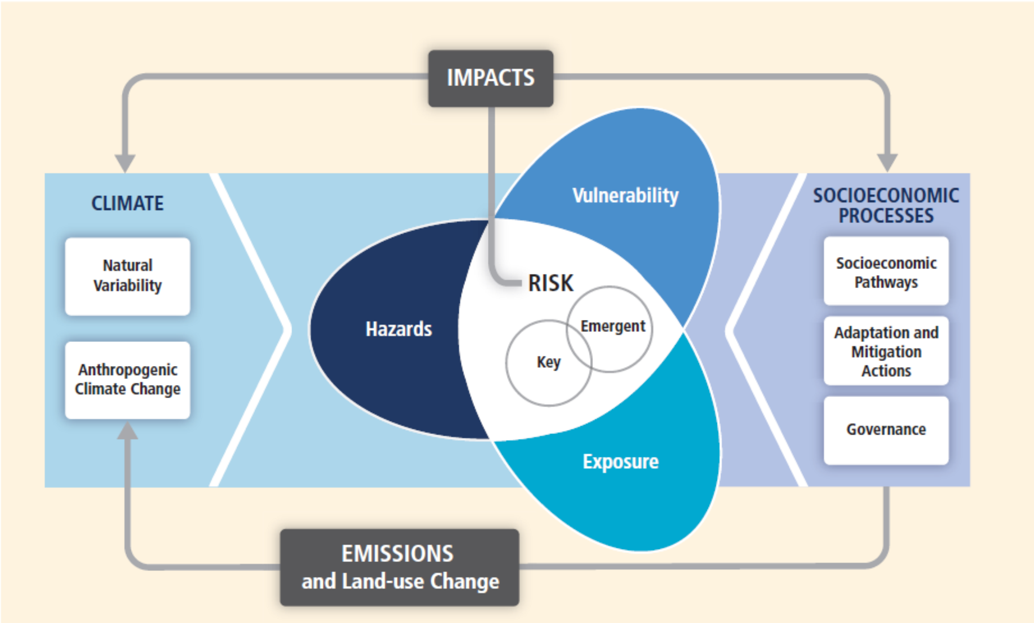

Fig 3. Framework of vulnerability and risk (Source: Oppenheimer et al., 2016)

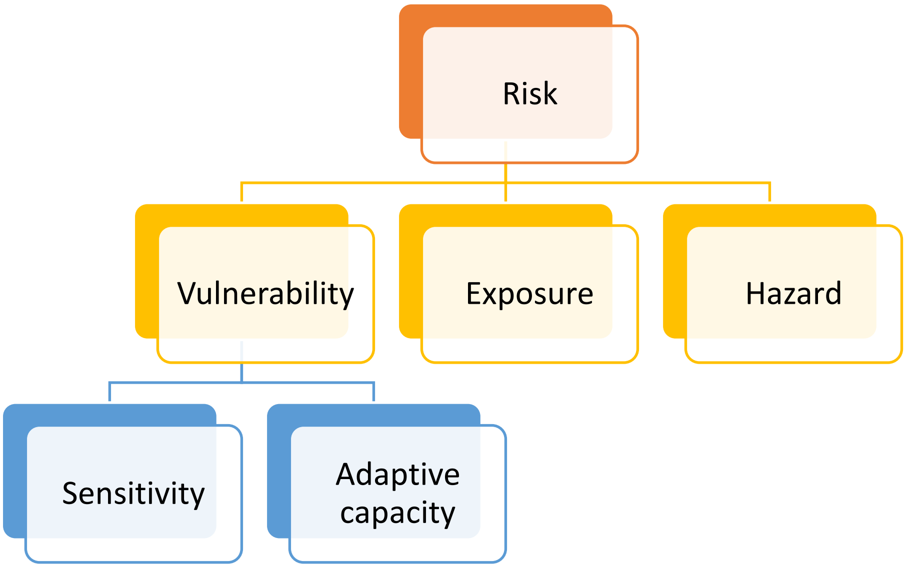

Fig 4. Dimensions of risk and vulnerability

The AR5 risk conceptualization furthers the risk analysis by identifying two kinds of risk: key risks and emergent risks. Key risks are potentially severe consequences arising when systems with high vulnerability interact with severe hazards. Different criteria are suggested to categorize a risk as key which are based on the magnitude of the risk, high vulnerability of a particular group of population, criticality of the sector in the economy. Emergent risks are those that are not direct consequences of climate change hazard but are results of responses to climate change. For example, migration of population from a region due to climate change related hazards may increase the vulnerability and thus risk of receiving regions; similarly increased groundwater extraction during a drought may increase the vulnerability and risk in future. Thus, emergent risks are a result of spatial linkages and temporal dynamics related to responses to changing climate.

Thus AR5 framework places more emphasis on identifying and managing risk and thus views vulnerability as a determinant. Such conceptualization and framework will be more relevant to policy making.

Methods of vulnerability assessment

Vulnerability, being a theoretical concept and multidimensional (Hinkel, 2001), is 'notoriously difficult to measure' (Crane et al., 2017). Considering that the definition of IPCC is the most adopted one in the context of climate change vulnerability, any assessment should ideally capture the future climate, examine its potential impact on agricultural performance (e.g. crop growth and yield) and then see how adaptation action reduces that impact. The resultant impact is considered as vulnerability. Such an operationalization of vulnerability assessment was done through crop simulation modeling (e.g. Olsen et al., 2000; Pathak and Wassmann, 2009; Boomiraj et al, 2010; Srivastava et al., 2010, Abdul Harris et al., 2013) and econometric methods (e.g. Ajay Kumar and Pritee Sharma (2013); Narayanan and Sahu, (2016); Praveen Kumar et al., (2014). Such methods are data and skill intensive and cannot easily be scaled up.

'Indicator method' is the most used method in assessing vulnerability for identifying hot spots of vulnerability to climate change. The method involves identification of indicators of different dimensions of vulnerability and risk, normalization and aggregation. The individual indicators can be combined into component and final indices of risk or vulnerability using weights derived from a variety of methods such as principal component analysis, factor analysis, analytical hierarchical process, expert consultation, etc. The choice of such methods is dependent on the nature of data, skills available, etc. The process of constructing vulnerability indices following indicator method is depicted in the following figure 5.

Fig 5. Process of building vulnerability and /risk index

Summary and conclusion

The term vulnerability has emerged as an area of multidisciplinary research in different thematic areas such as disaster management, poverty measurement and climate change. The term has been defined and interpreted in many different ways. In the context of climate change, the definitions and frameworks suggested by the IPCC have been often used and many different vulnerability assessments used these frameworks. Vulnerability assessments have over time became more multidisciplinary, more integrating in terms of climatic and non-climatic information, more stakeholder participatory and more policy oriented. Though many approached and methods of vulnerability are evident in the literature, the choice of such approach and method should be more determined by the context and purpose of vulnerability assessment.

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Chapter 6

Extension Approaches for enhancing Productivity in Rainfed Areas

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INTRODUCTION AND OBJECTIVES

Agricultural extension is the conscious communication of information to help farmers form sound opinions and make good decisions on farming. According to Ackah-Nyamike (2007), agricultural extension empowers farmers with the requisite knowledge, attitude and practices for enhancing productivity and welfare. In other words, agricultural extension has a philosophy of helping people to help themselves. The traditional view of agricultural extension in developing countries was very much focused on increasing production, improving yields, training farmers, and transferring technology (Davis, 2008). Extension delivery is primarily a government responsibility, though many other actors are involved, including development partners, private firms and non-governmental organisations. The ratio of extension workers to farmers is low at 1:1162 at national level (one agricultural officer serving 1162 farmers) as against recommended ratio of 1:750. The lack of access is compounded by extension agents' lack of funds for transport, further reducing extension worker access to farmers. Also, extension personnel may identify and know the solutions to problems faced by the farmers, and yet may not be able to disseminate the solutions to the farmers due to lack of appropriate extension teaching methods for transferring agricultural technologies. The role of extension personnel is to help farmers form healthy opinions and make good decisions by communicating and providing the information needed by farmers, besides that, they also play a role in helping farmers improve their farming and overall economic wellbeing.

Agricultural technology transfer methods/approaches refer to the techniques used by an extension system as it functions, for example, demonstration, or a visit by an extension agent to a farmer. There are several methods used in extension work. Some of these include individual/household extension method, group method, and mass media method. None of these methods can be singled out as the best one as they all have some advantages and disadvantages. According to Anandajayasekeram *et al.* (2008), the choice of a method depends on various factors such as the tenure system in the area, community organisation, and resources availability. For example, in an area where tenure is communal, or land management is based on communal efforts, a group approach is likely to be more effective than an individual approach. Meetings, field days, and approaches to schools may also be good options. Despite the importance of agricultural extension in communicating relevant information about improved production techniques to farmers, there are limited studies, to the best of our knowledge, that evaluate the effectiveness of the various agricultural technology transfer methods/approaches in India in general and Telangana, Andhra Pradesh (A.P.) states in particular. This paper therefore highlights effectiveness of various agricultural technology transfer (extension approaches) that are being used by the stakeholders of the agricultural extension delivery system in Adilabad district of Telangana and Anantapuramu district of A.P. The specific objectives of the study are:

1). To identify the existing extension approaches employed by extension officers of different agencies in study area.

METHODOLOGY

A sample of 120 farmers were randomly selected from Telangana state and from Telangana, Adilabad district were selected. The sample agencies selected for the study were Ekalavya Foundation (EF) an NGO, Jain Irrigation (JI) a private extension firm and State Department of Agriculture (SDA) representing the government extension agency. In Adilabad, Gudihatnoor (JI), Indervelly, Sirikonda (EF) and Ichoda (SDA) mandals were selected for the study. Care was taken in selecting the mandals (along with villages and respondent farmers (40 from each agency)) that were mutually exclusive to avoid overlapping of data from each agency i.e., Gudihatnoor was selected to collect data from JI, Indervelly and Sirikonda for EF and Ichoda for data from SDA. The data was collected using a pre-tested interview schedule and focus group discussion from the farmers belonging to each agency. Mean, standard deviation, t-test and Tukey HSD tests were employed for data analysis. Conclusions were drawn based on the interpretation of results.

Similarly, a sample of 120 farmers was randomly selected from the Anantapuramu district of A.P. The average annual rainfall in Anantapuramu is 550 mm. The sample agencies selected for the study were Watershed Support Services and Activities Network (WASSAN) an NGO, Coromandel Fertilizers Limited (CFL) a private extension firm, and the State Department of Agriculture (SDA) representing the government extension agency. In Anantapuramu, Nallacheruvu (WASSAN), Bukkarayasamudram (CFL), and Atmakur (SDA) mandals were selected for the study. Care was taken in selecting the mandals (along with villages and respondent farmers (40 from each agency)) that were mutually exclusive to avoid overlapping of data from each agency i.e., Nallacheruvu was selected to collect data from WASSAN, Bukkarayasamudram for CFL and Atmakur for data from SDA. The data was collected using a pre-tested interview schedule and focus group discussion with the fanners belonging to each agency.

RESULTS & DISCUSSION

The main crops in the study villages from Adilabad district in Telangana are cotton, soya and red gram in kharif and maize, chick pea, wheat and water melon in rabi. The average annual rainfall in Adilabad is 1000 mm.

Table 1. Pooled T-test Results for Extension Approaches from Ekalavya Foundation (EF), Jain Irrigation (JI) and State Dept. of Agriculture (SDA) in Adilabad district, Telangana.

S.No.	Extension Approaches	N	Mean
1.	Demonstration	120	5.00
2.	Training	120	3.58
3.	Exposure visit	120	4.30

S.No.	Extension Approaches	Mean Difference	t value	Sig. (2-tailed)
1.	Demonstration vs	1.425	31.44	0.001**

	Training			
2.	Demonstration vs Exposure Visit	0.700	16.66	0.001**
3.	Training vs Exposure Visit	-0.725	-11.73	0.001**

**Significant at 0.01 probability level

Results from table 1. indicate that Demonstrations (Group approach) were highly effective extension method followed by Exposure visits and trainings in that order. Results from Shaibu et al. (2018) also concur with our findings that the extension approach that was most perceived by farmers to influence adoption was demonstration (with mean value of 4.51). According to Aremu et al. (2015) and Anandajayasekeram et al. (2008), it is possible to reach large numbers of farmers within a short time at minimal cost and with great impact, using the demonstration method.

Other results from Adilabad district, Telangana

- Farmers' major perception about extension personnel was equal partners in both EF and JI at 95% and 85% respectively, while it was beneficiary of knowledge and expertise for SDA at 60%.
- Major constraints in adoption of technologies for EF, JI and SDA farmers from Telangana are technical and operative at 100%, 80% and 80% respectively.
- Jain irrigation in convergence with state horticulture dept. which provides subsidy to farmers installed drip systems in farmers' fields where water source exists. Water savings to the tune of 75% were reported by farmers with use of drip systems.
- As part of watershed development (funded by NABARD) initiated by EF, villages were provided with farm ponds, open wells. Rabi crop is taken now in these villages with availability of water source.
- Formation of farmer groups and Farmer Producer Organizations (FPOs) in the villages of EF had helped in getting good quality seeds, fertilizers and pesticides along with good price for their produce.
- The farmers from SDA agency villages expressed that Agricultural Extension Officers (AEOs) should visit their fields at least once in a week which is not

happening now. Regular crop advisories to farmers were absent in the surveyed villages. Requirement of quality seeds, drip facility, bullock drawn implements were raised by majority of farmers in the SDA agency villages.

In Anantapuramu district of A.P., the main crops in the study villages are ground nut, red gram, paddy, banana, tomato, and other vegetables. The average annual rainfall in Anantapuramu is 550 mm.

Table 2. Tukey HSD test Results for Extension Approaches from CFL, Wassan and SDA in Anantapuramu Dist., A.P.

S. No.	Extension Approaches	N	Mean
1.	Demonstrations	120	3.67
2.	Trainings	120	2.86
3.	Exposure Visits	40	l
4.	Group Meetings	80	2.82
5.	Farmer-to-Farmer Extension (FFE)	40	4.9

Tukey's Honest Significant Difference (HSD) test is a post hoc test commonly used to assess the significance of differences between pairs of group means.

The major extension approaches that were used to transmit information to farmers are given in the above table 2. Farmer to Farmer Extension (FFE) followed by demonstrations, training, group meetings and exposure visits (group approaches) were highly effective extension approaches in that order. Results from Ewbank et al. (2007) also concur with our findings. The FFE approach has the potential of supplementing existing extension approaches and improves farmers' access to extension services. FFE is effective in serving farmers' needs, institutionally more sustainable, comparably inexpensive, and used in areas where it is inadequate or absent of government extension staff. Furthermore, it is also thought to reach and include many poor farmers, thus increasing the adoption of technologies.

Other results from Anantapuramu district, A.P.

- Farmers major perception about extension personnel was advisor + input provider at 40% for CFL sample; facilitator + input provider at 57.5% for SDA, while it was facilitator + advisor + equal partners in research for WASSAN at 100%.
- Major constraints in adoption of technologies for CFL, WASSAN and SDA farmers are technical (like watershed management, illiteracy, less know-how on crops, less awareness of soil and water conservation measures) at 100% each respectively.
- House deliveries i.e., free delivery of fertilizers, pesticides and gypsum at the doorstep of farmers is being followed by CFL. Free distribution of Pseudomonas, Trichoderma cultures to citrus, pomegranate farmers by CFL. They facilitated marketing of crop produce during Corona pandemic.
- Navdanya system of multicropping (millets, pulses, fodder crops) promoting crop diversity by WASSAN. Advantages of this system are soil cover, efficient use of sunlight, moisture (from NE rainfall) and additional income of Rs. 10,000/- per acre. Seed multiplication taken up by farmers' cooperative, (Mutually Aided Cooperative Society) as a business venture.
- Water sharing among farmers in the form of networking of bore wells was introduced in *Pallevandlapally* village by WASSAN. Organic farming in the form of Jeevamritam for groundnut, red gram and tomatoes. 4 FPOs exist in one village. Credit and marketing are not a problem in these villages.

CONCLUSION

It is imperative that, the agricultural policies of Telangana should be aimed at empowering the Agricultural department, both technically and financially, to train farmers through field demonstrations, exposure visits and trainings since these approaches have proven to be effective in disseminating information to farmers in real time. Similarly, in Anantapuramu district of A.P., FFE followed by demonstrations, training, group meetings, and exposure visits were highly effective extension approaches for dissemination of technologies, information etc. to farmers in the study. Therefore the agricultural policies of A.P. should be aimed at empowering the

Agricultural department, both technically and financially, to train farmers through FFE, Demonstrations, Trainings, Group meetings and Exposure visits since these group approaches have proven to be effective in disseminating information to farmers in real-time. It was found from the study that extension was highly effective in NGOs followed by SDA and private firms in that order in the sample districts in both Telangana and A.P. Technology-led approaches like Information and Communication Technologies (ICTs) (like mobile, SMS, individual (individual farmer or household) and mass media approaches (like TV, radio) was shown less preference by farmers in information seeking in the study.

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Chapter 7

Climate Resilient Agriculture in India: Experience from National Innovations in Climate Resilient Agriculture (NICRA)

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The agriculture in India is highly vulnerable to climate change with 51 percent cultivated area under rainfed conditions. One or other part of the country is experiencing frequent extreme weather events causing sizeable loss to yield and income to the farmers at micro scale and to the Nation's economy at macroeconomic level. The smallholders (less than 2 ha) constitute 86.08 percent of the total numbers of the holdings in India. These small and marginal farmers are highly vulnerable to various stresses induced due to the changing climate. Mostly, cereals are the staple food of India, with the changing climate its production will be affected resulting in higher food prices. Increase in frequency and magnitude of heat waves, droughts, inland and coastal flooding, sea level rise and tropical cyclone etc. would decrease food stability and increases risk of food security. India is likely to lose 2.8 percent of its GDP because of climate change impact by 2050 and leads to significant reduction in living standards.

Climate change projections suggest that an increase in temperature by 2 to 3.5°C would reduce net agricultural income by 25 percent. Although an increase in carbon dioxide is likely to be beneficial to several crops, associated increase in temperature and increased variability in rainfall would considerably affect food production. The AR-5 of IPCC indicates a probability of 10 to 40 percent loss in crop production by the year 2080-2100. It is also evident through modeling studies that loss of 4 to 5 million tons in wheat production in future with every 1C rise in temperature. Climate change is likely to aggravate the heat stress in dairy animals and adversely affect their productive and reproductive capabilities. A preliminary estimate indicates that global warming is likely to reduce milk production in India to the tune of 1.6 million by 2020. Increasing sea and river water temperature is likely to affect fish breeding, migration and harvest. Indian coastline, which is about 7,517 km, is vulnerable to climate change impacts such as water intrusion and coastal salinity. A rise in temperature as low as 1°C could have a profound impact on survival and the geographical distribution of different fresh water &marine fish species. Therefore, it is very important for farmers and other stakeholders to adopt climate resilient technologies and reduce the losses. Simple adaptations such as change

in planting dates and crop varieties could help reduce the adverse effects of climate change to some extent. In the recent past increased extreme weather events have been experienced in some or other parts of the country viz., droughts (2000-2004, 2006, 2009, 2011, 2012, 2014 & 2015), floods (2005, 2006, 2012, 2014 & 2015), cyclones (2012, 2015), heat wave (2003, 2004, 2005, 2007, 2010 & 2016), cold wave (2005, 2006, 2008, 2011, 2012, 2013 and 2017), hailstorm (2014, 2015). Increased number of mid-season droughts and high intensity rains that take away fertile soil leading to water stress reduced food production, stability and livelihoods of the farmers in the country. Small changes in temperature and rainfall would have significant effect on the quality of cereals, fruits, aromatic and medicinal plants. Pests and diseases are highly dependent upon temperature and humidity, and therefore will greatly be influenced by climate change. The recent outbreak of whitefly on cotton in northwest India and pink bollworm at several cotton growing areas of the country is attributed to aberrant changes in weather.

Therefore, it is evident that climate change has become an important area of concern for India to ensure food and nutritional security for growing population. To meet the challenges of sustaining domestic food production in the face of changing climate and generate information on adaptation and mitigation in agriculture to contribute to global fora like UNFCC, it is important to have concerted research on this important subject. With this background, Indian Council of Agricultural Research (ICAR), under the Ministry of Agriculture and Farmers Welfare launched a network '*National Innovations* *in Climate Resilient Agriculture*' (NICRA) during the year 2011. NICRA aims to evolve crop varieties tolerant to climatic stresses like floods, droughts, frost, inundation due to cyclones and heat waves. Under this project about 41 Institutes of ICAR are conducting research under Strategic Research Component covering various theme areas viz., development of multiple stress tolerant crop genotypes, natural resource management, quantification of greenhouse gas emissions in agriculture and the develop technologies for their reduction, climate resilient horticulture, marine, brackish and inland fisheries, heat tolerant livestock, mitigation and adaptation to changing climate in small ruminants and poultry. Sate of the art infrastructure required or climate change research such as high through-put phenotyping platforms, Free Air Temperature Elevation (FATE), Carbon dioxide and Temperature Gradient Chamber (CTGC), high performance computers, automatic weather stations, growth chambers, rainout shelters, animal calorimeter, shipping vessel,

flux towers and satellite receiving station were established in the research institutes across the country under NICRA project.

Technology Demonstration Component (TDC) under NICRA aims to demonstration of location specific practices and technologies to enable farmers cope with current climatic variability. Demonstration of available location-specific technologies related to natural resource management, crop production, livestock and fisheries is being taken up in the climatically vulnerable districts for enhancing the adaptive capacity and resilience against climatic variability. Technologies with a potential to cope with climate variability are being demonstrated under Technology Demonstration Component (TDC) in 151 most vulnerable districts selected across the country through KVKs.

Institutional intervention Component under NICRA aims at creating enabling support system in the village comprising of strengthening of existing institutions or initiating new ones (Village Level Climate Risk Management Committees (VCRMC)), establishment and management of Custom Hiring Centers (CHCs) for farm implements, seed bank, fodder bank, creation of commodity groups, water sharing groups, community nursery and initiating collective marketing by tapping value chains. 100 CHCs for farm machinery were setup under NICRA project, which are being managed by VCRMC comprising of villagers. Module on use of ICT for knowledge empowerment of the communities in terms of climate risk management is also being planned in select

KVKs for generation of locally relevant content and its dissemination in text and voice enabled formats. 151 KVKs associated under NICRA projects have also taken initiatives such as participatory village level seed production of short duration, drought and flood tolerant varieties, establishment of seed banks involving these varieties were established in the KVKs, demonstration and of improved varieties of fodder seeds and establishment of fodder bank in NICRA villages. Details on the research under this project is as under.

Climate smart crop varieties

Large number of germplasms screened for drought, heat, salinity, submergence tolerance etc. in different field and horticultural crops, for identifying donors for stress tolerance. Number of advance breeding materials was generated and evaluated at multi-locations for developing new cultivars. Germplasm lines of rice and wheat tolerant to drought and heat stress have been collected from different climatic hot-spot regions of India. So far a total of 184 rice accessions were collected. Evaluation of wheat germplasm for drought tolerance with 1485 accessions was conducted to identify drought tolerance Innovative

lines based on 22 morpho-physiological traits. Based on the drought susceptible index a reference set will be developed for allele mining using micro satellite markers. Marker assisted back cross breeding was carried out using molecular markers link to the QTL governing drought tolerance into Pusa Basmati-1 rice varieties. Two rice genotypes for submergence tolerance was registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi. One salinity tolerant variety is in final year of All India Coordinated Research Project trials. Three superior heat tolerant hybrids were developed. Four drought tolerant rice varieties were released for Tripura. Two extra-early (50-55 days) green gram varieties were identified for summer cultivation (IPM 409-4, IPM 205-7) and one multiple stress tolerance redgram wild accession (*C. scarabaeoides*). A large number of soybean genotypes were evaluated for drought. Lines JS 97-52, EC 538828, EC 456548 and EC 602288 identified as relatively tolerant. These lines have been crossed among each other and with lines with superior agronomic background and are in F2-3 generations. Five heat tolerant and 12 drought tolerant genotypes in tomato. Number of mapping population in rice, wheat, maize was developed for identifying QTL for various abiotic stresses in these crops for utilization in Maker Assisted Selection (MAS) breeding.

Natural resource management

GHG emissions (CO_2, CH_4& N_2O) due to implementation of climate resilient interventions in various production systems (annual and/perennial crops, irrigated rice, inputs, livestock, forestry and land use change) were converted to an equivalent value (tonne CO_2 equivalent) in 7 villages of Gujarat and Rajasthan, which were found to be negative suggesting a sink in GHG emissions. Direct-seeded rice (DSR) with mungbean residue incorporation, brown manuring (BM) with *sesbania,* rice residue retention (RR) in zero till (ZT) wheat/*rabi* crops are important conservation agriculture (CA) practices. It was observed that mung bean residue (MBR) + DSR – ZTW – ZT summer mung bean (ZTSMB) gave highest system productivity, net return, water productivity and low GWP. In long term efforts to assess CA practices on productivity enhancement, nutrient use efficiency, soil health and quality, it was observed that seed (3.8 t ha^{-1}) and stover (5.6 t ha^{-1}) yields in maize in CA were on par with conventional system. Also, significantly higher grain (5.3 t ha^{-1}), stover (6.5 t ha^{-1}) yields and harvest index (0.44) were realized with balanced fertilization with NPKSZnB. Analysis of Resource Conservation Technologies (RCT) in NEH zone indicated that Conventional Tillage (CT) has higher cumulative soil respiration (> 18%) compared to zero tillage. Agroforestry offset carbon

dioxide from atmosphere is 0.77 tons of $CO_2 ha^{-1}$ $year^{-1}$and agroforestry system are estimated to mitigate 109.34 million tonnes CO_2 annually from 142.0 million ha of agriculture land. Further, it is estimated to offset 33 per cent of total GHGs emissions from agriculture sector annually at country level. The net eco-system methane exchange during rice growth period was the highest between active tillering to maximum tillering stage in rice. The diurnal variations in mean Net Eco-system Exchange (NEE) in submerged rice eco-system in both dry and wet seasons varied from + 0.2 to - 1.2 and + 0.4 to - 0.8 mg CO_2 m^{-2} s^{-1}. The cumulative seasonal methane emission was reduced by 75% in aerobic rice as compared to continuously flooded rice. The seasonal emissions were lower in slow-release N fertilizer, especially, when applied on the basis of Customized Leaf Colour Chart (CLCC). Zero tillage in wheat lowered the GWP as compared to tilled wheat. Similarly, CO_2, CH_4 and N_2O fluxes were influenced by tillage

/ anchored residue and anchored residues of 10 and 30 cm in zero till reduced the N2O emissions in rainfed pigeonpea-castor system. In efforts on mitigation strategies by reducing carbon foot prints through conservation agriculture in rainfed regions, carbon foot print from various practices like decomposition of crop residues, application of synthetic N fertilizers, field operations and input production indicated that there is a scope to reduce carbon foot prints by reducing one tillage operation with harvesting at 10 cm height with minimal impact on the crop yields. Long-term conservation horticultural practices in mango orchards improved the quality of soils through enhancing the organic carbon fraction and biological status, especially near the surface. Soil aggregates and water stability improved under conservation treatments. Cover crop, Mucuna, could conserve maximum moisture and reported higher Glomalin content in soil indicating the improvement in soil aggregation. Assessment of biochar on productivity, nutrient use efficiency and C sequestration potential of maize-based cropping system in North-Eastern Hill region indicated a higher Soil Microbial Biomass Carbon (SMBC), Dehydrogenase Enzyme Activity (DHA) and SOC with application of biochar @ 5.0 t/ha along with 75% RDF + 4 t/ha FYM, while exchangeable aluminium and exchangeable acidity were reduced. GHG inventory for different cropping systems and production systems. GHG emissions quantified from Conservation Agriculture (CA)–15-20 percent reduction, RCTs (Biochar, zero tillage, reduced tillage, mulching etc.). C Sequestration in different agroforestry systems (16-22 t C ha-1).

Greenhouse gas emission from agriculture and allied sector

Under NICRA, emphasis has been placed on the development of technologies, which can reduce the greenhouse gas emissions without compromising on yield. As part of this initiative, various ICAR institutes such as Indian Agricultural Research Institute (IARI), New Delhi, Indian Institute of Farming Systems Research (IIFSR), Modipuram, Indian Institute Soil Science (IISS), Bhopal, Central Arid Zone Research Institute (CAZRI), Jodhpur, ICAR-Research Complex for NEH Region (ICAR-NEH), Umiam are working on various themes related to the GHG emissions. Facilities like, Eddy Covariance towers are established at IARI, New Delhi and National Rice Research Institute (NRRI), Cuttack for continuously monitoring the GHG emissions from the crop fields during growing season so as to quantify precisely the extent of GHG emissions from the paddy systems. Research Facilities like Rainout shelter, Carbon dioxide Temperature Gradient Chamber

(CTGC), Free Air Carbon Dioxide Enrichment (FACE), Free Air Temperature Enrichment (FATE) etc. have been established to understand the impact of elevated carbon dioxide (eCO2) and temperature and develop crop varieties that can withstand these stresses. Practices which can further reduce the GHG emissions such as improved systems of paddy cultivation, fertilizer management, improved fertilizer materials, crop diversification, etc. are explored for further reducing the GHG emissions from the paddy-based systems. The proven mitigation practices, which can reduce the GHG emissions, are being demonstrated to farmers as part of the TDC of NICRA. The TDC of NICRA is being implemented in 121 climatically vulnerable districts of the country by taking one or cluster of villages in each of the vulnerable district.

Location specific, crop specific mitigation practices such as system of rice intensification, direct seeded rice cultivation (dry and wet methods of cultivation), soil test based fertilizer application, rational application of nitrogen, integration of trees especially fruit trees in the arable systems, efficient irrigation systems such as drip method and sprinkler method of application which can reduce the energy use while irrigating field crops, demonstration of zero tillage cultivation as an alternate to burning crop residues in rice-wheat systems of Punjab and Haryana where large quantities of rice residues are being burnt, integration of green manure crops in the existing cropping systems, promotion of green fodder crops and greater use of green fodder for livestock, etc. are being demonstrated as part of the technology demonstration component of NICRA in the 121 climatically vulnerable districts of the country. The proven resilient Innovative Extension

practices are being integrated in the development programs such as the Crop diversification in traditionally paddy growing regions as part of the National Food Security Mission (NFSM) wherein 1.02 lakh ha is being diversified from paddy to other less water consuming crops in the country during the year 2015-2016. Similarly, the paddy systems of cultivation such as System of rice cultivation, direct seeded rice are being promoted by the development programs as part of the NFSM where in 1.63 lakh ha area was brought under these improved methods of paddy cultivation in the country during the year 2015-2016. Such kind of efforts would contribute to reduction of GHG emissions in the country.

Horticulture

Climate change impacts several horticultural crops in the country. Flooding for 24 hours severely affects tomato during flowering stage. Onion during blub stage is highly sensitive to flooding, whereas warmer temperatures shorten the duration of onion bulb development leading to lower yields. Similarly, soil warming adversely affects several cucurbits. Reduction in chilling temperature in the recent years in Himachal Pradesh drastically affected apple production, and the farmers are shifting from apple to kiwi, pomegranate and other vegetables. More importantly, temperature and carbon dioxide are likely to alter the biology and forging behavior of pollinators that play key role in several horticulture crops. Under NICRA project research has been initiated at 5 ICAR Institutes viz., Indian Institute of Horticultural Research (IIHR), Bengaluru, Indian Institute of Vegetable Research (IIVR), Varanasi, Central Potato Research Institute (CPRI), Shimla, Central Institute of Temperate Horticulture (CITH), Srinagar and Directorate of Onion and Garlic Research (DOGR), Pune. High throughput screening of germplasm using plant Phenomics, Temperature Gradient Chambers, FATE Facility, Root imaging system, Environmental Chamber, TIR Facility, Photosynthetic System and Rainout shelter enabled to characterizes large number of germplasm lines and identify suitable donors for breeding against drought, heat stress and flooding in tomato, brinjal and onion. The technique for inter-specific grafting of tomato over brinjal has been standardized and large-scale demonstrations have been taken up to withstand drought and flooding in tomato. Environmentally safe protocol was developed for synchronizing flowering in mango, which is induced due to changing climate. A microbial inoculation with osmo tolerant bacterial strains has been developed to improve yield under limited moisture stress in tomato. Several resource conservation technologies viz., mulching, zero tillage, reduced tillage, biochar etc. have been demonstrated in climatically vulnerable districts across the country through KVKs. Large-scale adoption of this climate resilient technologies enables to adopt the changes associated with global warming and also keep pace with increasing demand for horticulture products in the country in the years to come.

Livestock

Under NICRA project climate change research facilities for livestock viz., CO2 Environmental Chambers, Thermal Imaging System, Animal Calorimeter, Custom Designed Animal Shed etc. have been established at ICAR-National Dairy Research

Institute (NDRI), Karnal and ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar. Biochemical, morphological and physiological characterization of indigenous cattle breeds were carried out and compared with exotic breeds. The traits identified in indigenous breed viz., heat shock proteins, air coat colour, wooly hair etc. that impart tolerance to heat stress could be used in future animal breeding programs to develop breeds that can withstand high temperature. Different feed supplements have been identified and tested successfully to withstand heat stress in cattle. Studies on prilled feeding in cattle showed that they help lowering stress levels and methane emission. Custom designed shelters system and feed supplementation with chromium propionate, mineral supplements (Cu, Mg, Ca and Zn) both in feed and fodder significantly improved the ability to withstand heat stress. At ICAR-North Eastern Hill Region, Umiam, the local birds of Mizoram are predominantly black in colour, small size, crown appearance on head, light pink comb with black, poorly develop wattle, small ear lobe, shank is brown to black and elongated. The average annual egg production of local birds is 45-55 eggs. Local birds are more tolerant to common diseases of poultry. Innovative deep litter pig housing model was developed that offers the advantages of better micro-environment both summer and winter, better physiological adaptation, protecting animal welfare and behavior, faster growth rate of piglets and higher performance and productivity and low incidences of diseases/ conditions. The performance of Vanaraja poultry under backyard farming at different altitude under diversified agro-climatic condition was evaluated. Vanaraja birds have high tolerance to incidence of diseases and showed wide adaptability under different altitude. Many of these climate resilient technologies viz., feed supplement, shelter management, improved breeds, silage making, de-warming etc. have been demonstrated in the farmers field through KVKs in the 121 climatically vulnerable
districts across the country. Up-scaling of these technologies through respective State Governments would enable the livestock farmers in the country cope with vagaries associated with climate change.

Fisheries

Under NICRA project climate change research facilities for Fisheries viz., Research Vessel, Green House Gases analyzer Agilent 7890A GC Customized, Fish Biology Lab, CHNS/O analyzer, Automatic Weather Station installed etc. have been established at

ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, ICAR-Central Institute of Brackish water Aquaculture (CIBA), Chennai and ICAR-Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar. Relationship of temperature and spawning in marine and freshwater fisheries sector is being elucidated so that fish catch in different regions can be predicted by temperature monitoring. A shift in the spawning season of oil sardine was observed off the Chennai coast from January-March season to June-July. Optimum temperature for highest hatching percentage was determined in Cobia. A closed poly house technology was standardized for enhancing the hatching rate of common carp during winter season. An e-Atlas of freshwater inland capture fisheries was prepared which helps in contingency planning during aberrant weather. For the first time a greenhouse gas emission measurement system was standardized for brackish water aquaculture ponds. Cost effective adaptation strategies like aeration and addition of immuno-stimulant in the high energy floating feed helped freshwater fish to cope with salinity stress as a result of seawater inundation in Sundarban islands. Relationship was established between increase in Surface Sea Temperature (SST) and catch and spawning in major marine fish species. Simulation modeling was used to understand the climate change and impacts at regional/national level.

Micro level agro-advisory

Under ICAR-NICRA project a concept of micro level Agromet advisories at block level was developed and on a pilot basis with the help block level forecasts provided by IMD, Agrometeorologists of AICRPAM cooperating centers and KVK subject matter specialists initiated in 25 selected blocks in 25 selected districts. AICRPAM introduced a new concept "Field Information Facilitators (FIFs)" who acts as the interface between the farmer and AICRPAM and KVK for Crop data collection and dissemination of MAAS. The Dissemination mechanism was strengthened with different methods used by the AICRPAM centers viz. Dandora, pasting posters at different important places where people frequently watch, through SMS to the mobile phones of the farmers who are registered with AICRPAM center and KVKs. Special mobile applications were also developed by AICRPAM centers for dissemination of AAS. The feedback obtained from the farmers stated that many of them were satisfied with the timely Agromet advisories which are benefitted them a lot. some of the success stories presented below. In reality expansion of these services throughout the country will benefit of farming community and helps in doubling of their income.

Policy support

Vulnerability assessment map prepared under NICRA is being used by different Ministries and several NGOs/CBOs.

 NICRA is also contributing to National missions like NMSA, Water mission, Green fund and INDC

 GHG inventory by NICRA partner institutes contributes to BUR reports

 Outcome of NICRA project supported some of the policy issues in Sates of Maharashtra (BBF Technology), Million farm ponds in the Sates of Andhra Pradesh and Telangana, ground water recharge initiatives (Southern states), drought proofing in Odisha, NABARD action plans, NICRA model village expansion in Assam etc.

 Contingency planning workshops organized every year in different States helps in preparedness to face weather aberrations.

Over all, NICRA project is contributing towards developing adaptation and mitigation strategies in the country and enabling to make Indian agriculture more resilient to climate change.

Conclusion

NICRA is a unique project, which brings all sectors of agriculture viz. crops, horticulture, livestock, fisheries, NRM and extension scientists on one platform for addressing climate concerns. It is very important to sustain the efforts made in the past few years and take forward the project for some more years. Over the past five years, the state-of-the-art infrastructure facilities have been established, standardized and put in to function in core institutes of ICAR to undertake the climate change research. Manpower (Scientists, Research Associates, Research Fellows, Technical Officers etc.) have been trained to handle and operate these facilities. However, some of these precious research facilities are yet to be utilized to the full potential. In other words, a large platform related to climate change research has been created in the country. Crop improvement for multiple stresses takes several years of research and multi-location testing. Efforts made under this project, in some cases resulted in development of varieties/hybrids ready for large-scale cultivation. Whereas, many are under different stages of development which may require few more years to be released as variety/hybrid/breed. Simulation modeling to assess the impact of climate change at regional level is still at initial stage. Standardization of minimum data sets and compilation of data from different sources have shown good progress. In the next phase, these data sets will be used for modeling. Capacity building for this activity will be emphasized and a dedicated group will be formulized. Research, essentially long term in nature, should continue further to achieve the intended outputs and outcomes.

Though there are some positive lessons and experiences emerging out of technology demonstration component, there is still considerable need to continue this activity to identify and demonstrate technologies that help deal with climate change. In fact, the technologies found to be performing well are getting fed into programs such as NMSA. There is still need to develop variety of adaptation options for different sub-sectors within agriculture, for different regions and for farmers with varying resource endowments. Such an effort is to be accompanied by identification of factors that help adopt technologies on a wider scale.

The commitments of the country to emission reductions require generate appropriate information and data on emissions as well as options that help reduce emissions. Techniques standardized so far under NICRA for estimation of GHG emissions from different management practices will be used for further reducing the carbon footprint of production systems in the country. Government of India has committed for the reduction of emission intensity of GDP by 32-35 percent by 2030 from 2005 levels, and the outputs of NICRA project contributing to several national project reports i.e., Intended Nationally Determined Contribution (INDC), Biennial Update Report (BUR), Nationally Appropriate Mitigation Action (NAMAs), National Mission on Sustainable Agriculture (NMSA) and several other Missions under National Action Plan on Climate Change. The system-wide impacts and responses to climate change need to be understood better and more comprehensively. The efforts in this direction, which have begun, recently have to be taken through their logical course for such an understanding is necessary to identify and prioritize various adaptation options. To sum up, the activities initiated few years back under NICRA should continue and expand in scope and content, and enable to develop multi location multi sector mitigation and adaptation strategies so that we combat major challenge posed due to climate change in Agriculture.

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Chapter 8

Climate resilient technologies to enhance climate resilience under different climate vulnerability in NICRA villages

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Climate Resilient Agriculture (CRA) involves integrating adaptive and resilience-building practices in agriculture to enhance the system's ability to withstand climate-related disruptions. It focuses on minimizing damage and ensuring rapid recovery by effectively managing natural resources such as land, water, soil, and genetic materials through the adoption of resilient practices. In response to recommendations from the Standing Parliamentary Committee on Agriculture, the Government of India, through the Ministry of Agriculture and Farmers Welfare, initiated a project on climate-resilient agriculture. This project was launched in February 2011 by the then Union Minister for Agriculture, the project is implemented by ICAR as "The National Initiative on Climate Resilient Agriculture (NICRA) till October 2017 and later as 'National Innovations in Climate Resilient Agriculture (NICRA). This is a flagship project of the Indian Council of Agricultural Research (ICAR) launched in the XI Plan period to comprehensively address issues related to climate change.

The project aims to enhance resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. The project consists of four components viz. strategic research through network, sponsored and competitive grants; technology demonstration and dissemination; knowledge management and capacity building. In strategic research component, both short-term and long-term research programs with a national perspective have been taken up to evolve adaptation and mitigation strategies in crops, horticulture, natural resources, livestock, fisheries and poultry. The second component of the NICRA is the Technology Demonstration Component (TDC) which deals with demonstration of the proven technologies for adaptation of crop and livestock production systems to climate variability. The technologies were implemented in selected vulnerable districts of the country by Krishi Vigyan Kendra (KVK) in a participatory mode, these demonstrations are of location specific interventions that help to enhance resilience with a view that such practices are eventually adopted on a larger scale by farmers. The project is under way in 151 districts involving over one lakh farm families across the country. The interventions are finalized in a participatory approach through the Village Climate Risk Management Committee (VCRMC) in the village panchayats after the PRA to assess the climate related problems in the village and baseline survey. The program was launched formally in all the villages by involving the state line department functionaries and leaders of the panchayats to ensure local ownership of the project from the beginning and convergence of related schemes are currently in operation in the panchayat.

As part of the TDC, 151 climatically vulnerable districts were identified based on comprehensive risk assessment made by the ICAR-CRIDA. Based on the vulnerability assessment, the districts are classified in to very high risk (1-109), high risk (110-310), medium risk (311-514), low risk (515-563) and very low risk (564-573) (Rama Rao *et al.,* 2019) of climate related problems (Figure 1). CRIDA has the responsibility of planning, coordination and monitoring of the program at the national level. The programme is coordinated by Eleven Agricultural Technology Application Research Institutes (ATARIs) and is implemented through Krishi Vigyan Kendra (KVKs) in their respective zones in the district (Table 1) Currently the programme is operational in 448 villages of 151 clusters from the 151 selected districts through farmer participatory approach.

Table 1. Zone-wise distribution of KVKs involved in Technology Demonstrations under NICRA

Zone	ATARI	States and Union Territories involved	No. of KVKs involved
I	Ludhiana	Jammu & Kashmir (5), Himachal Pradesh (4), Punjab (4) and Uttarakhand (4)	17
II	Jodhpur	Haryana (5) and Rajasthan (13)	18
III	Kanpur	Uttar Pradesh (17)	17
IV	Patna	Bihar (11) and Jharkhand (3)	14
V	Kolkata	West Bengal (7), Odisha (9) and Andaman & Nicobar Islands (1)	17

VI	Guwahati	Assam (4), Arunachal Pradesh (3) and Sikkim (2)	9
VII	Barapani	Tripura (1), Manipur (3), Meghalaya (4), Mizoram (4) and Nagaland (3)	15
VIII	Pune	Maharashtra (6) Gujarat (4) and Goa (1)	11
IX	Jabalpur	Madhya Pradesh (8) and Chhattisgarh (3)	11
X	Hyderabad	Andhra Pradesh (3), Telangana (1) and Tamil Nadu (3), Puducherry (1)	8
XI	Bengaluru	Karnataka (7), Kerala (6) and Lakshadweep (1)	14
		Total: 28 states + 5 UTs	**151**

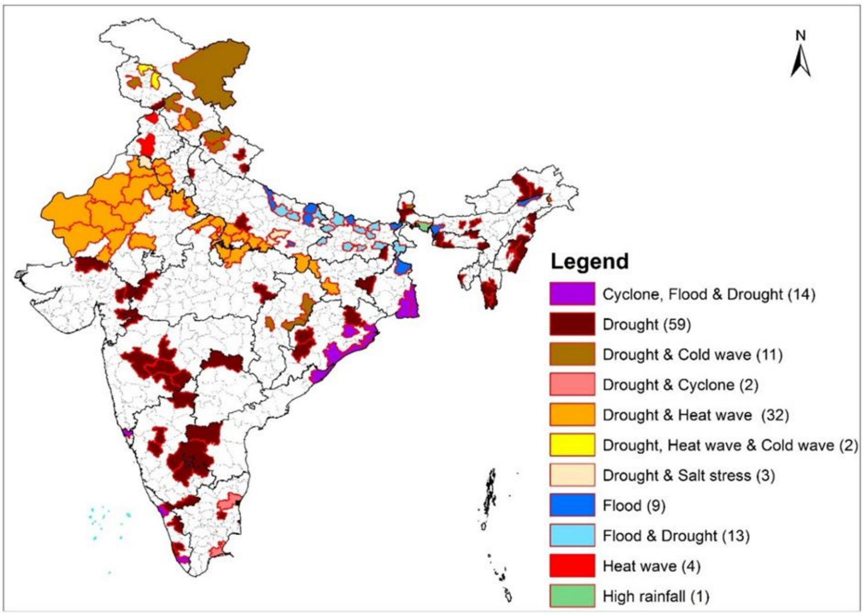

Fig. 1: 151 vulnerable districts under NICRA-TDC programme

The predominant climatic vulnerabilities addressed in this project were drought, prolonged dry spell, floods, cyclone, heat wave, high temperature stress, cold wave, etc. Technology interventions are identified and demonstrated depending on the bio physical environments and the dominant production systems. Prioritization of interventions is based on extent of exposure of the different farming situations prevalent in the village to climate vulnerability and the programme is finalized in consultation with stake holders. Creation of enabling conditions through village level institutions to enhance adoption of the practices and to promote spread of climate resilient technologies among farmers so as to enhance their adaptive capacity and coping ability to climate risks is an important aspect of TDC. Climate resilient practices and technologies were demonstrated in different farming systems modules like Rainfed

Farming system without Animals (FST 1), Rainfed Farming system with Animals (FST 2), Irrigated Farming system without Animals (FST 3), Irrigated Farming system with Animals (FST 4). The climate vulnerabilities were addressed through different modules:

Natural Resource Management

Interventions related to *in-situ* moisture conservation, biomass mulching, residue incorporation instead of burning, green manuring, water harvesting and efficient use, improved drainage in flood prone areas, zero tillage, artificial ground water recharge and water saving irrigation methods are being demonstrated.

Crop Production Technologies

Introduction of drought/ temperature tolerant varieties, advancement of planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through fumigation, staggered community nurseries for delayed onset of monsoon, location specific intercropping systems with high sustainable yield index, farming systems are being demonstrated.

Livestock and Fisheries Interventions

Use of community lands for fodder production which can be utilized during droughts/floods, augmentation of fodder production through improved planting material, improved fodder/feed storage methods, fodder enrichment, prophylaxis, improved shelters for reducing heat stress in livestock, management of fish ponds/tanks during water scarcity and excess water and promotion of livestock component as a climate change adaptation strategy are being taken up.

Institutional Interventions

Institutional interventions either by strengthening the existing ones or initiating new one related to community seed bank, fodder bank, custom hiring center, village climate risk management committee, collective marketing group, commodity groups, are important interventions being taken up as part of the project

Climate resilient technologies contributes towards minimizing the impact of variable climate during the stress years and contributes to higher productivity and farm incomes during the normal years. Climate resilient technologies can stabilize agricultural production in a sustainable manner. Some of the important and doable climate resilient technologies are listed and discussed below:

1. Climate resilient technologies for drought prone regions

Rainfed areas are highly susceptible to drought, with India's rainfed regions experiencing drought approximately once in every three years. The effects of drought often persist for three to six years, impacting water availability for people, livestock, and agricultural activities, including crop and fodder production. Droughts have a direct and adverse effect on agricultural productivity. Low rainfall regions face multiple biophysical and socio-economic challenges that hinder crop and livestock productivity. These challenges include irregular and insufficient rainfall, dry spells, droughts, land degradation, poor soil productivity, limited use of inputs and technology, inadequate fodder supply, and low-yielding livestock. However, the negative impacts of drought can be mitigated by adopting appropriate improved technologies at the right time and place.

A) Natural resource management (NRM) technologies

In low rainfall regions, natural resource management (NRM) technologies, including *in-situ* water management and water harvesting, play a crucial role in improving crop and livestock productivity. These technologies help to conserve soil moisture, ensuring its availability for an extended period while also providing water for supplemental irrigation during dry spells or moisture stress conditions. Various *in-situ* water management techniques, such as farm bunding, ridges and furrows, broad bed furrows, trench-cum-bunding, and compartmental bunds, have been evaluated for different environmental conditions and production systems to enhance their effectiveness.

In-situ water management practices for crop yield improvement

In-situ moisture conservation approaches conserves soil and water by reducing runoff, enables greater infiltration in to soil by increasing infiltration time, increase soil moisture, reduce soil evaporation and increase root system development. These methods collect rain water where it falls, and water is made available to overcome the stress during crop period contributing to higher yields. Several land treatments for *in-situ* rainwater conservation are developed for various rainfall regimes (Table 2). They are location and crop specific and based on slope, soil depth, rainfall intensity, nature of crop, spacing, etc.

Table 2. Impact of *in-situ* water management practices for low to medium rainfall regions

Technology	Study area	Rainfall (mm)	Crop	Yield improvement (%) over the farmers' practice
Trench cum bund	Tumkuru, Chickkaballapura, Davangere	696	Groundnut, Fingermillet, Maize	Up to 50
Ridges and furrows	Amravati, Jalna, Tikamgarh	921 - 1032	Soybean	25 to 35
Farm bunding	Namakkal, Palamu	640 - 1085	Groundnut Paddy	20 to 22
Compartmental bunding	Belagavi Pune	572 - 468	Rabi sorghum	25 to 87
Laser Land levelling	Jhunjhunu, Aurangabad	460 - 838	wheat	22 to 31
Raised bed and furrow	Adilabad	996	Cotton	15-19

In-situ moisture conservation practices in different crops

At Chikkaballapura district of Karnataka, different *in-situ* moisture conservation practices along with improved crop varieties in different crops increased the yield and net income (Table 3).

Table 3. Performance of crops under different *in-situ* moisture conservation and other practices at Chikkaballapura district, Karnataka

Crop/ Perennials	Technology demonstrated	NICRA Farmers		Farmers practice	
		Productivity (q ha^{-1})	Net return (Rs ha^{-1})	Productivity (qha^{-1})	Net return (Rs ha^{-1})
Sunflower (KBSH-78)	Percolation ponds, Drip irrigation, cycle weeder	21.7	70431	18.8	56758
Pigeon pea (BRG-4)	Drip irrigation, Nipping, pulse magic	18.1	45050	17.8	43336
Finger millet (KMR-316)	Short duration variety, Transplanting, Trench cum bunding	27.2	42935	25.2	38545

Field bean	Short duration, Drip irrigation, staking, pulse magic spray.	8.4	40530	8.2	38650
Tomato	Drip irrigation, plastic mulching, spraying of vegetable special,	287.5	262712	237	209995

(Source: Singh *et al.,* 2023)

Water harvesting structures for sustainable crop production during adverse climatic condition

Collecting rainwater through farm ponds and providing supplemental irrigation in rainfed areas is a key strategy for mitigating drought effects and improving agricultural productivity. Efficient collection and utilization of rainwater is particularly beneficial for crop cultivation in regions with low and erratic rainfall. The stored water allows farmers to provide life saving irrigation during periods of moisture stress, ensuring crop survival. In addition, the harvested water helps in cultivation of a post rainy season or summer crops thereby increasing the cropping intensity. These water harvesting structures such as farm ponds, check dams, percolation tanks, and groundwater recharge systems play a crucial role in increasing groundwater levels, especially in areas with low to moderate rainfall across various agro-ecological zones (Table 4).

Table 4. Impact of water harvesting structures and their efficient use as a supplemental irrigation to enhance the groundwater level and crop yield in low to medium rainfall regions

Structure	**Study area**	**Rainfall (mm)**	**Crop**	**Yield improvement (%) over the farmers' practice**
Farm pond	Davangere, Datia Chitrakoot	644 to 815	Finger millet, Wheat	11 to 19
Community pond	Namakkal Aurangabad Khammam	644 to 1125	Cotton, Rabi onion, Paddy	11 to 20
Check dam	Kalaburagi, Jehanabad	665 to 1074	Cotton, Paddy	Up to 14
Sand bag check dam	Pune, Guna, Datia	468 to 1120	Pearl millet, onion, Soybean, wheat	25 to 63
Recharging of	Jhunjhunu	460	Green gram,	Up to 25

wells with silt trap			Wheat	
Micro irrigation (Drip and sprinkler	Amravati	921	Soybean, chickpea	35 to 56

(Source: Chary *et al.,* 2019)

Irrigation through Jalkund for vegetables production

South Garo hills of Meghalaya face floods, traditionally in the month of June and September and besides theses floods water scarcity is observed during *rabi* and *summer*. Due to water scarcity in NICRA villages farmers were unable to cultivate high value vegetable crops. In these villages Jalkunds were created to collect water during floods and intense rains in rainfall season. Supplemental irrigation was given to crops from collected water during water scarcity and dry spells. Hence farmers were able to take up the vegetable crops and it resulted in 88, 33, 34 and 83% higher grain yield and 113, 58, 148 and 121% higher net returns of chilli, tomato, cabbage and french bean as compared to non-NICRA farmers (Table 5).

Table 5. Impact of irrigation through Jalkund on vegetables production in Asugre district -South Garo hills, of Meghalaya

Crop	Technology adopted/ demonstrated	NICRA Farmer		Farmers practice	
		Productivity (q ha^{-1})	Net returns (₹ ha^{-1})	Productivity (q ha^{-1})	Net returns (₹ ha^{-1})
Chilli	Irrigation through Jalkund	32	3200	17	1500
Tomato		190	11400	143	7200
Cabbage		130	5200	97	2100
French Bean		42	3360	23	1523

(Source: Singh *et al.,* 2023)

Minimum tillage and crop diversification with mustard

In Sepahijala district of Tripura, traditionally, farmers cultivate rice followed by mustard cropping. Due to prolonged dry spells in November, the mustard yields were reduced. Hence the minimum tillage technology was introduced in the village for rice-mustard cultivation, this intervention helps in soil moisture conservation and reduce runoff losses. A mustard variety - PM-30 was sown under minimum tillage in rice fallow.

This intervention, helped in 2 weeks early sowing of mustard crop weeks over farmers practice, in turn this helped the crop to escape moisture stress during flowering, which increased the productivity (32%), net returns (106%) and B:C ratio (29%) (Table 6).

Table 6. Impact of mustard under minimum tillage in Tripura

Technology adopted/ Demonstrated	Productivity (q ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
Mustard under minimum tillage	12.8	29837	1.8
Farmers practice	9.7	14464	1.4

B) High yielding drought tolerant varieties for minimizing drought stress on crop production

Drought in rain-fed areas is the major abiotic stress in India, the dry spells of different intensities will be increase in future due to climate change (Wassmann *et al.* 2009). Water deficit may occur early during the monsoon season or at any time from flowering to grain filling, and the intensity of the stress depends on the time and duration of water scarcity (Bunnag and Pongthai 2013). Sowing of high yielding and stress tolerant varieties is crucial to get the sustainable production in drought affected areas. Improved short duration and drought tolerant varieties which can escape from the moisture stress and efficient moisture utilization can help to get the higher crop yields under rainfed situations. Some of the improved drought tolerant varieties and cropping systems are given in the table 7 and 8.

Table 7. Performance of improved high yielding drought tolerant varieties

Location	Dry spells	Crops	Improved verities	% increase in productivity
Banda	6 dry spells of >10 days and 2 intensive rainfall	Green gram	Sikha	7
		Sesame	GJT-05	12
		Maize	Sartaj	8
		Sorghum	NJH-1175	15
		Pearl millet	HHB-67	10
Kanpur Dehat	2 dry spells of >10 days	Wheat	K1317	15
		Mustard	RH-725	22
		Tomato	Yuvaraj	23
		Brinjal	Navakiran	24
Tehri Garhwal	3 dry spells of >10	Bhindi	VL Bhindi-2/P-	46

	days and 4 dry spells of >20 days		10	
		Onion	02/AFLR	48
		Finger millet	VL- 352/PB-89	27
		Wheat	VL -967	44
		Soybean	VL-65	31
Ramanathapuram	Dry spells during crop reproductive and maturity stages	Paddy	TKM 13	15
			ADT 53	12
			RNR 15048	14

(Source: Singh *et al.,* 2023)

Table 8. Crops and cropping systems for drought prone regions

Location	**Dry spells**	**Cropping systems**	**% increase in productivity over sole cropping**
Tumakur	4 dry spells, erratic rainfall	Finger millet KMR-630 + pigeon pea BRG 4	30
Chitradurga	Frequent drought, erratic and uneven rainfall	Groundnut + Red gram (8:1)	18
		Groundnut + Castor (8:1)	20
		Groundnut + Field bean (8:1)	24

(Source: Singh *et al.,* 2023)

2. Climate resilient technologies for flood regions

A) Natural Resource Management interventions for flood prone regions

Drum seeding method of paddy

Alappuzha district of Kerala experienced water logging situation from May to September and it affected the paddy crop at seedling, tillering and flowering stages. Drum seeding of short duration variety Manu Ratna was taken up to reduce the quantity of seeds. Seeds were treated with bio agents (Pseudomonas) and foliar application of micro nutrients (Sampoorna) using drone was carried out. Technologies intervention in paddy increased the productivity and net income by 20 and 55% over farmer practice respectively (Table 9).

Table 9. Performance of short duration paddy variety under drum seed method of sowing at Alappuzha district of Kerala

Technology adopted/ demonstrated	**Productivity (qha^{-1})**	**Net returns (Rs ha^{-1})**
Manu Ratna and *Pseudomonas* seed treatment, sampoorna application	75	98400

Farmers practice:	62.5	63250

(Source: Singh *et al.,* 2023)

Soybean + pigeon pea intercropping with Broad Bed Furrow

Soybean + pigeon pea intercropping in Broad Bed Furrow (BBF) system at Sarola village of Tuljapur district in Maharashtra was taken up. The crop experienced water logged conditions 4 times during *kharif* season due to continuous rainfall of 159.5 and 138 mm for 5 days and heavy rainfall of 82.3 and 81.1 mm. A prolonged dry spell ascended for about 14 days. But the intervention realized higher productivity and net returns of 14, and 28% over sole crop (Table 10). During second and third extreme heavy rainfall events the BBF interventions helped to drain out excessive amount of water from the field and this avoided water logging situation. Similarly, the BBF helped to conserve higher soil moisture during dry spells.

Table 10. Broad Bed Furrow cultivation of soybean + pigeon pea intercropping

Crop	Technology adopted/ demonstrated	NICRA farmers		Farmers practice	
		Productivity (qha^{-1})	Net return (Rs ha^{-1})	Productivity (q ha^{-1})	Net return (Rs ha^{-1})
Soybean + Pigeon pea	(MAUS-158+BDN-711	18 + 2	100000	17.5	87500
Pigeon pea	BDN-711	13.5	55000	11.5	43000

(Source: Singh *et al.,* 2023)

B) Crops and cropping system interventions for flood prone regions

Staggered planting of rice

Dhubri district of Assam received heavy rains and floods frequently. Rice variety "Gitesh" using staggered planting under aberrant weather conditions, notable differences in productivity and net returns were observed. The staggered planting of "Gitesh" recorded 30 and 23% higher productivity and net returns over farmers' practice (Table 11).

Table 11. Performance of staggered planting rice variety "Gitesh" under aberrant weather condition at Dhubri and Namsai

Technology adopted/demonstrated	Productivity (qha^{-1})	Net returns ($Rs\ ha^{-1}$)
Gitesh	45.0	22900
Farmers practice of rice cultivation	34.5	17600

(Source: Singh *et al.,* 2023)

Flooding is a major challenge for rice production in the country. Heavy and intense rainfall events cause flash floods due to overflow of rivers and canals or sometimes tidal movements in coastal areas. Continuous high rainfall in a short span leads to water logging and heavy rainfall with high speed winds in a short span due to cyclonic storms this cause inundation of paddy fields and lodging of the crop at grain filling and maturity stages which results in huge losses to the farmer. Some of the resilient paddy varieties can withstand the water logged conditions and produce sustainable yields (Table 12).

Table 12. Performance of submergence tolerant paddy varieties

Location	**Submergence**	**Improved verities**	**% increase in productivity**
Bhadrak	33 days i.e. from July 3rd to August 7^{th}	Swarna sub-1	117
West Garo Hills	flash flood twice (772 mm in 3 days in June and 326.6 mm in 3 days in October)	Gitesh	124
		Ranjit Sub-1	132

Improved variety of Bajra and mustard

Bharatpur District of Rajasthan had experienced severe flood from August to October. The improved variety of bajra (HHB-299) and mustard (DRMRIJ-31) increased the productivity and net returns by 2.9 and 2.1 q ha^{-1} and 6460 and ₹ 16613 ha^{-1} over the farmer's practice (Table 13).

Table 13. Yield and Economics of Bajra and Mustard at Bharatpur district, Rajasthan

Technology adopted/ demonstrated	***Demo (NICRA farmers)***		***Farmer's practice***	
	Productivity (qha^{-1})	**Net returns ($Rs\ ha^{-1}$)**	**Productivity (qha^{-1})**	**Net returns ($Rs\ ha^{-1}$)**
HHB-299 (Pearl millet)	19.6	26253	16.7	19793
DRMRIJ-31 (Mustard)	19.6	93733	17.5	77120

(Source: Singh *et al.,* 2023)

Livestock interventions in rainfed and irrigated farming systems

In NICRA villages of different states, location specific green fodder like bajra, oat, hybrid Napier, multi cut sorghum, perennial fodders like guinea grass, Rhodes grass and signal grass, legume crops like *Stylosanthus hamata*, hedge Lucerne, and subabul were introduced. The introduction of fodder improved the milk yield and gross returns to a tune of 12.3 to 125% and 17.5 to 105.6 % (Table 14).

Table 14. Strategies for improving Fodder availability during climate stress

State	KVK	Technology adopted/ demonstrated	% increase over control in productivity	% increase over control in returns
Punjab	Mandi	Bajra PL-101	44.9	44.8
Punjab	Poonch	Oat as Green fodder Bajra	17.0	23.1
Maharashtra	Jalna	DHN-6 (Napier Grass)	42.9	105.6
	Beed	Phule Jaywant	125	108
Gujarat	Banaskantha	Multicut sorghum	37.1	36.8
		Hybrid Napier	28.1	15.6
		Silage - cow	17.5	25.8
Karnataka	Chitradurga	Perennial fodder production	12.3	70.1
	Haveri	Multicut fodder sorghum variety CoFS-31	13.2	40.8

(Source: Singh *et al.,* 2023)

Nutrient management for resilience of cattle production

Scientific nutrient management of cow and buffalo are important to overcome the mineral deficiency and cope with various stresses and increase milk production in milch animals. It includes area specific mineral mixture, chelated mineral mixture, azolla, supplementation to cattle for increasing their resilience to climate change (Table 15) in different NICRA villages. It was observed that the nutrient management increased resilience of livestock to different stress situations, hence the milk yield of cattle and meat yield of goats were increased to a tune of 9.1 to 56.2% and returns were increased by 6.6 to 56.2%. This increase in milk yield and net returns indicate the potential of the nutrients to mitigate various stresses.

Table 15. Nutrient management approaches for improving of milk yield and economics during climate stress

KVK	Technology adopted/ demonstrated	% increase over control in productivity	% increase over control in returns
Bhagalpur	Chelated mineral mixture in cow	26.0	25.5
Darbhanga	Feeding of Pusa Mineral Mixture (crossbred cows)	15.2	15.2
South Garo Hills	Mineral mixture supplementation and Vaccination	33.3	33.3
Bhind	Mineral mixture supplementation and Vaccination	15.2	15.2
Durg	Azolla	39	15.2
	Mineral mixture and liquid Ca	36	30
Reddipalle	Mineral mixture + Urea molasses blocks	25	25.6
Banaskantha	Azolla	19	6.6
	Mineral block	18	24
	Silage	39	23
Ahmednagar	Silage & Mineral mixture	9.1	6.8

(Source: Singh *et al.,* 2023)

Back yard poultry farming

To sustain livelihoods and supplement income of small and marginal farmers backyard poultry, of different varieties like Rajashree, Vanaraja, Dual-purpose poultry (Kuroiler), Rainbow roaster, Grampriya, Aseel were introduced in NICRA villages of different vulnerable districts in different states. The various interventions increased the yield of eggs, meat tune of 12 to 83%and gross returns by12 to 84%, respectively (Table 16).

Table 16. Backyard Poultry farming

State	KVK	Technology adopted/ demonstrated	% increase over control in productivity	% increase over control in returns

Uttar Pradesh	Kaushambi	Back Yard Poultry Farming	19	72
Sikkim	Siang South	Vanaraja birds	49	75
Nagaland	Tuensang district	Vanaraja birds	83	84
Nagaland	Mon	Dual-purpose poultry (Kuroiler)	60	51
Meghalaya	Ri-Bhoi district	Rainbow rooster	50	67
Maharashtra	Tuljapur	Grampriya	57	57
Andhra Pradesh	Reddipalle	Rajashree	18	18
Mizoram	Siah	Semi intensive	12	12
Mizoram	Serchip	Rainbow roaster	71	70

(Source: Singh *et al.,* 2023)

Fish production in community tanks

In Bhadrak district of Odisha, Fish production in community ponds was demonstrated, which resulted in higher productivity and profitability of 125% over unscientific fish production (Table 17). Hence farmers who adopted this intervention realized higher economic returns.

Table 17. Impact of Fish production in community tanks in Bhadrak district, Odisha

Technology adopted/ demonstrated	**Production/ year***	**Gross returns (₹ animal^{-1})**
Fish production in community tanks	18 q year^{-1}	216000
Unscientific cultivation	8 q year^{-1}	96000

(Source: Singh *et al.,* 2023)

Improved shelter management for the animals

In NICRA adopted village, low cost improved piggery shelter for low temperature stress was demonstrated. This low-cost improved piggery shelter could withstand the low temperature stress (cold wave) in the village and obtained 11.7 higher piggery meat yield and net returns over the farmer's practice of open rearing system (table 18).

Table 18. Impact of pigs under intensive system through construction of low-cost pigsty

State	KVK	Technology adopted/ demonstrated	% increase over control in productivity	% increase over control in returns
Odisha	Ganjam	Cattle shed with concrete flooring, Straw thatched and Mosquito net	15	15
		Low cost improved piggery shelter	75	11
Mizoram	Siha	Pig-pen model (deep litter housing)	18	50
	Lawngtlai	Improved shelter	20	20
Manipur	Senapati	Low cost improved piggery shelter for cold stress	10	12
Meghalaya	Ri-Bhoi	Improved shelter for pigs	16	16
Assam	Namsai	Pig (HDK-75, Hampshire cross): Rearing of pigs under intensive system through construction of low-cost pigsty	24	30

(Source: Singh *et al.,* 2023)

3. Climate resilient technologies for Heat stress

The rising temperature of the environment has resulted in heat stress for several agricultural crops. Heat stress reduces the photosynthetic activity of the plant, flowering and seed setting, which resulted in reduced crop productivity. Heat wave is an unusual increase in maximum and minimum temperature with departure from mean exceeding by more than 5 ^{o}C, occurs mostly during the winter/summer season in the North-eastern and western parts of India. Heat waves typically occur between March and June and cause permanent damage to plant growth and development (Bal *et al*., 2022). The resilient technologies were demonstrated in these districts which can minimize the heat stress. Some of the technologies demonstrated were timely wheat sowing which realized wheat yields up to 97% of normal yields. Further, adoption of heat tolerant wheat varieties, Raj-4079, HD 3059, K1317 resulted in 10-12% higher yields over farmers practice, multiple heat tolerant paddy variety Swarna Samriddhi Dhan, heat tolerant pea variety IPFD 12, green gram variety Pusa-1431, Mustard variety KBH-5106, RH-749, stress tolerant cowpea variety Kashi Kanchan, and lifesaving irrigation in cucurbits. Technologies which are resilient to heat stress are given in the table 19.

Table 19. Performance of improved crop varieties and crop diversification to high temperature

Location	Crop	Improved varieties or Technology adopted	% increase over control in productivity
Kathua	Wheat	Crop diversification with blackgram (BBG-5)	9.3
	Sesamum	RT-351	100
	Maize	Double Dekalb	35
Chitrakoot	Wheat	K-1006	28
Bolangir	Cabbage	Pusa Cabbage	21
Kushinagar	Wheat	Zero tillage	14
Durg	Wheat	Zero tillage	22
Siaha	Cabbage	Ryozeki	49

(Source: Singh *et al.,* 2023)

Strategies to mitigate heat stress

At Gurdaspur Punjab, cultivation of heat tolerant wheat variety PPB 869 and DBW 187 increased the yield by 11 and 4 % and net returns by 14 and 7 % respectively (Table 20). Spray of KNO_3 @ 0.5% at boot leaf and anthesis stages can minimize the yield losses. Foliar spray of 1.5% KNO_3 recorded 4 and 8 % higher yields and net returns respectively over control (Table 21).

Table 20. Cultivation of heat tolerant and short duration varieties of different crops

Crops	Technology adopted/	NICRA farmers		Farmers practice	
		Productivity	Net return	Productivity	Net

	demonstrated	(q ha^{-1})	(₹ ha^{-1})	(q ha^{-1})	return (₹ ha^{-1})
Basmati rice	PB 1121	42.5	78100		
Basmati rice	PB 1509	48	93900		
Wheat	PBW 869	51	79333	45.1	68377
Wheat	DBW 187	47	74030	45.1	68377
Sesamum	RT-351	13.0	18750		
Wheat	K-1006	50.3	71483	36.1	46839
Cluster bean	RGC-1033	9.5	35550	6.2	17033
Moth bean	RMO-2251	7.7	34557	4.9	22803
Green gram	GM-07	10	48920	7.6	33161

(Source: Singh *et al.,* 2023)

Table 21. Spraying of 1.5% KNO_3 spray

Technology adopted/ demonstrated	NICRA farmers		Farmers practice	
	Productivity (q ha^{-1})	Net return (₹ ha^{-1})	Productivity (q ha^{-1})	Net return (₹ ha^{-1})
1.5 % KNO_3 spray	67.5	86685	64.8	79625

(Source: Singh *et al.,* 2023)

Wheat was sown after tillage around 1st week of December, due to which the crop was affected by the heat stress in the months of March, April. This coincides with the reproductive and grain filling stage of wheat crop. The heat stress in wheat caused grain shrinkage and caused 14.6% lowered productivity. Besides this the paddy crop residues are burnt for land preparation to sow wheat. Burning of crop residues cause air pollution and to avoid this menace, early sowing of wheat by zero till mechanism is recommended. The sowing of wheat with zero tillage is a significant departure from traditional agricultural practices, offering a sustainable solution to contemporary challenges. Zero till drill (ZT) revolutionizes the cultivation of wheat by minimizing the disturbance of the soil, thereby requiring only one pass of a tractor for soil preparation, seeding, and fertilization. This process not only reduces the costs associated with production but also conserves time and resources. Early sowing of wheat with happy seeder or super seeder recorded 6 and 4 % higher seed yield over control.

Table 22. Early sowing of wheat by cultivation of short duration rice variety and zero tillage sowing of wheat

Technology adopted/ demonstrated	NICRA farmers		Farmers practice	
	Productivity (q ha^{-1})	Net return (₹ ha^{-1})	Productivity (q ha^{-1})	Net return (₹ ha^{-1})
Happy seeder	52.3	97067	49	88712

Super seeder	51.3	90282	49	88712
Zero tillage	42.0	52184	36.0	33912
Zero tillage	18.9	21500	14.8	15680

(Source: Singh *et al.,* 2023)

4. Climate resilient technologies for low temperature/ cold stress and frost

Mulching is a climate resilient technology that promotes *in-situ* soil moisture conservation, organic matter mineralization, soil heat retention and weed control. Cabbage is a cool season vegetable that performs exceptionally well in summer months of cold arid Ladakh. The improved cabbage variety Summer-King gave 22% higher yield against farmers' practice (without mulch). Use of mulch increased organic matter decomposition, heat regulation and moisture retention. Cultivation of hybrid broccoli also increased the yield by 66%.

Vegetable cultivation in poly houses

Poly house helps in providing insulation and protection against low temperatures. This is especially beneficial in regions with colder climates, maintain optimal temperature and humidity levels, which is crucial for growth. The controlled environment minimizes the risk of damage to vegetables from rain, hail, or wind.

Table 21. Vegetable production under poly houses for cold/ frost stress

Location	**Crops**	**% increase in productivity**
Tuensang	Cabbage	38
Chamba	Colour capsicum	41
Anantnag (*Kharif*)	Cucumber, Pumpkin, Tomato, Brinjal	61
Anantnag (*Rabi*)	Cauliflower, Knol khol, onion	51
Tehri Garhwal	Tomato	56

(Source: Singh *et al.,* 2023)

Conclusion

Climate-resilient technologies play a vital role in addressing challenges like drought, floods, heat stress, and extreme weather events, ensuring agricultural sustainability and improve farmer livelihoods. Innovative interventions such as *in-situ* and ex-situ water conservation techniques, flood- and heat-tolerant crop varieties, advanced irrigation methods, and climate-smart livestock and poultry management have significantly enhanced productivity and farmers incomes. Similarly, resilient livestock, poultry, and fisheries management practices have strengthened rural livelihoods. By adopting these adaptive strategies, farmers can build resilience, secure food and water resources, and sustain agricultural growth despite climate uncertainties.

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Chapter 9

Scaling up Agrometeorological Advisory Services in India

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Agriculture is becoming increasingly risky due to climate change, unpredictable weather patterns, soil degradation, and water scarcity. Rising temperatures, irregular rainfall, and extreme weather events like heat/cold waves, hailstorms, floods, and droughts have made crop yields uncertain, affecting farmers' incomes (Bal and Minhas, 2017). Additionally, pests and diseases are becoming more resistant to conventional control methods, leading to higher production costs. Market volatility, fluctuating commodity prices, and supply chain disruptions further add to the uncertainty. Small-scale farmers, who often lack financial support and advanced technology, are particularly vulnerable. As risks in agriculture grow, the need for timely contextual weather-based advisories for better risk aversion/management strategies becomes more urgent.

Agromet Advisory Services

The provision of accurate weather forecasts can be extremely beneficial to farmers' decision-making before and during the crop season when it comes to scheduling inputs and maximizing their use. A delay in the commencement of monsoon or a drought in the middle of the season can hamper agricultural production, which has multiple consequences for the country's economy. This emphasizes the need for a robust weather forecasting system and the establishment of crop- and region-specific agromet advisories. A timely agromet advisory can save money on inputs (fertilizers, seeds, plant protection agents, and so on), labour, and the produce itself (especially at the harvest time after the crop reaches physiological maturity). Stigter (2011) defined agromet advisory as 'all agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers. To make farmers self-reliant, sensitizations of the farmers are necessary and provision of timely and accurate AAS with suitable crop management advisory is to be ensured (Bal and Sarath Chandran, 2020).

Evolution of agromet advisory services (AAS) in India

The India Meteorological Department launched AAS as a farmers' weather bulletin (FWB) on All India Radio in 1945. In 1976, IMD launched AAS in partnership with state agricultural departments from its state meteorological centres. Since 1991, the National Centre for Medium Range Weather Forecast (NCMRWF) has been providing quantitative weather forecasts for a total of 5 agrometeorological field units (AMFUs) with a spatial resolution of 250 km in the medium range (3 days). In 1993, the spatial resolution was improved to 150 km, and in 1999, it was further improved to 75 km. At the agro-climatic zone level, the temporal resolution of forecast was extended from three to five days in 2006. As the AMFU network grew from 5 units in 1991 to 130 units in 2007 to cover all the agroclimatic zones, these two systems (the forecast system of IMD and NCMRWF) combined into one single system in 2007. IMD began issuing multi-model ensemble weather forecasts (50 km spatial resolution and 5-day temporal resolution) at the district level on June 1, 2008. AAS is currently a multi-institutional and multi-disciplinary endeavour. It includes the Indian Council of Agricultural Research (ICAR), state agricultural institutions, state agricultural departments, non-governmental organizations, the media, and others, in addition to IMD. In 2018, IMD in collaboration with IITM, Pune, and NCMRWF has started issuing forecasts for extreme weather events using an ensemble prediction system. National Council of Applied Economic Research (NCAER) has assessed the impact of AAS of Gramin Krishi Mausam Seva (GKMS) of IMD and reported that the average annual income of farming households worked out to be Rs. 2.43 lakh for those who modified 1 to 4 crop management practices; Rs. 2.45 lakhs for those who modified 5 to 8 practices and Rs. 3.02 lakhs for those who adopted all the nine changes, against Rs. 1.98 lakh for farmers did not adopt AAS (NCAER, 2020).

Although the spatial resolution of medium-range weather forecasts has been enhanced to the district level, the practical relevance of these advisories at the farmer level is inadequate. This is owing to the wide range of crop types, cultivars, and climatic conditions (especially rainfall) that exist within a district. To address these challenges, the ICAR's All India Coordinated Research Project on Agrometeorology (AICRPAM) launched a pilot project in 2011 to develop and disseminate block-level AAS through a network of 25 cooperating centres around the country (Vijaya Kumar *et al.*, 2017). It uses IMD's block-level weather forecast and input from the field information facilitator (Fig. 1). The agrometeorologist of AICRPAM developed AAS bulletin at Krishi Vigyan Kendra with the help of various multidisciplinary Scientists.

AICRPAM has recently developed dynamic crop weather calendars (DCWC) for automating agromet advisories using prevailing and forecasted weather (Vijaya Kumar *et al.*, 2021). To make farmers self-reliant, sensitizations of the farmers are necessary and provision of timely and accurate AAS with suitable crop management advisory is to be ensured (Bal and Sarath Chandran, 2020).

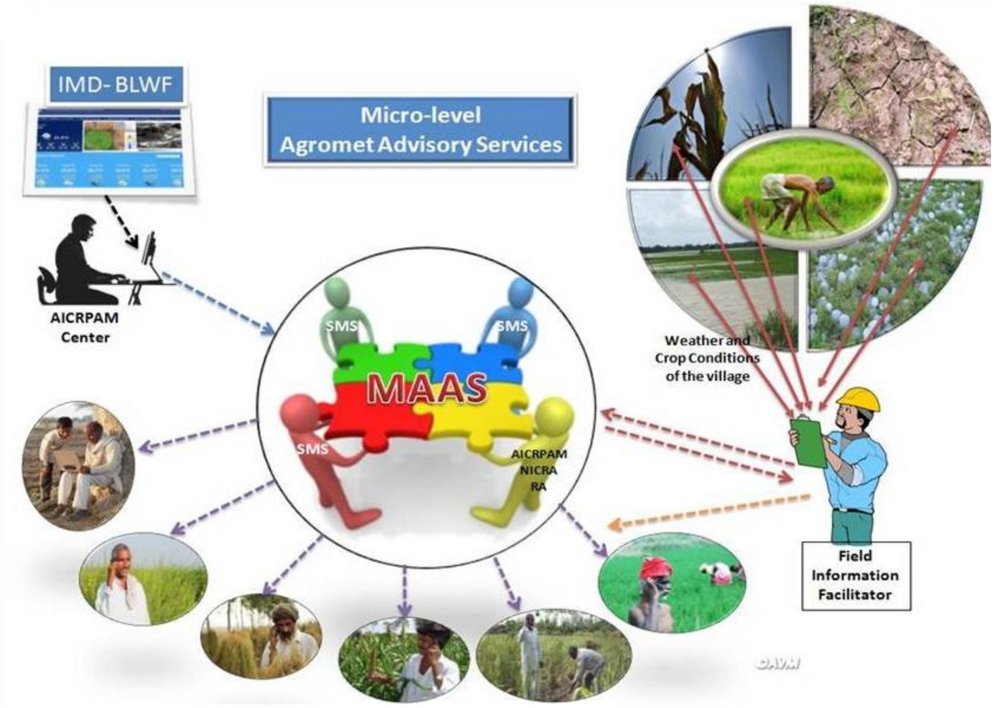

Fig. 1. Development and dissemination of MAAS (Vijaya Kumar *et al.*, 2017)

Scaling up of AAS

At present in India, Agromet Advisories are being disseminated mainly by the India Meteorological Department (IMD) in collaboration with the Indian Council of Agricultural Research (ICAR) besides several SAUs, ICAR institutions, NGOs, and private organizations. However, to scale up the AAS in India, a multi-pronged approach integrating technology, policy support, community engagement, and private sector involvement is required. Here are some key strategies:

1. Enhancing Infrastructure & Data Collection

- Expand the Automatic Weather Stations (AWS) and Agromet Field Units (AMFUs) network.
- Utilize satellite remote sensing and IoT-based sensors for real-time data collection.
- Strengthen district-level agromet advisory units with better forecasting tools.

2. Leveraging Digital Technologies

- Develop and promote mobile apps, IVR (Interactive Voice Response) systems, and SMS-based alerts in regional languages.
- Utilize AI/ML for predictive analytics to improve the accuracy of forecasts.
- Integrate advisories into platforms like Kisan Suvidha, Meghdoot, and Damini apps.

3. Improving Last-Mile Connectivity

- Strengthen Krishi Vigyan Kendras (KVKs) and Farmer Producer Organizations (FPOs) as key dissemination points.
- Train and empower local agromet volunteers to bridge the gap between scientists and farmers.
- Use community radio, WhatsApp groups, and social media for rapid information sharing.

4. Strengthening Public-Private Partnerships (PPPs)

- Collaborate with agribusinesses, weather forecasting startups, and telecom companies for wider reach.
- Promote insurance and risk management products linked with agromet advisories.
- Encourage corporate social responsibility (CSR) investments in weather information services.

5. Capacity Building & Farmer Awareness

- Conduct regular training programs and workshops for farmers on interpreting and utilizing agromet advisories.
- Develop customized advisories based on different agro-climatic zones.
- Promote climate-smart agriculture practices using agromet insights.

6. Policy & Institutional Support

- Strengthen coordination between IMD, ICAR, State Agricultural Universities, and NABARD for a unified approach.
- Encourage state governments to integrate agromet advisories into existing agricultural extension services.
- Provide financial incentives for small and marginal farmers to access premium weather services.

7. Monitoring & Feedback Mechanisms

- Establish farmer feedback loops to improve advisory relevance and accuracy.
- Use big data analytics to assess the impact of advisories on farm productivity.
- Foster a continuous learning approach by updating advisories based on user experience and field validation.

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Chapter 10

Farmer-Centric technology transfer in rainfed areas-Experiences of farmer FIRST project

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Research and Development efforts are being made to achieve food security and credit goes to the frontline extension systems-National Demonstrations (ND) of 1965, Krishi Vigyan Kendras in 1974, Operations Research Project in 1975, Lab to land program in 1979, Training and visit Systems in, Technology Assessment and Refined programs of 1995 and Farmer FIRST Programme (Farmer, Innovations, Resources, Science and Technology) in 2014.

The Rainfed production system, being fragile and fraught with many challenges from management of natural resources to bridging yield gaps to deriving livelihood and income source from crop production and value addition, the success of crop production depends on effective and timely utilization of available natural resources. Rainfed farming face complex environmental extremes, while the farmers have traditional wisdom for combatting these adverse weather conditions. These are the reservoir of untapped potentials to sustain agricultural practices suitable to the local environmental conditions. Most of the technologies generated in the institutions are partially adopted due to lack of active participation of farmers in technology generation and validation processes. Many extension systems and approaches operationalized in rainfed areas were mostly technology centric rather than farmer centric like in the Technology Assessment and Refinement (TAR) program. Envisioning doubling farmers' income from rainfed areas and improving livelihood and income, a holistic extension approach has been introduced keeping farmer at the center, 'Farmer FIRST, an initiative of ICAR, that considers farmer innovations and resources as the basis for social action and technological development. The paradigm shift from transfer of technology model to decentralized farmer participatory model of extension as proposed and developed by Chambers 1989, consider the fact that benefits derived from former model were not reaching to end users except the resource rich. Besides, many strategies were adapted such as the Participatory extension approaches (PEA) which were advocated as an alternative approach to the linear, knowledge driven transfer of technology approach, which generally engages in dissemination of 'one size fits all' technology and practices to clientele representing different socio- economic and diversified agroecological regions.

Transfer of technology models, non-participatory in nature generally constrained in dissemination of NRM technologies being a critical issue for dryland areas. Acceleration of NRM technology necessitates empowering farmer communities through participation (Wassie et al 2014 cited in Omer Hinde 2022). Also, the success of any development project depends on extent of engagement of stakeholders in generation of outcomes aligned to objectives of the programs. Ensuring participation of stakeholders through key strategic ways at every step of program constitutes the challenges. There are number of strategies to draw participation of stakeholders namely action research methodology, farmer-led extension, farmer participatory research and extension (Chambers 1989). Advantages derived from Participatory extension approaches are farmer engagement in participatory learning process, addresses individual and community needs and acknowledges local knowledge of farmer in technology development.

Challenges of PEA in drylands

Many of extension methods followed in participatory extension such as on-farm demonstrations, farmer field school, capacity building and institutional developments fully require funding ensure change particularly in drylands where the on-farm demonstrations on soil and water conservation practices are capital intensive which again need more funding. Successful farmer engagement from inception to full completion and communication of results of project with farmer participatory extension approach requires a range of skills and trade- offs among partners, respect for farmer knowledge and also guiding farmers during every stage on farm trails essential (Anda Adamsomne et al 2022).

Impact of farmer participation approach on development of Rainfed areas

Widespread initiatives of participatory extension approach worldwide have been developed and significant one being the Participatory Integrated Climate services for Agriculture (PICSA) pioneered by Dorward et al 2015, which addresses climate change challenges, have been successfully implemented in Zimbabwe and Kenya. At present, climate smart agriculture has gained attention as environmental problems limited the production systems and building resilience considered paramount important and essential. A multi stakeholder participation, a strategy in building climate resilience for climate smart agriculture found inevitable. Another popular approach prevalent in Egypt to achieve food security: Participatory Extension and Advisory Services (PEAS), promoted for integrating need oriented advisory services for small holders. (Emmad et al 2022). Famers in a community are most impacted with degradation of natural resources and to resolve the problems requires their active participation particularly in watershed areas. Farmer participatory watershed development approach responds to need and priorities of farmers and believed to reverse land degradation. (Pretty, 1995). Farmer participation as recorded from watershed development project in Ethiopia has revealed that factors which significantly contributed to participation were age, education, distance from watershed, farm size and dependency ratios of farmers (Mekonen Debara and Teklu Gebrertsadik, 2023), that suggest the extent of participation would be influenced by diversified community's demographic and socio-economic status.

About Farmer FIRST Programme (FFP)

The Farmer FIRST Programme (FFP) is a frontline extension programme of ICAR. It is an initiative and approach to take agriculture beyond the production and productivity of farm, at the same time to protect the smallholder agriculture against heterogenous conditions and risk prone realities of farming through a holistic farm development plans placing emphasis on various domains of a farm such as natural resource management, production management of crops, livestock, farm mechanization, horticulture, climate resilient technologies, storage and market, value chains, innovation and information systems by enhancing farmers-scientists interface.

FFP approach is mainly intended to focus on Farmer's Farm, Innovations, Resources, Science and Technology to bring social action and technological change. In this concept, farmers play a significant and central role in identification of problem, prioritization, conducting demonstrations and evaluation of outcomes. The technological change ensured with appropriate integration of indigenous and research-based knowledge through a series of farmer-scientist interaction mechanisms put in place at field level to gain acceptance, adoption and success. Farmer FIRST is an opportunity for the researchers, extension professionals and farmers to work together and find appropriate ways through assessing different solutions. During the process, farmers get an opportunity to solve their problems or try out new ideas that they themselves could not do without the support of the researchers and extensionists. It improves better access to extension programs, services and information about technologies, markets, process and enhances farmer-to-farmer exchange of information. Strategies adopted to enhance production systems, profitability, income and marketability through farmer first approach through enhancing Farmer-Scientist Interface, Technology Assemblage, Application and Feedback, Partnership and Institution Building and Content Mobilization has significantly impacted farmer participation and enhancement of income. It has also focussed on local knowledge systems, when managed over a period leads to innovation and a key to sustainable development.

Integrated farming systems approach is multifunctional, contributing to food security and livelihood enhancement. Promotion of the IFS model through effective combination of one or more enterprises with crop components such as livestock, poultry, goats, or bees (depending on the availability of resources) and effective recycling of waste for sustainable natural resource development have been found to be more profitable and environmentally sustainable. In semi-arid areas, with a predominance of small and marginal farmers – who have limited finances and limited access to resources such as land, water, inputs, credit and technology – farmer is now being encouraged to adapt to the IFS model on a small scale to earn a decent income from each of the enterprises that is sufficient to meet livelihood needs.

Technology Assemblage, Application and Feedback: The approach has adequately created an impact benefitting 400 farm families and farms through effective utilisation of harvested water and loss of soil with construction of effective check dams and water harvesting structures; demonstration of new varieties of pigeonpea leading to cent percent seed replacement in villages, increased yield by 32 percent over local farmer practice ; diversification with vegetables and floriculture improved income of farmers; enhanced food and nutritional security with adoption of backyard poultry from inclusion of eggs in the diet by introduction of *Srinidhi*, a low-input- backyard poultry technology, besides backyard poultry also found to supplement the earnings of poor farmers and landless laborers. The protein diet with eggs obtained from backyard poultry provided the adequate energy in the diet that met BMR requirements in all categories of people in the family. Livestock development with sheep farming and fodder production technology enhanced the livestock- based livelihood of farm households. Farmers' capacity building in rainfed technologies, organising exposure visits resulted in co-knowledge production and learning among the farming community.

Key takeaways of farmer centric extension approach:

a. Collaboration and partnership

Under the farmer FIRST project a strong collaboration has been built at field level with partners who could equally contribute to the development. A joint-decision making held at 'Farmer-scientist interface' meeting to plan interventions, meeting organised with a multidisciplinary team of scientists possessing expertise in diversified fields of agricultural science and practice suggested, designed farm trials in consultation with farmers and institutions at local, regional and national levels have received attention and stand as an effective decion making body at field level. The theme for farm demonstration selected at Site planning implementation group (SPIG) forum held at beginning of the cropping season. At SPIG meeting farmers and scientist discuss, debate and draw conclusions upon the type of project interventions to be taken up during the season. Subsequently, an Institute advisory committee (IAC) meeting held at Institute level with nodal officers, experts, funding agencies to review and monitor the interventions, thereby suitable adjustments made in interventions based on guidelines set by project and stakeholders' feedback.

b. Co Knowledge production and exchange learning process

Technology assemblage, application and feedback component addressing multiple problems with solutions drawn from sub sectors: natural resources: soil and water conservation practices, crops, horticulture, livestock have significantly promoted knowledge exchange and co- learning between farmer and research.

Conclusions

Application of Farmer participatory approaches in rainfed areas bridge the information and resource use gaps through co-production of knowledge and learning with engagement of stakeholders at various levels. The Paradigm shift from linear TOT model 'researcher-extension-farmer' to farmer participatory approach strengthens 'farmer to farmer;' exchange of information leading to scaling up of innovation.

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Chapter 11

Institutional Interventions for technology transfer

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Technology transfer in agriculture extension involves the dissemination of innovative agricultural technologies, practices, and knowledge from research institutions to farmers and stakeholders. This process aims to enhance agricultural productivity, efficiency, and sustainability. It begins with the development of new technologies through research and development efforts conducted by various institutions and organizations. Before being transferred to farmers, these technologies undergo validation and adaptation to ensure their suitability across different agro-ecological zones. Extension agencies and community based institutions play a crucial role in the transfer process by providing training, organizing field demonstrations, and disseminating information through various channels. Farmer participation and feedback are essential for the success of technology transfer initiatives, as they help tailor extension efforts to meet the specific needs and challenges faced by farmers. Continuous monitoring and evaluation are conducted to assess the adoption and impact of technologies, guiding further refinement of extension strategies. Overall, technology transfer in agriculture extension contributes to the development and sustainability of the agricultural sector, benefiting farmers and communities by improving livelihoods and food security.

However agricultural technology transfer faces challenges due to the complexity of agricultural systems, lack of awareness among farmers, resource constraints, and sustainability concerns. Community institutions are crucial in addressing these challenges by customizing technologies to local contexts, raising awareness, providing education and resources, and offering ongoing support services. Their deep understanding of local conditions, ability to mobilize resources, and close connections to communities make them essential partners in promoting the adoption of innovative agricultural technologies, ensuring effectiveness, sustainability, and responsiveness to farmers' needs.

Role of Institutions in technology transfer Community based institutions play a vital role in technology transfer within the agricultural sector due to several key reasons.

Connect with rural stakeholders.

Firstly, grassroots institutions are deeply embedded within local communities, possessing an intimate understanding of their needs, challenges, and cultural contexts. This proximity allows them to tailor technology transfer efforts to suit the specific requirements of farmers in a given area. They can effectively communicate the benefits of new technologies in ways that resonate with local farmers, thereby increasing adoption rates.

Credibility established over the time

Secondly, grassroots institutions often have established trust and credibility within their communities. Farmers are more likely to accept and adopt new technologies when they come recommended or endorsed by familiar and trusted entities. Grassroots organizations, such as farmer cooperatives, community-based organizations, and local agricultural extension services, can leverage this trust to facilitate the adoption of innovative agricultural practices.

Established communication network

Moreover, grassroots institutions serve as Conduits for information dissemination and knowledge sharing. They act as intermediaries between research institutions, government agencies, and farmers, translating complex scientific information into practical, actionable guidance that is accessible to local communities. By providing training, organizing field demonstrations, and offering ongoing support, grassroots institutions bridge the gap between research and practice, ensuring that farmers have the necessary resources and skills to successfully implement new technologies.

Sense of belongingness.

Furthermore, grassroots institutions foster a sense of ownership and empowerment among farmers. When farmers are actively involved in decision-making processes and are encouraged to participate in technology transfer initiatives, they are more likely to embrace change and take ownership of their agricultural practices. Grassroots organizations empower farmers to become agents of change within their communities, leading to sustainable and locally-driven agricultural development.

Grassroots institutions play a critical role in technology transfer within the agricultural sector by leveraging their local knowledge, building trust, facilitating information exchange, and empowering farmers. Their close connections to communities make them invaluable partners in efforts to promote the adoption of innovative agricultural technologies, ultimately contributing to increased productivity, sustainability, and resilience in farming systems.

Institutional Interventions for technology transfer : CRIDA experiences

Salaha samiti-initiative- DFID experience

Salaha samitis were social interventions implemented under a project entitled "Enabling Rural Poor for Better Livelihoods Through Improved Natural Resource Management in SAT India" which was executed by CRIDA in collaboration with two State Agril. Universities Viz., ANGRAU, Hyderabad, UAS, Bangalore, ICRISAT and BAIF a leading NGO. This project was funded by DFID-NRSP, UK and was for a duration of 30 months from October,2002 to March, 2005

Salaha Samiti" is a term where "Salaha" means advice or counsel, and "Samiti" translates to committee or group. In the context of Indian agriculture, a "Salaha Samiti" typically refers to advisory committees or groups formed at the village or community level. These committees are composed of local farmers, agricultural experts, extension workers, and government officials.

The primary purpose of a Salaha Samiti is to provide advice, guidance, and support to farmers in various aspects of agriculture, including crop selection, cultivation techniques, pest management, soil health, water conservation, and post-harvest practices. These committees serve as platforms for sharing knowledge, exchanging ideas, and addressing common agricultural challenges faced by the community.

Project flow: The PRA exercise was conducted to know the existing situations and formulate the action plans with the participation of the villagers.

As a first step Gramasabhas and Focus Group interactions were held and new Self Help Groups were formed besides existing once. Advisory Committees for the cluster of villages Viz., Salaha Samithis/Central Project Management Committees were formed for each cluster consisting of representative from the selected villages. The Salaha Samithis played a major role in smooth implementation of the project interventions.

The capacity building of the group of farmers from the selected cluster of villages was taken up by training them on employment generation activities like nursery raising, repair of implements, Artificial Insemination, vermicomposting etc,. etc.

Additionally, Salaha Samitis served as intermediaries between farmers and project partners advocating for the needs and interests of the farming community and facilitating access to agricultural inputs, adoption of technological interventions, decision making and other support services.

Overall, Salaha Samitis were grassroots institutions that contributed to the development and sustainability of agriculture by fostering collaboration, knowledge-sharing, and collective action within rural communities. They play a vital role in empowering farmers, enhancing agricultural productivity, and promoting rural livelihoods.

Stakeholder and Community Partnerships- Experiences of NICRA

Technology demonstration component of NICRA was implemented in a cluster of villages from each of selected 153 districts which are vulnerable to climate change impacts of extreme events like droughts, floods, cyclones, heat wave, cold wave, frost and salinity. The program was piloted by the KVK or Farm Science Centre, under the technical guidance of Agricultural Technology Application and Research Institutes (ATARI). Indian Council of Agricultural Research (ICAR) Institutes and State agricultural university (SAU) systems located near to selected vulnerable district. At the district level, the project is being implemented by selected KVK/ICAR institute/SAU and at the village level by institutions established in the villages such as Village Climate Risk Management committees (VCRMCs) for ensuring effective participation by farming community.

Community Institutions facilitated and strengthened under ICAR-NICRA

The focus of the programme is not only to demonstrate the climate resilient agriculture technologies but also to institutionalize mechanisms at the village level for continued adoption of climate smart practice in sustainable manner. This also results in strengthening the existing institutional mechanisms at the field level for successful technology adoption and up scaling. It is important to have appropriate institutional mechanism in place for successful implementation and sustainability of any agricultural development programme. Hence *institutional interventions like community seed bank, fodder bank, farm machinery custom hiring center etc. are being implemented under NICRA through active involvement of farmers /stake holders across the districts*. The activities of these institutions are given below.

Village Climate Risk Management Committee (VCRMC)

A VCRMC representing all the categories of farmers in the village is formed with the approval of gram sabha in all NICRA villages. This committee is fully involved in the NICRA programme and implementation of technological interventions VCRMC participates in all village level discussions including planning, finalizing interventions, selection of target farmers and area, and liaison with gram panchyat and local elected representatives. VCRMC maintains joint bank account which is used for all financial transactions under NICRA including maintaining farmer's contributions for different activities, handling of payments recovered from custom hiring centres.

Custom Hiring Center

Timely access to farm machinery for sowing, harvesting etc. is an important component of adaptation strategy to deal with climatic variability. Therefore an innovative institutional arrangement in the form of a farm machinery custom hiring center has been created in each of the 100 selected villages. The rates for hiring the machines/ implements are decided by the VCRMC. The revenue generated would be used for repair of farm implements and maintenance of custom hiring centre.

Seed Banks

Provision timely seed for farmers (non hybrids but stress tolerant improved varieties) is one of the most relevant institutional interventions relevant to meet the goal of NICRA. In this process, a group of 20-25 farmers has been selected for seed production of relevant varieties for 2-4 major crops of the village in all the 100 districts. The farmers group is trained and given seed and money to organize the activity.

Fodder Bank

Livestock is one of the most important components of dryland farming systems, which plays a stabilizing role during climatic shocks. Sharp reduction in fodder production from private as well as common lands due to either drought or flash floods is the key impact of climatic variability on livestock production. Hence, Fodder Bank is a very important institutional arrangement for enhancing climate resilience of livestock production systems in dry land/ rainfed regions. Enhancing production, conservation and storage of fodder by involving SHG's / User groups is the objective.

Conclusion

Community institutions are essential for overcoming the challenges associated with agricultural technology transfer. Their close connections to local communities, knowledge of local conditions, and ability to mobilize resources make them valuable partners in efforts to promote the adoption of innovative agricultural technologies. The efforts of institutions in raising awareness, organizing training sessions, and advocating for farmers' needs, these institutions empower rural communities and contribute to the sustainability and productivity of agriculture. Thus, the collaboration between technology transfer initiatives and community institutions is crucial for driving agricultural development and ensuring the welfare of farming communities. By working collaboratively with researchers, policymakers, and farmers, community institutions can help ensure that agricultural technology transfer efforts are effective, sustainable, and responsive to the needs of farmers and their communities.

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Chapter 13

Carbon offsets from agriculture and it's potentiality for carbon credits

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Introduction

Climate change has resulted in global warming that had shown negative impact on agriculture by reducing productivity in various means that led to the urgent need for sustainable and climate-resilient agricultural practices. Climate change resulted in extreme weather events, heatwaves, droughts, floods, sea-level rise, thawing glaciers, ice sheets, changes in precipitation patterns such as droughts, floods, loss of biodiversity due to extinction risk for temperature-sensitive species.The growing awareness about harmful levels of Greenhouse Gases (GHG) (Fig 1) and the resulting Worldwide Warming phenomena, has forced the government authorities and private organizations to implement systems that would help in reducing the amount of carbon dioxide in the atmosphere. The atmospheric CO_2 concentration has increased by > 2 ppm y^{-1} in the last decade, (Yoro and Daramola 2020). Some of the pressing causes that lead to CO_2 emission in agriculture are shown in figure 2. Fossil fuel combustion and deforestation have increased CO_2 inputs to the atmosphere without matching increase in the natural sinks that draw CO_2 out of the atmosphere (oceans, forests, etc.), these activities have caused the size of the atmospheric carbon pool to increase which has negative environmental impacts. Increased CO_2 concentrations, driven largely by industrialization have led to glaciers melting, rising sea levels, and higher global temperatures. The small imbalance between atmospheric carbon sequestration and the emission of carbon into the atmosphere may lead to remarkable decadal variations in climate change. Adoption of improved practices that enhances carbon sink is the approach to mitigate climate change with additional income avenues through carbon credits to farmers. Conservation tillage, crop stubble management, mulching, cover-cropping, integrated nutrient management, conversion from annual to perennial crops or pastures, and livestock management are known to reduce GHG emissions and increase carbon storage. Temperature plays a crucial role in shaping Earth's climate.

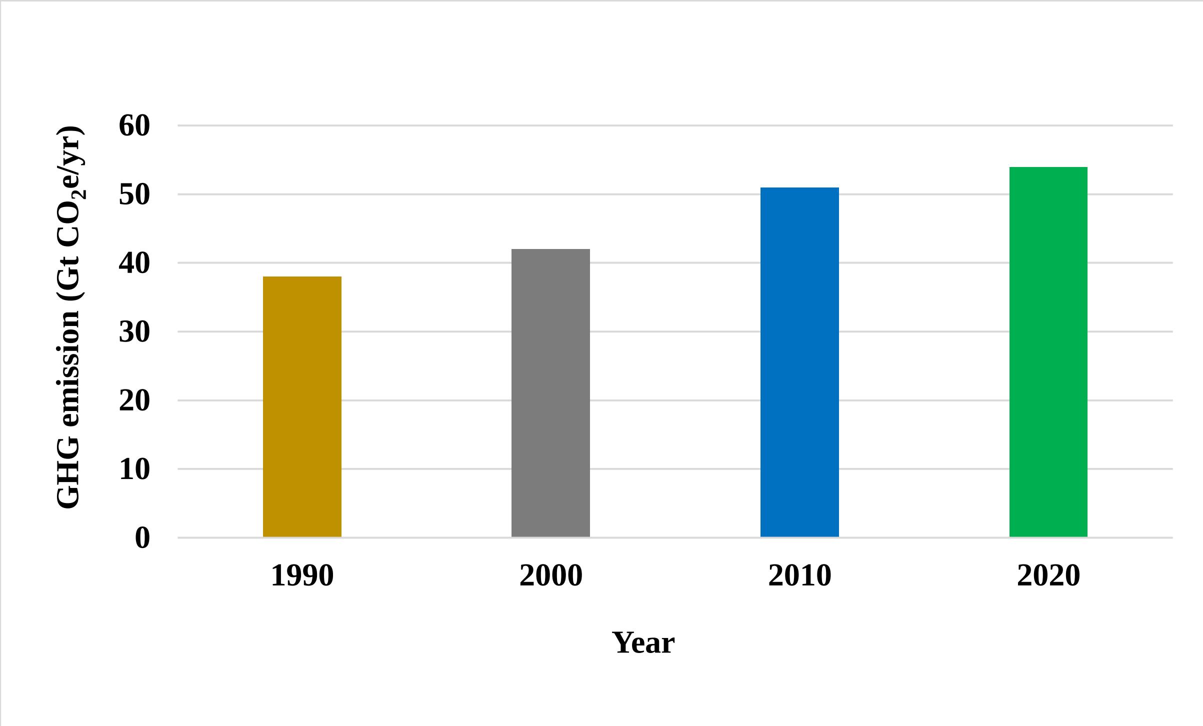

Fig 1: Change in GHG emission (Gt CO_2e/year) over a period of time

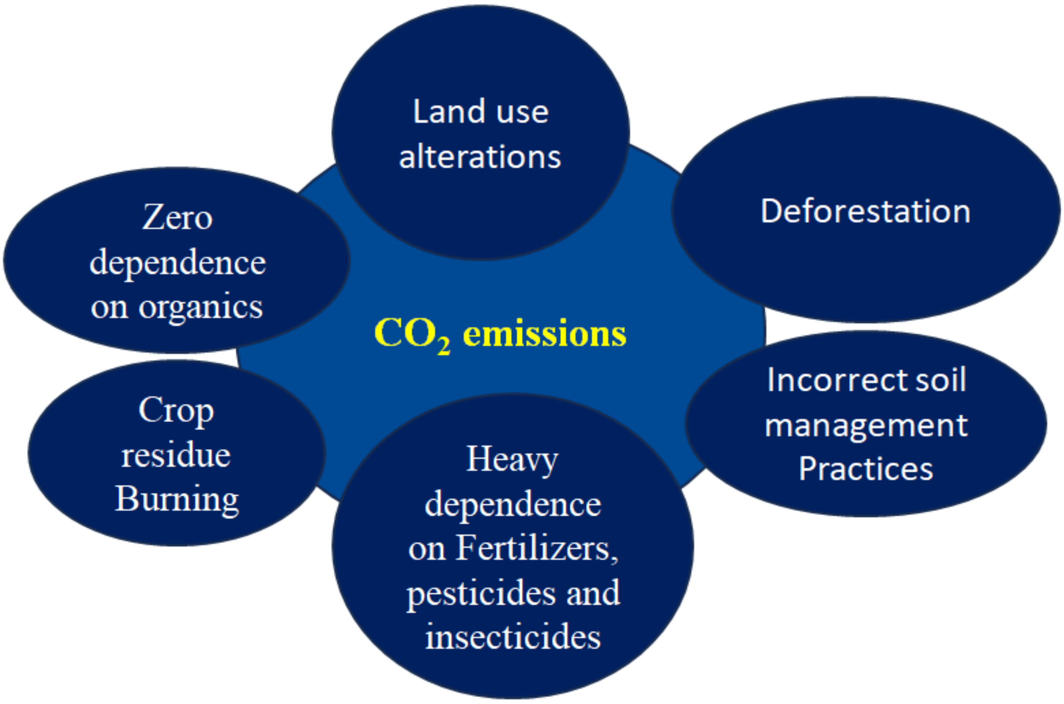

Fig 2: The causes of CO_2 emission in agriculture

Agriculture carbon credits are demand driven in the voluntary carbon market with significant growth in transaction volume that increased by 283% from 2021 to 2022 (Forest Trends' Ecosystem Marketplace, 2023). India has more than 50 agricultural carbon credit projects targeting 16.5 million hectares (Verra 2024). This is how India is becoming part of a global trend where governments invest in projects and/or establish their own carbon markets to meet the Nationally Determined Contributions (NDC). Carbon credits generated in a country cannot be traded internationally without the host country's knowledge and consent. According to the Rulebook's Decision 2/CMA.3 Annex, which outlines guidance on cooperative approaches under Article 6.2 of the Paris Agreement, authorization from the host country is mandatory for the trade of Internationally Transferred Mitigation Outcomes (ITMOs). Similarly, when it comes to emissions reductions (ERs) from collaborative projects under Article 6.4, the host country must authorize the use of these ERs for meeting its Nationally Determined Contributions (NDCs) or other international mitigation obligations. This requirement underscores the sovereignty of countries over the carbon credits produced through cooperative efforts, reinforcing their rights and control in the international carbon market. The concept of "Sovereign Carbon" has emerged to reflect this recognition of national authority in managing carbon emissions and trading credits (Kishwan, 2023).

Now, both compliance and voluntary carbon markets are one that helps to reach its NDC targets (PIB, 2023). However, a policy challenge arises because carbon credits sold internationally cannot be counted toward India's NDCs, leading the country to consider using domestically generated carbon credits to fulfil its commitments and ensure the environmental benefits contribute directly to its national goals. Unlike voluntary markets, Compliance markets are regulated by mandatory national, regional, or international carbon reduction regime that aims at energy intensive emitters. Compliance markets include the European Union Emissions Trading Scheme, New Zealand's Emissions Trading Scheme, and Australia's Carbon Credit Units scheme (QCI, 2024). However, there are several voluntary offset programmes, such as Japan's Voluntary Emission Trading Scheme and Australia's Emission Reduction Fund. Private and non-governmental offset programmes also encourage GHG mitigation activities worldwide. There are some programmes that operate in both compliance and voluntary markets such as the US's American Carbon Registry and Climate Action Reserve. All these programmes have to follow certain methodologies for estimating soil carbon sequestration (QCI, 2024). The concept of carbon credits has its roots in the Kyoto Protocol that aims at reducing greenhouse gas (GHG) emissions.

About Kyoto protocol

The Kyoto Protocol was initiated by the United Nations Framework Convention on Climate Change and ratified by 181 countries and the European Union as a whole, individual entity in 1997, and was put into effect in 2005. The Kyoto Protocol came into effect in 2005, setting legally binding targets for 37 industrialized countries to limit or reduce their overall greenhouse gas emissions ("GHG Emissions") by an average of at least 5% below their respective 1990 levels during the period of 2008-2012. This protocol was proposed by the international community to address and reduce greenhouse gas emissions that have led to global climate change. The Protocol makes it mandatory for commercial entities emitting above the permitted limit of carbon dioxide to cut down their emissions to prescribed levels, or they should buy carbon credits certificates which can be transacted in the market, or alternatively pay a charge for the emissions, which is referred to as carbon tax.

What is carbon credit?

International treaties have set quotas on the amount of GHG countries can produce, which in turn set quotas for businesses. Instruments like carbon credits and carbon offset were introduced in order to improve the scenario by encouraging firms to be more environment friendly in conducting their business. One carbon credit allows one tonne of carbon dioxide or a corresponding amount of other greenhouse gases to be discharged in the air. Businesses that are over their quotas must buy carbon credits for excess emissions, while those below can sell their remaining credits. This exchange of credits between businesses is known as carbon trading. These credits can be exchanged between businesses or bought and sold in international markets at prevailing market price at two exchanges, namely the Chicago Climate Exchange and the European Climate Exchange. The Multi-Commodity Exchange of India (MCX) may soon become the third exchange in the world to trade in carbon credits. The amount of global emissions can be controlled through the buying and selling of carbon credits in the carbon trading method. It is quite simple and convenient to purchase Carbon Credits from a number of firms, just like any other monetary instrument, as they are traded in an open market. The aim is to limit the worldwide carbon emissions within permissible levels. The system also motivates the organisations to be more eco-friendly so that they can increase their earnings by selling carbon credits. As carbon credits are freely traded in the market, they make it very easy for businesses to follow the system. There are no complex rules or procedures to adhere to, which enhances their acceptance and makes the system highly successful. Carbon credits can also be purchased even if you are not a part of any organisation in order to lower your own carbon footprint. The money that you put in this manner is routed to fund ecological projects in any region on the planet so that the emissions made as a result of your activities can be neutralized. This sale and purchase in carbon credits helps limit the unchecked emissions of greenhouse gases throughout the world. Organizations responsible for atmospheric pollution are made to pay for their acts while ones taking positive steps are rewarded. In the present scenario, the market of carbon credits has a direct impact on the firm's financial analysis. This has caused firms to actively seek ways to decrease their emissions and adopt cleaner ways of doing business. Thus, the whole system motivates companies and governments to promote environment friendly processes that reduce greenhouse gas emission. Carbon trading, also referred as emissions transacting, it is a joint effort designed to limit the amount of carbon that businesses, organizations and other entities produce over a specific period of time. The ones who are selling are companies that use clean technology and those buying are the world's polluters. In future, the menace of global warming can be effectively handled by this system. The adoption of carbon sequestration projects also participates in carbon trading through earning carbon credits which largely depends on markets.

Carbon sequestration is the process of capturing and storing carbon in the soil plays a crucial role in reducing atmospheric CO_2. This mechanism involves storing carbon in various means as shown in Figure 3. Soil carbon (C) sequestration implies transferring of atmospheric CO_2 into soil of a land unit through its plants. Benefits of soil C sequestration include: advancing food and nutritional security, increasing renewability and quality of water, improving biodiversity, and strengthening elemental recycling. The removal of CO_2 from the atmosphere and storage in diverse carbon sinks is referred to as soil carbon sequestration soil carbon sequestration is defined as, 'process of transferring CO2 from the atmosphere into the soil of a land unit through units plants, plant residues and other organic solids, which are stored and retained in the unit as part of the soil organic matter (humus)'. The cycling of carbon between soil and environment creates a source-sink dynamic. Plants primarily mediate the sequestration process through photosynthesis and store CO2. During the death of whole plants, living plants shed some portion of their leaves, roots and branches each year. Since all parts of the plant are made up of carbon, the loss of these parts to the ground is a transfer of carbon (a flux) from the plant to the soil. Dead plant material is often referred to as litter (leaf litter, branch litter, etc.) and once on the ground, all forms of litter will begin the process of decomposition. When dead organic matter is broken down or decomposed (consumed by bacteria and fungi), CO2 is released into the atmosphere at an average rate of about 60 Pg Carbon /year globally. But because it can take years for a plant to decompose (or decades in the case of large trees), carbon is temporarily stored in the form of organic matter of soil. However, retention time of sequestered carbon in soil varies and can range from short-term (immediately released back to the atmosphere) to long-term (millennia) storage. carbon sequestration aims to transfer atmospheric carbon into soil sinks by increasing both organic and inorganic carbon components in the soil over the long term, thus improving the ecosystem's carbon balance. Indian soils are severely degraded due to conventional and intensive farming practices, impacting soil carbon stocks and underscoring the need to maintain carbon concentrations above critical thresholds to enhance soil quality.

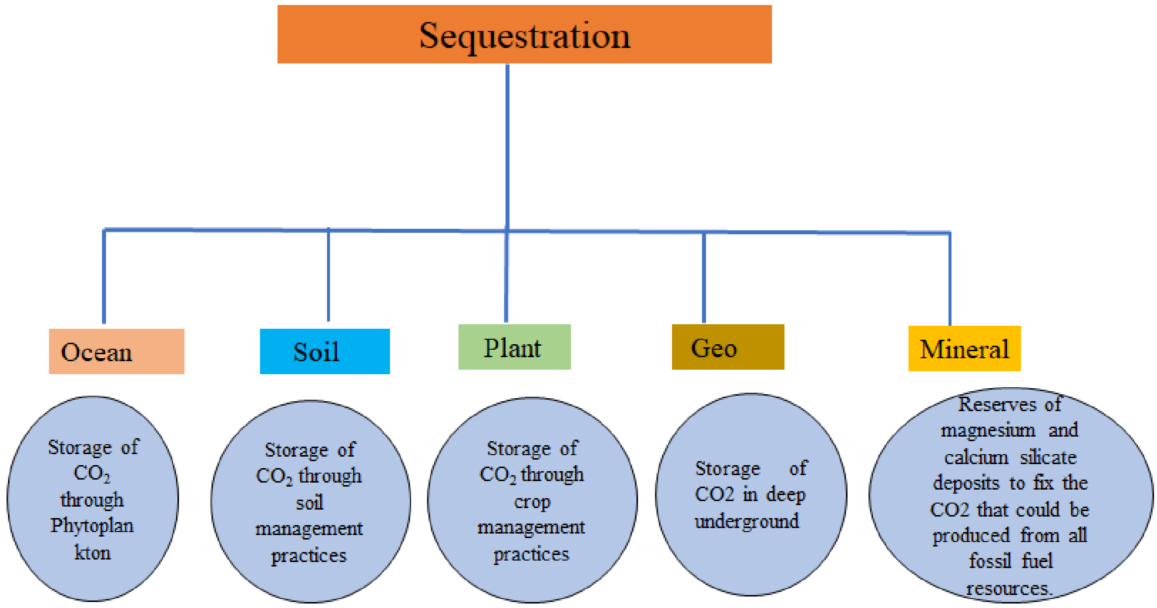

Fig 3: The different types of carbon sequestration in different types of environments

It is reported that about 75 percent of global CO_2 mitigation is possible through carbon sequestration program where forest play a lead role with maximum sequestration rate. Generally, subsidies are provided for carbon storage above the baseline. So, in this context, National programs can promote forest carbon sequestration to avoid leakage etc. It also has flexibility to address local institutions and property rights such as overlapping claims to timber, grazing, fuel wood and non-timber forest products from the same forests. It is reported that about a quarter of the desired global carbon dioxide (CO_2) mitigation over this century is possible through forest. However, carbon crediting systems monitoring and enforcement is critical to maintain incentives for long-term storage. Reducing emissions from deforestation in developing countries (REDD+) has taken about 10 years to develop into what it is today. Countries like India and China, along with the Coalition for Rainforest Countries, have played key roles in shaping this effort within the United Nations Framework Convention on Climate Change (UNFCCC). However, putting REDD+ into action is still a challenge. Countries need time to build their skills, prepare the necessary documents, and set up systems to monitor and evaluate how well REDD+ is working. To speed up the implementation of REDD+ in developing countries, several policy issues need to be addressed. These include how the voluntary market operates, how to implement REDD+ effectively in India and its states, and the challenges related to national forest reference levels compared to local approaches (Kishwan, 2023). Biomass in the world's forest is reported to store about a trillion tonnes of carbon dioxide (CO_2). Forests appear to be sequestering an additional 4 billion tonnes (sink) of CO_2 per year (Mendelsohn et al., 2012). Productive forests can sequester up to 11 tonnes of CO_2 per hectare per year in above ground biomass and additional carbon below ground. However, it needs to be ensured that it continues to be a sink with existing climate change scenario. The amount of C sequestrated by different soil properties, land management practices, vegetation types etc is shown in Figure 4. The sequestration rate is affected by a number of factors. For example the sequestration rate is high for plantation crops while low for turf grass (Table 1). A study reported that 8% of the direct annual greenhouse gas emission from agriculture would mitigate global SOC sequestration of 0.12 Pg C $year^{-1}$ (Poeplau and Don, 2015). Mainly intercropping, cover crops and balanced fertilizer application has huge potential to enhance soil carbon sequestration. Another strategy is to engineer the cover crops with deeper root systems.

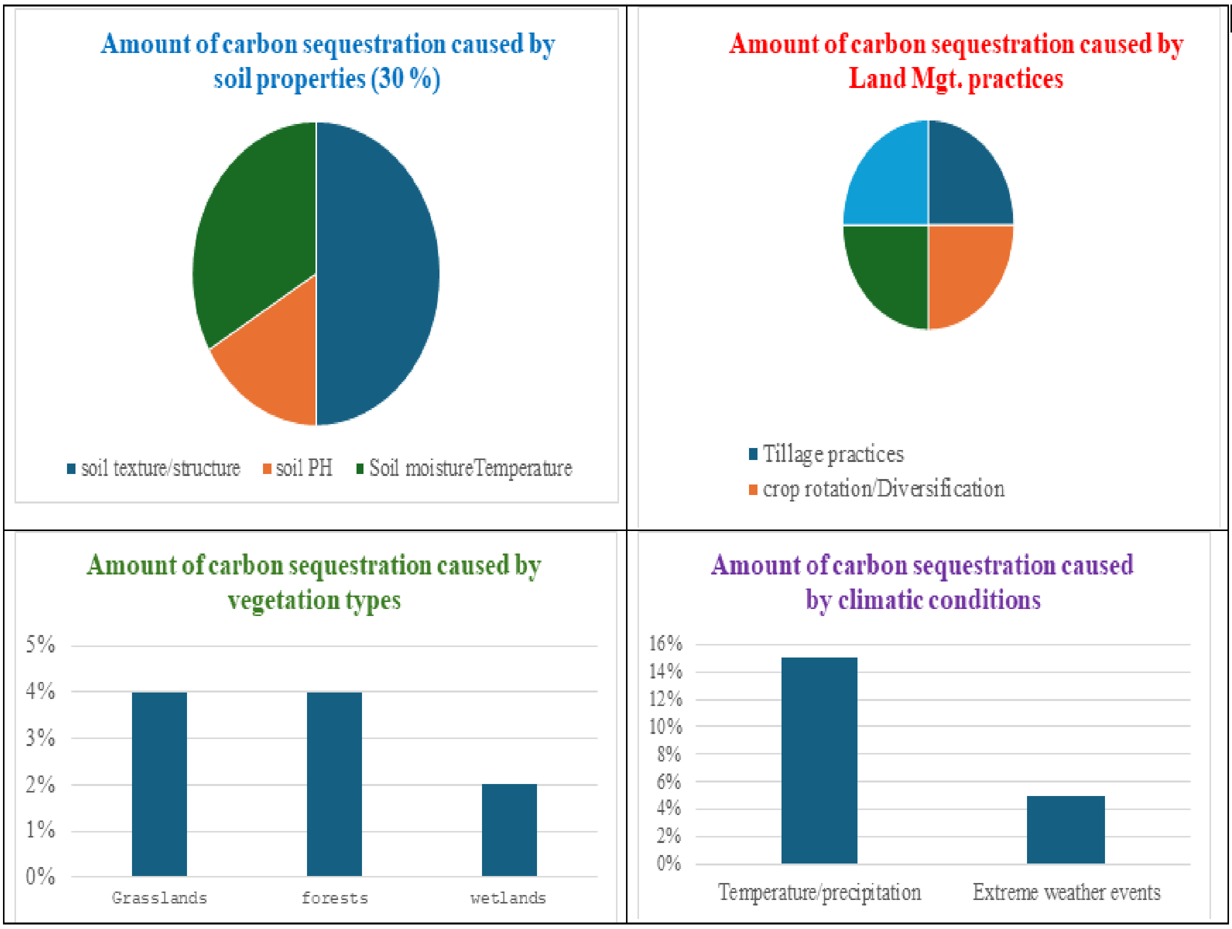

Fig 3: The amount of C sequestrated by different soil properties, land management practices, vegetation types and climatic conditions

Table 1: Amount of carbon sequestration through Horticultural crops (Mg C/ha/yr)

Type of Horticultural crops	Above ground	Below ground
Fruit crops	2.4-2.8	1.2-1.6
Vegetable crops	0.6-0.9	0.6-0.9
Turf Grass	0.3-0.4	0.3-0.4
Plantation crops	3-4.2	1.8-3

The creation of the carbon market came forth as a tool for managing, controlling, and reducing greenhouse gas emissions, combining environmental responsibility with financial incentives. Presently almost global carbon credit trading was estimated at 5 billion, with India's contribution at around 1 billion (Bansal et al., 2023). China is currently the largest seller of carbon credit with maximum market share (Xu et al., 2023).

The Kyoto Protocol also introduced three market based mechanisms to assist countries in finding ways to meet their targets.
These market-based mechanisms include:

- ✓ The Clean Development Mechanism ("CDM")
- ✓ Joint Implementation ("JI")
- ✓ The International Emissions Trading ("IET") mechanism.

Article 12 of the Kyoto Protocol created the framework for the CDM. The CDM allows any of the 37 industrialized countries bound by the Kyoto targets to implement an emissions reduction project in a developing country and, in doing so, generate a marketable Certified Emissions Reduction ("CER") credit. Each CER represents the equivalent of offsetting one metric ton of carbon dioxide and can be traded or sold to count towards meeting an industrialized country's GHG Emissions reduction targets under Kyoto. Article 7 of the Kyoto Protocol established the JI, a mechanism similar to the CDM. Under the JI, industrialized countries could jointly collaborate with other industrialized countries in pursuing and implementing emissions reduction projects in order to meet their Kyoto targets. The IET, an international trading program, sprung from Article 17 of the Kyoto Protocol. The IET allowed industrialized countries with unused, excess carbon allowances to sell these excess allowances to other industrialized countries that had otherwise exceeded their targets

Before a project can sell carbon offsets in the voluntary market, the project must first enroll and be registered with a voluntary carbon offset program, often also referred to as a registry. There are several voluntary carbon offset programs that register projects in the United States, including the American Carbon Registry, Verified Carbon Standard (Verra), the Gold Standard Impact Registry, and the Climate Action Reserve.5 Each program has its own criteria, methodologies, and protocol for quantifying the GHG Emissions reductions of a project, but programs often look to international sustainability programs as well as domestic certification standards for registration standards and requirements.

Types of Carbon Markets

The term carbon market refers to the buying and selling of emissions permits that have either been distributed by a regulatory body or generated by Greenhouse Gas (GHG) emission reduction projects. GHG emission reductions are traded in the form of carbon credits, which are equal to one metric ton of CO2, (tCO_2e), the most common greenhouse gas. Carbon markets can be separated into two major categories: compliance markets and voluntary markets.

Compliance markets: Compliance markets are created and regulated by mandatory regional, national, and international carbon reduction regimes like the Kyoto Protocol. The biggest success of compliance markets so far has been to send market signals for the price of mitigating carbon emissions. The total traded volume in the compliance carbon market grew from 4.8 Giga-tons (Gt) in 2008, to 8.7 Gt in 2009. Demand is driven by the emitters who must operate within proportion of the cap that has been allocated to them. An emitter has to buy additional emission permits, as soon as it exceeds the amount that has been initially allocated to it. However, demand falls due to employment of mitigation technologies or due to fall in the production output of the firm.

Voluntary markets: Voluntary carbon markets function outside of the compliance markets, enabling companies and individuals to purchase carbon offsets on a voluntary basis. The voluntary market reflects the sum of all transactions of carbon credits and allowances, where the final purpose of cancelling or retiring the carbon credit is not to comply with legislation or to fulfil agreements between companies and governments. The voluntary carbon market, although much smaller than the compliance market, is now growing rapidly. The voluntary carbon market (VCM), where carbon credits are traded, is witnessing a surge in popularity, with an increasing number of carbon credit registries, projects, proponents, and related businesses such as insurance and ratings. Currently the voluntary carbon market (VCM) is small representing 0.2% of global greenhouse gas emissions which may further expand. There is a chance if the voluntary projects can attempt to reduce emission beyond then that can be with existing project where average prices are now $ 3-5 t CO_2eq as compared to the price increase to $ 20-50 per tonne of CO_2 equivalent by 2030.

A domestic carbon market needs proper support and administration for a larger future to meet NDC aspirations of the country.

For successful domestic carbon market, it should focus on:

- ✓ Examination of present trade of various environmental instruments (ESCerts, REC, CERs and VERS)
- ✓ Fungibility across instruments and their role in a domestic voluntary carbon market
- ✓ Calibration and effective management of demand and supply of instruments
- ✓ Permission and play for intermediaries (traders and BFSIs)
- ✓ Participation of non-energy sectors with potential environmental footprint and reduction opportunities and types of instruments that can be transacted
- ✓ (Entry and exit barriers for international trade of emission reduction units.
- ✓ Fair and transparent price discovery Registry management and operation (short, medium- and long-term view)
- ✓ Participation protocol and methodology (registration and operationalisation of candidate projects).
- ✓ Monitoring and reporting of carbon market performance.

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Chapter 13

Digital Tools for Scaling up Agriculture Extension Models

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Introduction

Agriculture today is evolving in an environment of rapid changes in technology, markets, policies, demography and natural environment. These changes pose to the national agricultural sectors and rural communities are context specific and complex, and therefore putting new demands on all actors in and round the agricultural sector to innovate and develop new ways of collaborating to generate knowledge and put it into use at the required pace (Daane, 2010). Agricultural Productivity and Sustainability (COM, 2012) also states that increased and sustainable agricultural output will be achievable only with major research and innovation efforts at all levels.

Innovation is here defined as the implementation of a new or significantly improved product (good or service) or process, marketing method or a new organizational method in business practices, workplace organization farmers have a long tradition for sharing of knowledge in cooperatives or farmer learning groups, but there is a gap between the provision of agricultural research results and the application of innovative approaches in practical farming. (http://www.oecd.org/site/innovationstrategy/defininginnovation.htm.).

Also, global agriculture has witnessed a paradigm shift in the past few decades and extension mechanism need to stay ahead and equip the farmers by developing their management and decision-making skills. But the ground reality is hard-hitting with only one extension worker available for every 2879 farmers in India (Mukherjee and Maity, 2015). As an aftereffect of globalization, agriculture needed to change rapidly to keep pace with the global economy but infrastructural issues, low productivity, poor extension coverage, and low quality manpower became major challenges which still persist. Increasing climate variability would aggravate the problem of food and nutritional security of the growing population in India. Concerted efforts are required for mitigation and adaptation to reduce the vulnerability of Indian agriculture to the adverse impacts of climate change and make it more resilient.

In a world where information drives the change, extension needs to be adept with latest digital media to influence and facilitate farmers.Information and communication technology (ICT) tools, including hardware like mobile phones and tablets, applications with the capacity to create digital surveys, and software that allows users to upload data to storage facilities in real-time, have reduced the conventional challenges associated with remote data collection .New knowledge does not or takes too long time to reach the farmers, and the needs of practical farming are not communicated sufficiently to the scientific community. Thus, new collaborative methods and ICT may be important tools to solve some of these gaps by improving access to results, knowledge exchange and communication as well as preservation and education. This paper summarizes key issues, challenges and lessons derived from literature, case studies and practice concerning the role ICT can play in extension systems. It elaborates on recurring issues and describes innovative experiences and emerging practices that are enhancing the delivery of timely information that fits the needs of farmers. Various extension models are being adopted by different public and private organizations in dissemination of knowledge using digital tools to the farmers are discussed in the paper.

ICT in Agricultural Advisory and Extension Systems

Agricultural advisory systems have changed over the past decades, especially in regard to public extension, as farmers receive information from a wide range of ICT sources. These changes in ICT during the past two decades have been rapid and far-reaching, from the costly, colossal, energy-consuming equipment once available to the very few towards the booming and continuously changing mobile, wireless, and Internet industries for the many. In the last two decades, public and private actors operating in rural contexts in developing countries have widened their array of methods for disseminating knowledge through radio programmes, videos and other ICT-based methods. ICT has the potential to respond to a number of challenges that confront public extension systems. Public extension systems face difficulty in reaching all farmers due to the lack of financial capacity and staff to physically meet all farmers and communities. This is exacerbated by the fact that farmers are sparsely populated across large areas and oftentimes isolated. Strong public extension services only manage to directly reach about 10% of the farmer population, and this is even less if operating funds are limited (Bell, 2015). Another key challenge is that farmers increasingly request specified and varied information, as farming is becoming more and more market orientated. Even farming systems in relatively homogenous agricultural areas differ in type of crops cultivated, inputs, ratio/labour machinery and quality standards used. In order to be truly effective, information and knowledge has to be tailored to meet the needs of the individual farmer. Another limitation of public extension services is the nonrecurring character of information and knowledge provision to farmers. In the most optimal case, the information delivered is updated and renewed by means of regular exchanges between extension officers and farmers. However, the disadvantage of this is that it is costly and time consuming. The absence of a local facilitator or expert means that these efforts do not always result in adoption by the farmer (FAO, 2015).

Emerging Practices to Improve the Delivery of Information through ICT

Presently, a wide variety of approaches are being tried to use ICT to enhance extension services. Approaches differ in the format and the means by which the information is transferred; for example,by text, voice or picture, and through queries or SMS messages.In some cases, there is direct communication between the sender and the farmer. In others, the messages are disseminated through a farmer extension worker or a local facilitator that has access to the Internet. Some approaches support two-way interaction enabling the farmer to respond to or request from the provider. ICT-based extension advisory methods are relevant in areas such as preproduction, production, post-harvest and marketing, financial services, and gathering and distributing of data. Different tools are suitable for different applications (Saravanan *et al.,* 2015). In general TV, radio and video are used for awareness creation and transfer of technology. Mobile phones are mainly utilized for collecting and disseminating advisory and market information, such as prices and location. Web portals provide unique opportunities for information sharing and linking with other stakeholders and e-learning is specifically interesting for educational purpose. Social media integrates all functions; from providing advice and sharing knowledge to creating awareness, linking with other actors, and technology transfer.

Harnessing Social Media in Agriculture

The power of the 21st century is now literally in our hands. We have never before had Social Media (Fig 1) a powerful tool to connect with millions of people from the comfort of our own home, and all around the world. Social media has given power to the voice of the everyday man, and whilst that may come with its challenges, the opportunities. Social media is now a mainstream form of communication around the world, and continues to grow in popularity with the increase in the number of smartphones, and the ease of use whilst on the go.

It is staggering to believe that in little as two short decades, the evolution of the Internet and social media has taken place right before our very eyes. It was only in 1991 that the World Wide Web became public, only 15 years since Google was created and only nine years since Facebook was invented in a small Harvard dorm room. We now live in a world where wondering about the unknown is often followed by the phrase "Google it" and people feel as though they have lost their right arm if they don't have their cell phone at the other end of it. There are now 1.5 billion users of social technologies in the world, and that number continues to grow (Chui, et al., 2012). Limited research available shows that there are increasing trends in farmer and agribusiness uptake in social media as the popularity of smartphones increase.Social media refers to the means of interactions among people in which they create, share, consume and exchange information and ideas in virtual communities and networks.

Kaplan & Haenlein (2009) define social media as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the "creation and exchange of user-generated content."

Types of Social Media

Twitter

Twitter is an online social media site and micro blogging service, which limits the messages you send to only 140 characters long. Messages or "tweets" give users the power to share and create ideas quickly and efficiently across the world. There are now over 500 million users of Twitter around the world. Twitter the most useful and enjoyable tool for following agricultural interests, networking with other farmers and agribusiness people as well is interacting with entrepreneurs and other inspiring people within and outside of agriculture.

Facebook

Facebook is one of the most commonly used and known social media platforms in the western world. It is most commonly used for individuals to connect with their family and friends online and share personal information such as photos, updates and more with your select group of friends.Privacy settings allow your personal pages to be only accessed by whomever you choose. Facebook is also now widely used for businesses and interest groups to build a fan base and also connect and interact directly with their consumers and clients. There are now approximately 1.4 billion users of Facebook worldwide which is to be useful for farmers and industry to connect with consumers. It is also a useful place for more in depth discussions as there is no limit on the number of characters that can be used. Photos and other content can also be shared easily

YouTube

YouTube is a video streaming service which allows users to create and upload videos to the website which then can be shared to anyone worldwide. There are approximately 1 billion unique visitors to the YouTube website each month and 100 hours of video footage is uploaded to YouTube every minute. Videos are often more appealing to a lot of people as more of their senses are exposed to the content including sound and visuals.There are countless other social media platforms in existence such as LinkedIn (professional social networking), Instagram (photo sharing platform), Pinterest (Pin board platform for collating ideas),Vine (6 second video clip platform) and Blogging (User generated content on subjects of interest). Community radio, telecentres, videos, virtual communities of practice and social media enable farmers and others to 'gain a voice' (see Table 1 for a detailed overview). Also, many extension interventions combine ICT channels such as mobile phone services with traditional communication channels,like radio (USAID, 2010).

Table 1 : Types of ICT's to achieve various EAS function

***** appropriate *** moderately appropriate * less appropriate – blank cell denotes not appropriate

Extension functions	Information and Communication Technologies (ICTs)													
	TV		Radio		Mobile phones (basic)		Computer/laptop/smart phones							
							Without internet			With internet				
	TV broadcast	Video with DVD	Radio broadcast	Community radio	Text	Voice	Expert systems/ interactive multimedia CDs	Digital video	Animation	Web site/ web portal/ knowledge banks/ online repositories	Tele/video conference	Smart phones/ mobile apps	e-Learning platforms	Social media
Awareness	*****	***	*****	*****	*	*	*	*****	*****	***	*	*****		*****
Information	*****	*****	*****	*****	*****	*****	***	*****	*****	*****	***	*****	***	*****
Promotional	***		***	*	***	***	*	***	***	***		*		***
Advisory	***	***	***	*****	***	*****	*****	***	*****	***	***	*****		*****
Knowledge sharing	*****	*****	***	***	***	***	***	***	***	*****	*	*****		*****
Documenting & sharing Indigenous Technical Knowledge (ITK)	***	*****	*	*****		*		***		***		*		*****
Technology transfer	*****	*****	***	*****			*****	*****	***	*****		***		*****
Training		***						***			*****		*****	
Education/ e-learning	*	***	*	*				***		***		*	*****	
Market information & linking			*	***	*****	*				***		*****		*****
Credit and banking access					*****					***		*****		
Input linking	*		*	***	*****	***				*****		*****		***
Mass advisory	*****	*	*****	*****	***			*	***	***		*****		*****
Business planning												***		
M&E, enumeration, survey										*****		*****		
Linking with AIS actors				*****	*					*****		*		*****
Feed back				*****		*****				*****	***	*****	***	***
Target groups	Farmers, agripreneurs, input dealers, stakeholders in value chain, extensionists	Farmers, agripreneurs, extensionists	Farmers, agripreneurs, input dealers, stakeholders in value chain, extensionists	Women farmers, agripreneurs, stakeholders in value chain, input dealers	Literate farmers, agripreneurs, input dealers, stakeholders in marketing channels, extensionists	Farmers, agripreneurs, input dealers, stakeholders in marketing channels, extensionists	Literate farmers, extensionists, agripreneurs	Farmers, agripreneurs, extsensionists	Illiterate farmers, extensionists	Literate farmers, agripreneurs, input dealers, stakeholders in marketing channels, extensionists, policy makers	Farmers, extensionists	Mostly literate farmers, entrepreneurs, input dealers, stakeholders in marketing channel and value addition, extensionists	Extensionists, researchers, academicians, farmers, agripreneurs, policy makers	Literate farmers, agripreneurs, input dealers, stakeholders in marketing channels, extensionists, research and academic institutions, experts, policy makers

Source: Modified from: Bell, M. and Payne, J. 2011 *ICT options to enhance agricultural extension. The MEAS ICT Matrix.* Available at: http://www.meas-extension.org/resources/ict

Although positive experiences are numerous, few of the ICT based extension services have managed to scale up to a large number of farmers. In the following sections, case studies that demonstrate innovative use of ICT are presented.In recent years a lot of social media and other ICT tools have been developed (Table 2 and Table 3) which may enable creation, sharing and preservation of knowledge:

Table 2 : ICT tools developed for sharing and preservation of knowledge

Knowledge portals:	These are ICT tools for searching and access to web based knowledge. Knowledge portals enable a common platform for delivery of information from

	diverse sources.
E-document management systems	They are pieces or collections of software that can digitize and store documents in a digital format. This ICT tool is used as a database, allowing for searching and sorting of the documents collected.
Data warehouses	These are databases used for reporting and data analysis. It is a central repository of data which is created by integrating data from one or more disparate sources.
Groupware or collaborate software	This is software, which helps facilitation of action-oriented teams working together over geographic distances by providing tools that aid communication, collaboration and the process of problem solving. Additionally, groupware may support project management functions, such as task assignments, time-managing deadlines, and shared calendars.
Community of practice (CoP)	This is a group of people who share a craft and/or a profession. The group can evolve naturally because of the members' common interest in a particular domain or area, or it can be created specifically with the goal of gaining knowledge related to their field.
Social communities of interest	It is a community of people who share a common interest or passion. These people exchange ideas and thoughts about the given interest, but may know (or care) little about each other outside of this area.
Individual communities of interest	They are ICT tools for individuals to manage personal knowledge and networks.

Table 3: Software types, evaluated tools (in bold text) and other examples of tools of the different types and successful examples of application of the tools, mainly in agriculture

Software type	**Tools evaluated**	**Successful examples :**
Knowledge portals (KP)	*Search engines:* Google, Yahoo *Slide and document sharing:* **Slideshare** *Video and photo sharing:* **YouTube**, Flickr	VOA3R, eXtension, Chil
E-document management systems(E-MS)	*Digital libraries:* Groen Kennisnetin NL, **Organic E-prints**	Organic Eprints, Agriwebinar
Data Warehouse (DW)	Eurostat, **FADN**	FADN
Groupware (GW)	**Wikipedia,** **Yammer,** **Crowdsourcing**	British Farming Forum, Lego Cuusoo, Climate CoLab, P&G Connect+Develop, Betacup Challenge
Community of practice (CoP)	**ResearchGate,** **Erfaland**	Disease surveillance and warning systems, IDRAMAP
Social communities of interest (SCI)	**Facebook,** **LinkedIn**, **Google+,** **Ning**, Quora	AgTalk+,. E-Agriculture, Jeunes-agricultuers, E-agriculture, Rede Inovar
Individual communities of interest (ICI)	**Wordpress,** **Twitter**, blogs	AG Chat

Social media Applications developed

There are many applications and ICT-enabled tools for data collection purposes Some of other prominent examples of use of major social media platforms in agriculture are given Table 4.

Table 4 : Examples of ICT-enabled tools for data collection purposes

Name of Group/Community/Pages	Description	Target users	Region
Facebook			
By farmers			
Livestock Information and Marketing Centre (https://www.facebook.com/groups/Livestock.TN/)	Members (farmers,extension personnel, scientists, market functionaries, consumers ,etc.) of this group share information related to livestock production, management, marketing, etc.A separate page is also on Facebook related only to marketing of livestock(https://www.facebook.com/Livestock.Market)	Agricultural stakeholders related to livestock	Tamil Nadu,India
Turmeric Farmers' Association of India (https://www.facebook.com/turmeric.farmers)	This page was created by turmeric farmers to stabilize price of turmeric in the market. Till date, the farmers connect through the page and share information to keep turmeric price stable and increase marketing opportunities of turmeric.	Turmeric farmers	India
Natural farming Development Centre	Members of the group share information related to organic	Farmers interested in	Tamil Nadu,

(https://www.facebook.com/groups/NaturalFarmingTN/).	farming, permaculture, hydroponics, aquaponics, Natural Repellents, *etc*	organic and zero budget agriculture	India
National Ecological Producers Association (APNE) (https://www.facebook.com/anpe.peru)	Information related to ecological farming is shared through the page.	Farmers	Peru
By extension centres			
Krishi Vigyan Kendra, Namakkal (https://www.facebook.com/krishi.namakkal	Krishi Vigyan Kendra, Namakkal communicates information related to farmers' training programmes, availability of inputs *etc.* through this account	Agricultural Extension stakeholders	South Asia
By extension professional networks			
Agricultural Extension in South Asia (AESA) (https://www.facebook.com/ groups/428431183848161/)	Members post links to relevant publications on extension and advisory services, announcements of workshops and conferences, major policy decisions on extension, reports of meetings / workshops and blogs relevant to the broader theme of extension	Agricultural Extension stakeholders	South Asia
Global Forum for Rural Advisory Services (GFRAS) (https://www.facebook.com/groups/gfras/)	This page provides information related to advocacy and leadership on pluralistic, demand-driven rural advisory services.	AEAS Professionals and others	Global
By extension personnel			

Vivasayam Karkkalam (Let us Learn Agriculture) (https://www.facebook.com/groups/madhualan	Mr. Madhu Balan, a public extension officer started Facebook group to cater the information needs of famers in 2012.This group, exchange information on improved farm technologies, initiates discussion with other farmers and extension personnel, share information and photos on best practices by other farmers, government schemes, *etc.* Question and answers, nformation on Terrace garden, hydroponics are most discussed topics in this group.	Farmers and others those who are interested in agriculture	India
Twitter			
Farmers			
AgChat (https://twitter.com/agchat)	The AgChat (Twitter online discussion group by the AgChat Foundation) started in 2009 by a group of American farmers is widely used in USA, UK, Australia,New Zealand and Ireland for facilitating discussions of industry issues between farmers and agribusinesses	Farmers, entrepreneur, farm product consumers	USA, UK, Australia, New Zealand, Ireland
Agriculture Proud (https://twitter.com/AgProud)	Twitter handle of Ryan Goodman, a young farmer and rancher from Montana, US. Through his Twitter account he shares his experiences of farm life	Agriculture enthusiasts, consumers, and fellow farmers	USA

	and answers questions of fellow farmers, agriculture enthusiasts, and consumers		
Extension centres			
USDA (https://twitter.com/USDA)	The Twitter handle of U.S. Department of Agriculture shares latest news, events, and information in agriculture	Farmers, extensionists, development practitioners	USA
INGENAES (https://twitter.com/INGENAES)	This Twitter handle of Feed the Future initiative Integrating Gender and Nutrition within Agricultural Extension Services shares information and genderappropriate, nutrition-enhancing technologies to improve life and livelihood of women farmers	Researchers, extensionists, farmers	Global
Professional networks			
MEAS (https://twitter.com/MEAS_extension)	Twitter handle of the project Modernizing Extension and Advisory Services shares good practice strategies and related information to ultimately raise farm income and enhance livelihood of rural poor of 12 selected countries of Asia and Africa.	Development	Global
GFRAS (https://twitter.com/infogfras)	This page provides information related to advocacy and leadership on pluralistic, demand-driven rural	Extensionists, development	Global

	advisory services.	practitioners, researchers, policy makers	

Source :(Suchiradipta Bhattacharjee, Saravanan Raj, 2016)

According to Chowdhury (2001), ICTs play an important role in food security through facilitating accessibility to related policies and information for market communication, improving market profitability, helping farmers to make decisions, increasing diversity in rural economies and reducing the cost of living. Some of the *success stories of ICT/ICM in agriculture are discussed below.*

Technology Dissemination through Innovative Extension Models. Various Extension models are being adopted by different public and private organizations in dissemination of climate resilient technologies and to enhance the preparedness of the farmers. A few such innovative models which have been pilot tested and in practice are discussed here.

aAQUA: ICT-enabled knowledge services to farmers in India

The aAQUA which stands for almost All Questions Answered, evolved quickly into an online farmer knowledge exchange platform built by young agricultural extension staff. (Malcom, 2011). aAQUA (Fig.3) is operational since December 2003 and demonstrates to farmers by variety of technologies that included mobile phones, website and SMS-based services jointly by the Developmental Informatics Lab of the Indian Institute of Technology-Bombay, Vigyan Ashram and KVK Baramati (NGOs) in Maharashtra.It allows members using a web browser on a computer to create, view and manage content in local languages.On

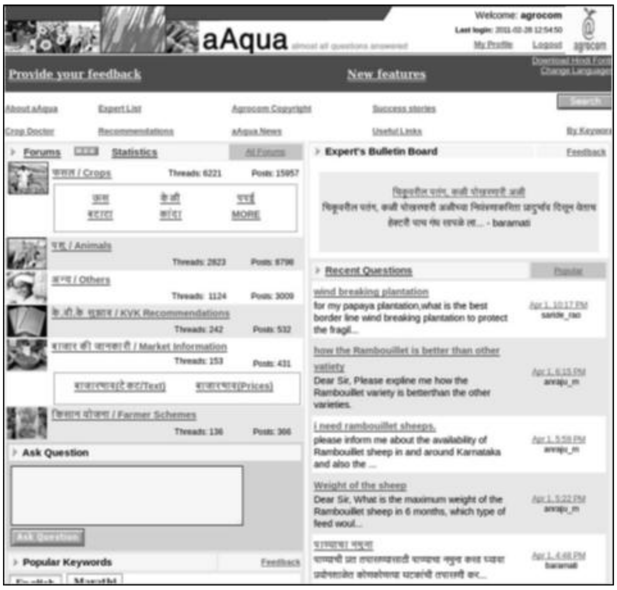

Fig. 3: Home page of aAqua . Source : Malcom **(** *2011)*

aAQUA, content is organized in the form of discussion fora based on the types of categories of queries posted by farmer or experts. There are 22 fora comprising 6 categories that included crops, animals, KVK recommendations, farmer schemes and market information etc. The fora are open to all users for browsing without any charges for non commercial use (Malcom, 2011).

Marketing and distribution of agricultural produce:

One of the applications using ICT for agricultural marketing is Agmarknet which is discussed below:

Agmarknet: an agricultural marketing information system *:*

In India in order to provide an effective information exchange on market price, the Directorate of Marketing and Inspection, Department of Agriculture & Cooperation, Ministry of Agriculture, and the Agricultural Informatics Division, National Informatics Centre, Ministry of Communications & Information Technology, collaborated to create the Agricultural Marketing Information Network (Fig 4). The project aims at establishing an efficient nationwide system for the collection and dissemination of market information, and computerizing data on market fees, market charges, storage and modes of transportation (www.agmarknet.nic.in).

Fig 4 : Agmaket Portal

Community e-centres to improve agricultural productivity:

Rural access to ICT through community e-centres can be used to improve agricultural productivity by connecting the rural poor to direct markets, and by giving them ready access to information on the prices of inputs and products. In villages around Pondicherry, villagers operate local "knowledge centres", which are part of a network of telecentres established by the Swaminathan Foundation. These operators adapt data and information from public sources for their own weather bulletins, which they post on notice boards for the local fishermen. The telecentre also broadcasts appropriate information over loudspeakers, to benefit those who are illiterate, and publishes a local newsletter.

Another example is the e-Choupal model (Fig 5), established by a private Indian tobacco company. These telecentres are operated by ITC-trained local farmers, and provide the agricultural community with access to good practices in agriculture and market prices for commodities.

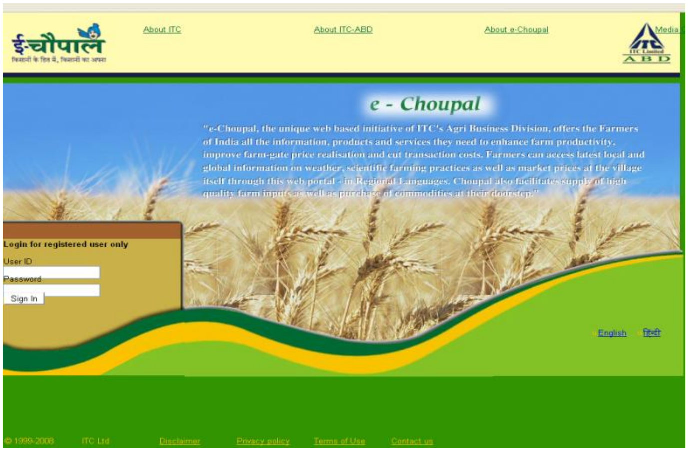

Fig 5: e-Choupal (http://telecentresap.org/meeting/cmap2007/India_Presentation_eChoupal.pdf).

***Public-private partnerships in e-agriculture: stakeholder roles and incentives**:*

A public-private partnership is an initiative formed and operated jointly by a Government or a public sector entity and one or more private sector companies, non-governmental organizations or civil society organizations. Some examples of public-private partnerships in Asia include the e-Choupal centres, Life Lines-India, Krishi Vigyan Kendra, and the Kisan Call Centres in India; the Commonwealth of Learning—supported Lifelong Learning for Farmers Project in various countries; the Grameenphone Community Information Centers in Bangladesh; and the e-Haat Bazaar in Nepal.

Harita-Priya: A Wireless Sensor Networks (WSN) based Disease Forewarning and Crop Advisory Model

In 2015, a C-DAC Team deployed 74 WSN nodes in 5 villages of Anantapur District, Andhra Pradesh state, covering approximately 450 acres of groundnut crop. These WSN nodes sense the micro-climate at crop canopy level on real-time basis and transfer the data periodically to a remote server, through a field 'Gateway' having Internet access. At the server, crop centric 'Decision Support Models' analyse the data received from the field and alerts are generated for pest/ disease forewarning or irrigation scheduling. Based on the alerts generated by the system, the Agriculture Department sends personalized crop advisories to the farmers via SMS in Telugu language.

***e-Arik (e-Agriculture)**:* Using ICTs to Facilitate "ClimateSmart Agriculture" among Tribal Farmers of North East India

A 'Village Knowledge Centre' was established under e-Arik project with a computer, internet link, printer, scanner, phone and TV at Yagrung village in Pasighat, Arunachal Pradesh. The eArik project staff regularly undertake field visits to observe crop conditions and to diagnosis pests, diseases, nutrient deficiencies and physiological problems. They digitally document these issues using ICTs in the field and, via email and webcam, communicate them to staff at the eArik Research Laboratory at the Central Agricultural University. Problems are analysed by the experts (who also sometimes undertake field/advisory visits) and recommendations are passed on to the eArik Village Knowledge Centre by email and then to the concerned farmers by phone or personal face to face communication by farmer facilitators. Dissemination of information and good practices was also addressed by innovative approaches such as farmer to farmer communication and local self-help groups. Besides, a portal (www. earik.in) was established under the project to provide information on crop cultivation and other agricultural practices; basic information about agriculture and rural development departments of the government; specific information on government schemes related to farmer welfare and day to day market information and weather forecasts *etc.* A total of 500 farmers were covered in 12 villages.

Principles and Process to Strengthen the Delivery of Information through ICT

To successfully improve extension systems with ICT, a number of context conditions have to be met. First of all, success of ICT is dependent on the knowledge of people on how to use devices

and navigate the Internet. For example, hosting web portals and e-learning platforms requires advanced technical knowledge and computer skills. The same applies for app-development. Second, ICT only achieves impact when the mode used corresponds to the interest and capacity of the user group. Web portals, e-learning and text-based SMS messages are only useful for literate farmers, whereas video, voice-based advisory services and community radio are more suitable for illiterate people. The tools selected have to match the purpose, content and clientele. Moreover, integrating traditional media and new ICTs can expand the reach of extension, but a high adoption rate requires farmers to be engaged in determining relevance and developing content and allowed to interact with information/service providers (Francis and Addom, 2014).

Third, it is important to realise that ICT does not generate content but acts as a vehicle to disseminate it. People make use of the services provided only when the content is of interest to them. This is more probable when services are timely, specific, contextualised and targeted. Moreover, ICT based services alone are not enough. They create greater synergy when combined with other extension methods like farmer field schools and demonstrations. To achieve widespread impact, institutionalising ICTs is therefore necessary (Christoplos, 2010). There has been an assumption that with the 'right' technological investment, extension agencies will achieve new objectives and become more sustainable. However, innovations within ICT must be adapted to prevalent constraints, such as institutional structures, human and financial capital constraints, in order to be scaled up and successfully implemented (Christoplos, 2010).

For ICTs to successfully enhance extension, Saravanan *et al*. (2015) suggest the following steps for implementation, each step depends on the situation and judgement of the extension organisation:

Successful Implementation of ICT

The first action of the organisation/ministry/agency that is going to use ICT-based extension should be an assessment of the needs of the target community. 2 To adapt, monitor and evaluate ICT enabled services it is important to conduct benchmark surveys before introduction. Benchmark surveys also help to get a good overview of the actual situation.3 Based on the needs assessment and benchmark surveys, localised and customised content needs to be developed.4 ICT tools need to be selected and developed, in such a way that they correspond to the desires and needs of the target group.5 The target audience should be sensitised on the presence of the services and how to access them.6 The newly developed ICT-based services are introduced and used in extension.7 To ensure sustainability of the services, it is recommended to search for partnerships with stakeholders present in the target area or seek for integration of the services in the public agricultural extension system.8 Monitoring and adaptation is important, especially in the beginning of the project. Modifications should be made when the project does not correspond to the needs of the audience.9 Finally, an impact assessment should be realised to determine the degree of success of the project.

Challenges for Promoting ICT in Extension

Despite the promise and potential of ICT in extension services,there are numerous challenges facing ICT as an extension strategy, which can be seen in the list below:

1.One key challenge is the scaling up of ICT in extension services. Many ICT interventions fail to scale up and achieve widespread adoption due to market fragmentation and the lack of financially sustainable business models that will attract private sector investments in innovative solutions for small-scale agriculture (World Bank, 2016). Rather than assuming that an ICT approach will always be cost-effective and yield a better outcome, there is a need for a more understanding of the underlying institutional environment and constraints (World Bank, 2016**)**.

2.Complex and dense information, such as nuanced information on agricultural practices and inputs, have to be converted into ICT-based messages (Aker, 2011). To transform these into SMS messages or videos requires the capacity to summarise complex information into concise

3.Whereas the expansion of mobile phone access has been rapid and commercially self-sustaining, even among many of the poor, the same does not hold for the Internet. In the long run, however, the Internet can have an even greater impact on rural growth. Much depends on finding sustainable business models that encourage its spread in the poorest parts of the world (World Bank, 2016).

4.Even with the information provided from the ICT intervention,it is not guaranteed that the farmer will act upon this information because of the inaccessibility of alternative markets and the complex interlinked relationships between buyers and sellers in low-income developing economies (World Bank, 2016).

5. Communicating information in the national language might lead to misunderstanding or low adoption rates, as in many rural areas farmers only speak local languages. In regard to adoption rates, integrating traditional media and new ICTs can expand the reach of extension. However, to achieve high rates of adoption, farmers need to be engaged in determining the relevance and content that will be shared and distributed to other farmers (Francis and Addom, 2014). This also relates to the capacity of the farmer to search information. Even if the information is simple and the message is fast and timely, reception depends on farmers' understanding of the phone, computer or any other medium used. This holds also for the extension worker or call centre agent sending the information; in case farmers respond with questions he or she must be able to search the answers and respond in an understandable way (USAID, 2010).

6. Another challenge is the diversity of farmers. Having the potential to tailor and personalise messages, ICT initiatives can reach a diverse and large number of farmers. However, this requires good knowledge of the user group.

To make sure that not only the entrepreneurial young farmers receive the information it is important to differentiate between the farmers in a community. For example, women and elderly often have lower literacy and schooling rates than young men. This requires the development and use of adapted information and training materials. In this respect, audio-visual tools are more likely to offer opportunities to reach women farmers (Quisumbing and Pandolfelli, 2009).

Conclusion

Policymakers and other stakeholders need to be aware of how appropriate ICT-based instruments can help to influence agricultural practice as well as support efforts and initiatives to promote food security and sustainable agriculture. To realize the full potential of ICT-enabled agriculture, Governments need to provide the following:

(a) A sound, market-oriented ICT regulatory framework;(b) Incentives such as a sound business and taxation environment to encourage investor and donor involvement in ICT infrastructure development in Asia and the Pacific;(c) The preconditions for interregional collaboration in Asia and the Pacific through, for example, the introduction of common standards and ICT-based monitoring and forecasts; (d) Support to research institutions and other nonprofit organizations that use ICT tools to assess and transmit commodity prices, thereby allowing markets to emerge;

(e) Initiatives that combine existing media channels, such as rural radio stations, with ICT to match potential local demand with global content and to distribute the information widely in the relevant languages.

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Chapter 14

Potential of Natural Farming in Rainfed Areas

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Rainfed areas, which constitute 65-70% of the country's agricultural land, often suffer from lower-than-expected productivity due to inadequate management. As a result, the average yield remains suboptimal. In India, rainfed farming relies heavily on the southwest monsoon, which occurs between June and September and serves as a lifeline for these regions.

Over time, farming methods in India have evolved significantly. Earlier, farmers relied on traditional techniques, but now they employ various innovative approaches. Rainfed areas, primarily dependent on rainfall, form an essential part of Indian agriculture. However, they face several challenges, including erratic rainfall, low soil fertility, and water scarcity. In this context, natural farming emerges as an effective solution. The principle of natural farming focuses on reviving traditional farming practices and enhancing agricultural production through biological processes.

This method eliminates the use of chemical fertilizers and pesticides, improving soil quality while positively impacting farmers' health and the environment. Adopting natural farming in rainfed areas can increase farmers' income, mitigate climate change effects, and maintain ecological balance. Diverse crop rotations and agroforestry systems improve nutrient uptake from the soil and make more efficient use of water and light. This effectiveness is due to the different patterns of root development and leaf distribution that occur ove3r time and across space (Altieri, 1999; Vandermeer, 2008). Soils with high functional diversity of microorganisms, commonly found after decades of Natural Farming practices, develop disease-suppressive properties and can enhance resistance in plants (Mäder et al., 2002; Fliessbach et al., 2007). The ecosystem approach is a strategy for integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way (FAO, 2004). This approach utilizes appropriate scientific methodologies that focus on different levels of biological organization, encompassing the key structures, processes, functions, and interactions among organisms and their environments (Barton et al., 2012). It recognizes that humans, with their cultural diversity, play an essential role in many ecosystems (Molina et al., 2006).

Natural and organic farming are examples of environment-friendly agricultural practices. These methods not only yield healthier produce but also help conserve the environment. Consequently, both the government and farmers are actively supporting such initiatives.

Challenges in Rainfed Agriculture and Natural Farming

Rainfed agriculture faces numerous challenges. Given its dependence on nature, inadequate policies, lack of resources, and insufficient investment often lead to lower productivity. While fertile soil is an asset, issues such as soil erosion pose significant obstacles to natural farming in these areas.

Natural farming is inherently complex. When implemented, it involves certain principles that are challenging to apply directly. Therefore, establishing a common framework for measuring success is essential. Engaging with diverse stakeholders while respecting scientific perspectives is crucial to determining the purpose and utility of natural farming. Bringing together individuals involved in natural farming fosters shared learning and enhances the effectiveness of this approach. Additionally, when promoting and expanding natural farming, special attention must be given to specific locations and farm conditions.

The success and expansion of natural farming in a region depend on multiple factors, including land ownership, land use patterns, water availability, livestock, and family support. The goal of natural farming is typically to increase yield, profitability, and biodiversity while reducing emissions and the use of synthetic fertilizers.

By developing support systems for irrigation, farm organization, product enhancement, and market integration, natural farming can yield better results even in less favorable regions. With the exception of estimated labor costs, natural farming reduces labor expenses as family members contribute to farm work. However, labor availability depends on family size and structure. Categorizing farms based on land size and family characteristics can help identify small-scale farmers who can effectively practice natural farming with available family labor and natural resources.

To sustain natural farming at the grassroots level, it is essential to manage soil health and nutrients effectively. Without proper nutrient management, some farmers may resort to synthetic fertilizers or unbalanced organic materials, compromising consumer trust and product quality.

Natural farming avoids the use of synthetic fertilizers in soil preparation, thereby preventing environmental degradation. The selection of crops is a critical aspect of natural farming. Priority should be given to crops such as millets, pulses, and oilseeds, which require minimal resources. Additionally, multi-layer cropping systems, which ensure continuous plant production, should be encouraged.

For the sustainability of low-cost natural farming, resource-sharing is vital. This can facilitate access to fodder, natural pest control, and fuel. The combination of natural farming with agroforestry has shown promising results.

Market and Economic Benefits of Natural Farming

The benefits of natural farming become more evident when farmers receive fair prices and adequate market access. Implementing diverse marketing strategies and focusing on value addition can improve market reach and profitability. Portable canopy stalls at common areas, roadside locations, offices, and transport hubs can attract consumers and increase sales. Creating consumer groups through platforms like WhatsApp or local telephone networks can facilitate direct supply of fresh produce from farmers to consumers. Establishing dedicated outlets at district or block headquarters can help sell produce collected from farmers or producer organizations. Additionally, an e-commerce platform can enhance market accessibility and enable direct sales.

For successful marketing, farmers and producer organizations should focus on aggregation, efficient supply chain management, and value addition.

Key Advantages of Natural Farming in Rainfed Areas

1. **Water Conservation**: Natural farming techniques like mulching, crop rotation, and soil structure improvement help conserve water, maximizing the retention of rainfall.
2. **Soil Quality Enhancement**: By eliminating chemical fertilizers, natural farming boosts microbial activity, increasing soil fertility and making it more suitable for rainfed regions.
3. **Ecological Balance**: Natural farming promotes beneficial insect populations that help control harmful pests, thus maintaining ecological balance.
4. **Economic Benefits**: Since natural farming does not require chemical inputs, farmers' costs decrease, leading to increased income and economic stability.
5. **Sustainability**: Adopting natural farming in rainfed areas enhances agricultural sustainability and resilience against climate change, ensuring consistent crop production.
6. **Crop Diversity**: Natural farming encourages crop diversification, which strengthens ecosystems and helps control pests and diseases.
7. **Community Participation**: Engaging local communities in natural farming fosters knowledge-sharing and improves the adoption of sustainable farming techniques.
8. **Ecosystem Services**: Natural farming conserves ecosystem services such as pollination, soil formation, and climate regulation, contributing to long-term agricultural stability.
9. **Health Benefits**: Chemical-free farm produce enhances human health, benefiting both farmers and consumers.
10. **Local Market Development**: The growing demand for natural farm products supports the expansion of local markets, providing farmers with new income opportunities.
11. **Technical Training and Awareness**: Educating farmers on the benefits of natural farming and offering technical training can encourage them to adopt new methods and innovations.
12. **Climate Change Mitigation**: Natural farming reduces greenhouse gas emissions by enhancing soil carbon sequestration, thus combating climate change.

13. **Support for Small and Marginal Farmers**: Natural farming is particularly beneficial for small-scale farmers as it requires low initial investment, making economic self-sufficiency achievable.
14. **Research and Development**: Advancing research in natural farming can lead to innovative solutions and technologies that support agricultural growth in rainfed areas.

The potential of natural farming in rainfed areas extends beyond improving agricultural productivity; it also plays a crucial role in economic, social, and environmental development. With the right efforts, these regions can set new standards in sustainable agriculture. Farmers in rainfed areas should dedicate a portion of their land to natural farming!

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Chapter 15

Gender Issues in Agriculture and Climate Change Scenario

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Gender inequalities are persistent in agriculture sector in terms of gaps in how much money women earn for their work in agriculture as well as gaps in the productivity of their land plots, the size of land they have access to, their access to agricultural technologies, their access to digital tools and their financial access. Besides all these, there are also persistent discriminatory social norms that women and girls face, which may constrain how much they can work outside the home or how far they can travel to do their work. So, when you combine these material gaps and inequalities with discriminatory social norms, it becomes very hard for women to achieve the same level of outcomes as men. In general, men are responsible for managing agricultural inputs such as equipment, fertilizers, and pesticides, as well as transportation to markets, while women are involved in work that requires more manual labor and less dependence on specialized inputs and equipment, such as weeding, fodder collection, maintenance of crop storage, kitchen gardens, and caring for farm animals.

Global livestock production is also marked by a gender divide in labor. Women are more likely to own and maintain regionally adapted breeds and small animals such as sheep, goats, and poultry, whereas men specialize in larger and improved livestock species, namely cattle. Within large livestock management, there is frequently a clear gender division of labor, with women, for example, being responsible for providing water to cattle (Chanamuto and Hall, 2015). Cattle are particularly vulnerable to the effects of climate change on grazing pastures, therefore men in cattle-raising areas may face disproportionate income and asset risk (McKune *et al.*, 2015).

In India, around 65% of female workers rely on agriculture, accounting for 55-66% of overall agricultural production (Census 2011). Women make up a larger proportion of casual agricultural labor, but more men work for wages in the non-farm economy. According to Kapoor (2011), women who work casually are poorer than men who work for a wage. According to the Economic Survey 2017-18, as men leave India, agriculture is becoming more feminized, with a rising proportion of women working as cultivators, agricultural laborers, and entrepreneurs (PIB 2018). As a consequence, current gender disparities in agriculture are expected to worsen.

Evidence suggests that women in agriculture prefer food crops over income crops (UNDAW & UNESCO, 2010). By 2050, climate change is expected to reduce South Asian rice production by 14%, wheat production by 49%, and maize production by 9% (Asian Development Bank 2013: 10). While the impact of climate change may differ per country in this region, severe price rises are unavoidable for these important food crops. Because of the growing share of women among small-scale food crop farmers, as well as their poor bargaining power (ibid), any future price increase will have a significant impact on women.

Climate change has become a global threat to both sustainable agricultural development and food security. The reliance of developing countries on rainfed agriculture and natural resources exposes millions of smallholders to climatic risks. Climate change has an impact on both rural men and women's abilities to secure their livelihoods. Rural communities worldwide are trying to coping with escalating challenges brought out by the climate change. As the disasters become more frequent and severe with time, the burden on rural communities intensifies. Climate change is likely to aggravate gender disparities if attempts to incorporate gender concerns into climate change responses are not prioritized (Skinner, 2011; Ahmad *et al*., 2014) as the women who are bearing the heaviest brunt of these impacts, including significant financial losses. In general, gender inequality plays a significant role in determining women's adaptive capacity to climate change. Every year, women farmers and female-headed households are suffering from very large losses due to climatic shocks such as heat stress or flooding, compared to those experienced by male-headed households. FAO report says that due to heat stress, female-headed households lose 8 percent more of their income every year than male-headed households and that accounts to $37 billion a year. Similarly, flooding has an impact on decreasing female-headed household income by 3 percent, which is $16 billion a year compared to male-headed households. The report also highlights that if climate change increases by another one degree Celsius, female-headed households could lose 34 percent of their income compared to male-headed households. Climate change is also increasing the women's working hours. On average, women spend 4 hours a day on unpaid domestic and care work, while men spend less than two. This means that climate change can add to the burden of tasks such as gathering water or wood, or any other care duties necessary to keep a household or farming operation running. Climate change has also an impact on fisherwomen's livelihoods and coping strategies, and in certain situations, it may result in large-scale migrations. (Fatima Noor Khan *et al*., 2018; Smriti Misra and Pushp Bajaj, 2020).

Limited Ownership Rights: According to the 2011 Census, approximately 65% of India's female workforce is employed in agriculture, while only 13.87% of landholdings are owned by women. While the percentage of female operational holders increased from 12.79% in 2010-11 to 13.87% in 2015-16, and the area operated by women increased from 10.36% in 2010-11 to 11.57% in 2015-16 (MoAFW 2018), female ownership remains relatively low in comparison to male ownership. Women's lack of ownership rights prevents them from accessing institutional finance and bank loans, as well as government agricultural benefit schemes, limiting their decision-making and productive capacity (Saxena, 2012). Climate change causes more threat on women's land rights by causing desertification, soil degradation etc.

Lack of Access to Financial Resources: Most rural financial programs in India are planned with the male head of their homes as the intended recipient, neglecting to recognize women as productive agricultural agents with their own financial demands and limits. Landlessness also hinders women's access to rural financing because they do not have collateral to provide. Furthermore, women are unable to purchase fertilizer, improved seeds, pesticides, or implement sustainable agricultural techniques that can increase agricultural production due to a lack of capital investment money (Fletschner and Kenney, 2014; Chatterjee, 2021).

Lack of Training in Agriculture: most of the time, there is a lack of training programs that educate women about climate and weather information, as well as help them increase their capacity to use this knowledge, limiting their ability to adapt to climate change (Chatterjee, 2021).

Gender-insensitive Technology Choices: Technology facilitates an efficient use of natural resources and increases farmer revenue through agricultural productivity. While suitable technical options can greatly reduce women's stress in activities like as transplanting, crop sowing, and fertilizer management (Khatri-Chhetri *et al*., 2020), a lack of concern for women while developing these technologies results in widespread exclusion. They have less money and fewer opportunities to use transportation than males, which limits their access to new technology. Agricultural technology, including farming implements and vehicles such as tractors, is frequently incompatible with women's physiology because it fails to adequately assist women in doing their activities and is sometimes irrelevant to the local conditions of the productive system (Chatterjee, 2021).

Strategies to tackle gender inequalities

Strengthening women’s land rights

Promoting gender-sensitive agriculture extension services

Enhancing women’s participation in decision-making

Supporting women-led climate change initiatives

Conclusion

Climate change causes and exacerbates systemic disparities between men and women. This is especially true in many parts of the world where women rely on climate-sensitive jobs such as agriculture and manual labor to earn a living. Women are disproportionately affected by the climate issue. A gender-responsive approach to both climate change resilience and economic resilience within the agricultural sector is critical for addressing women's increased vulnerability and empowering them in the face of climate change.

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