Central Research Institute for Dryland Agriculture
Indian Council of Agricultural Research

Climate-Smart Agriculture Technologies and Practices in India

Consortium for Scaling-up Climate Smart Agriculture in South Asia (C-SUCSeS) Project
(IFAD Grant No. 2000001968)

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SAARC Afghanistan Bangladesh Bhutan India Maldives Nepal Pakistan Sri Lanka

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SAARC

SAARC Agriculture Centre (SAC)

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This book 'Climate-Smart Agriculture Technologies and Practices in India' contains the climate-smart agriculture (CSA) technologies and practices of India produced as an output of the inventory of CSA technologies conducted by the National Focal Point of C-SUCSeS project of India and the associates working under the Central Research Institute for Dryland Agriculture (CRIDA), and Indian Council of Agricultural Research (ICAR). The CSA technologies and practices in this publication are those of the authors gathered from various sources and do not imply any opinion whatsoever on the part of SAC.

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Foreword

South Asia is one of the most vulnerable regions to climate change as much of the population depends on agriculture for livelihood. It is estimated that South Asia may lose nearly 2% of its GDP by 2050 and a loss of nearly 9% by 2100 in a business-as-usual scenario due to climate change. Currently, South Asia is home to more than a quarter of the world's hungry and undernourished people and needs to double its food production to feed the burgeoning population, expected to reach 2.68 billion by 2050. Studies have shown negative impacts of climate change on people's livelihoods and well-being, such as water supply, food production, human health, availability of land, and ecosystems impacting human capital development and productivity growth which are critical for sustainable development.

Climate resilient agriculture is an integrated approach that can address the challenges of food security and climate change is increasingly being promoted in South Asia with significant promising outcomes. India has taken up several initiatives to minimize the impact of climate change and to promote climate-resilient agriculture. Indian Council of Agricultural Research (ICAR) has initiated a network project i.e., National Innovations on Climate Resilient Agriculture (NICRA) to enhance the resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. The National Mission for Sustainable Agriculture (NMSA) promotes climate-resilient farming practices, soil health improvement, organic farming, agroforestry, etc. which aim at productivity improvement, enhancing resilience, reducing greenhouse gas emissions, and ensuring food security in changing climate.

The initiatives being taken up in India by the National Agriculture Research and Extension system have led to the development of several location-specific resilient technologies for various production systems in the country and for various climatic stresses, which are similar in the SAARC region. Several of these technologies were also tested under on-farm and found to be promising. About 50 such promising technologies are compiled in this publication, which can be taken up in similar environments in South Asia. Details of technologies are presented comprehensively.

I believe the book is of immense use for various stakeholders promoting climate-resilient agriculture practices in the region and can contribute towards the sharing of information, technologies, and adoption benefiting farmers in the region.

(Himanshu Pathak)

22nd September, 2023
New Delhi

Preface

Climate change and variability have become significant challenges affecting global agricultural production. These changes manifest through rising temperatures, unpredictable rainfall patterns, rising sea levels, and increased occurrences of extreme weather events like droughts, floods, cyclones, heat waves, cold waves, and hailstorms. Additionally, there is an uptick in biotic stresses that threaten food production and the livelihood security of communities. Vulnerable regions, including countries like India, face the brunt of these climatic uncertainties, especially farmers and local communities.

In response to these challenges, Climate-Smart Agriculture (CSA) has emerged as a comprehensive approach to address the adverse impacts of climate change. CSA aims to increase agricultural productivity, reduce greenhouse gas emissions, and adapt the food production system to changing climatic conditions. A key aspect of CSA technologies is their focus on minimizing the impact of climate-related stresses without compromising crop yields. In India, numerous ongoing programs have identified promising technologies within the National Agriculture Research and Extension System that can help mitigate the impact of various climatic stresses. These technologies have been field-tested through initiatives such as the National Innovations in Climate Resilient Agriculture (NICRA), Climate Change, Agriculture, and Food Security (CCAFS), and various other government and development organizations. The evidences of the performance of these technologies are readily available.

This publication compiles these promising Climate-Smart Agriculture (CSA) technologies that have demonstrated their effectiveness in smallholder farming situations. It provides detailed information about these technologies, including their performance during both stress and normal years, profitability, critical input requirements, and more. The publication also suggests potential pathways for scaling up the adoption of these promising technologies, such as integrating them into existing development programs, forging partnerships with various development institutions, industry collaborations, and encouraging entrepreneurship. The promising CSA technologies are categorized into knowledge-smart, weather-smart, water-smart, nutrient-smart, carbon-smart, and energy-smart solutions. The publication discusses the potential benefits of adopting these technologies, including increased productivity, enhanced adaptation to climate change, reduced greenhouse gas emissions (mitigation), and the promotion of sustainable development. Some of the natural resource management technologies are particularly crucial for improving water availability in the landscape, creating a foundation for the success of other crop and animal-related technologies.

It's important to note that the suitability of these promising technologies varies by location and crop type, and thus, their scalability depends on their compatibility with specific agricultural systems. This publication is intended to serve as a valuable resource for various stakeholders in India and the SAARC region, aiding in the dissemination and adoption of climate-smart technologies to tackle the challenges posed by climate change in agriculture.

Authors

Acknowledgments

The Consortium for Scaling-up Climate Smart Agriculture in South Asia (C-SUCSeS) project has a primary goal of expediting the identification and expansion of viable Climate-Smart Agriculture (CSA) interventions through national policies and programs. This is achieved by establishing efficient mechanisms for knowledge sharing, policy dialogues, and cooperation among the SAARC (South Asian Association for Regional Cooperation) countries. In India, the program operates in four distinct locations: Dhubri (Assam), Bathinda (Punjab), Almora (Uttarakhand), and Kurnool (Andhra Pradesh). These locations represent the Rice-Rice, Rice-wheat, the Himalayan, and the rainfed systems, respectively.

A valuable CSA inventory has been compiled, comprising promising technologies tailored for smallholders. This inventory serves multiple purposes, including the validation of technologies through participatory research in selected locations and the development of strategies for scaling up CSA technologies using various approaches. The knowledge and experiences gained from this project will be shared with SAARC member countries to facilitate cross-learning and provide policy support.

The project owes its success to the guidance and support of Dr. Himanshu Pathak, Secretary of DARE (Department of Agricultural Research and Education) and Director General of ICAR (Indian Council of Agricultural Research), as well as Dr. Trilochan Mohapatra, Former Secretary of DARE and DG-ICAR. Dr. S K Chaudhari, Deputy Director General (NRM), has played a crucial role by offering continuous encouragement and advice during program implementation. The constant support of Dr. Md. Baktear Hossain, Director of the SAARC Agriculture Centre (SAC) in Dhaka, has been invaluable in ensuring the success of the program in South Asia. Mr. Kinzang Gyeltshen, Regional Programme Coordinator, has demonstrated unwavering perseverance and support in project implementation.

Acknowledgments extend to the guidance and financial support from various institutions, including the SAARC Agriculture Centre (SAC), International Food Policy Research Institute (IFPRI), International Fund for Agricultural Development (IFAD), and SAARC Development Fund (SDF), all of which have been instrumental in the program's implementation. Lastly, heartfelt gratitude goes out to the farmers who have embraced resilient practices, contributed to their dissemination, and placed their trust in the program.

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Contents

List of Table

List of Figures

Acronyms

ATARI	Agricultural Technology Application Research Institute
CRIDA	Central Research Institute for Dryland Agriculture
CSA	Climate Smart Agriculture
etc	Etcetera
GDP	Gross Domestic Product
GHG	Green House Gases
i.e.	That is
ICAR	Indian Council of Agricultural Research
KVK	Krishi Vigyan Kendra
MSL	Mean Sea Level
NICRA	National Innovations on Climate Resilient Agriculture
PAU	Punjab Agricultural University
PSB	Phosphate Solubilising Bacteria
Viz	Such as

1. Introduction

1.1 Overview of the agricultural scenario in India

Indian agriculture serves as the cornerstone of the country's economy, with approximately 54.6% of the population dependent on it, a notable decrease from 75% during India's independence in 1947. Over this period, agriculture and related industries have consistently contributed around 18% to India's GDP (Annual Report, 2021). However, despite this significant role, resource availability per capita in agriculture remains roughly 4-6 times lower than the global average. This scarcity is further exacerbated by increasing population pressure and the conversion of arable land into non-agricultural uses.

In India, out of a total geographical area of 329 million hectares (mha), roughly 139 mha are currently under cultivation, with a cropping intensity of 143% (Annual report, 2021). Remarkably, around 55% of the total net cultivable area consists of rainfed. India's agricultural sector has evolved from a food-deficient to a food-exporting nation primarily due to science-led innovations, resulting in a multifold increase in agricultural production from 135 million tons in 1950/51 to over 1300 million tons in 2021/22. This remarkable growth has occurred despite mounting abiotic and biotic stresses and deteriorating natural resources.

India's agricultural output is sufficient to sustain approximately 18% (1.38 billion) of the world's population, making it the second-largest producer of wheat and rice globally. Food grain production has surged from a mere 51 million tons (Mt) in 1950/51 to 314 million tons during 2021-22, which is 23.80 million tons higher than the previous five-year average. Record production has been observed for rice, maize, pulses, oilseeds, gram, rapeseed, mustard, and sugarcane. The Indian agricultural sector has grown at an average annual rate of 4.6% in the last six years, albeit at a slightly reduced rate of 3.0% in 2021-22 compared to 3.3% in 2020-21.

Over the four decades since the inception of the Green Revolution in the late 1960s, India has made significant strides in agriculture. This progress has resulted in food self-sufficiency, reduced poverty, and economic transformation for millions of rural families, effectively ending widespread hunger and starvation. However, the industry began to face challenges in the mid-1990s, marked by a slowdown in output growth, stagnant or decreasing farmer incomes, and agricultural distress. Climate change has further exacerbated these issues, leading to land and groundwater degradation and a decline in total factor productivity. To meet the demands of the growing population by 2050, there is an urgent need to double agricultural productivity through efficiency-mediated improvements.

Indian agriculture faces several pressing issues, including the declining average size of land holdings, decreasing from 0.725 hectare in 2003 to 0.592 hectare in 2013 and further to 0.512 hectare in 2019. Moreover, approximately 36.5% and 23.4% of the land area are deficient in plant-available zinc and boron, respectively. The need to increase food production substantially, given the rising population and income levels, is evident. Rainfed agriculture covers 50% of India's area and contributes to 40% of the country's food production. In many districts, yields fall below the national average, leaving ample room for improvement. For instance, in the case of rainfed rice, which accounts for 55%

of the total rice area, the average yield stands at approximately 1 ton per hectare, with high-yielding varieties adopted to only a limited extent (32%), and the achievable yield is around 2500 kg/ha.

To address these challenges and revive the agricultural sector, the adoption of climate-smart agriculture (CSA) technologies becomes crucial. CSA offers a wide range of prospects to mitigate the impact of climate change and improve agricultural sustainability.

1.2. Impact of climate change on agriculture

Agriculture stands as one of the most vulnerable sectors to the impacts of climate change. Globally, the agricultural sector faces enormous challenges in meeting the demands for food, energy, and other agricultural products for a growing and diversifying population. The effects of climate change on crop yields can be severe, potentially leading to yield reductions of up to 60%, with grain protein content expected to decrease by 1.1% in wheat (Asseng et al., 2019). Climate change and variability are anticipated to reduce global crop production by 2% - 6% on average (IPCC, 2014), with projected yield declines of 6.0% for wheat, 3.2% for rice, 7.4% for maize, and 3.1% for soybeans (Zhao et al., 2017). The escalating global warming poses an extreme risk of dryland water scarcity and food supply instability. The current global warming level of 1.5°C is linked to increased desertification, land degradation, and adverse impacts on food production and supply systems. Land use contributes significantly to global greenhouse gas emissions, including CO_2 emissions from deforestation, CH_4 emissions from rice cultivation and ruminant livestock, and N_2O emissions from fertilizer use.

Droughts are a complex and severe climate-related hazard that affects large areas around the world each year, resulting in significant losses to economies, environments, and societies. India, with its monsoon-dependent agriculture, is particularly susceptible to frequent droughts, leading to substantial economic and environmental losses. Various types of droughts, such as late monsoon onset, early withdrawal, and terminal droughts, severely impact rainfed agriculture. Specific regions highly vulnerable to drought include Western Rajasthan, parts of Haryana and Punjab, Bundelkhand in Uttar Pradesh, Marathwada in Maharashtra, Southern Bihar, Madhya Pradesh, Southern Gujarat, Rayalseema in Andhra Pradesh, and Karnataka (Bhadwal et al., 2007). Changes in precipitation patterns could result in economic activity and livelihood losses in arid and semi-arid regions.

Floods, caused by high rainfall events and waterlogging, can lead to submergence and anoxic conditions that adversely affect crop growth and yields. Flash floods can wash away or destroy entire agricultural areas and crops. India has experienced substantial crop losses, affecting about 8.5% of the total gross cropped area (18.2 million hectares) due to floods from 2017-2019 (Shagun et al., 2021). The intensity of extreme floods is on the rise, impacting areas that were not historically flood-prone. States like Assam, Bihar, and Uttar Pradesh are frequently affected, with incidents also occurring in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Odisha, Maharashtra, Chhattisgarh, Madhya Pradesh, and Rajasthan due to excessive rainfall combined with heavy rainfall within a short period.

Heatwaves are becoming more frequent and intense in India, negatively impacting crops and various agricultural sectors, including dairy, poultry, and fisheries. Low water availability compounded by heatwaves has significant implications for food security. These events can lead to drinking water shortages for humans and livestock and the drying of long-established horticultural orchards. India and its neighboring countries experienced a severe and prolonged heatwave from mid-May to mid-June in 2019. The heatwave in 2022 also had significant impacts on agriculture, horticulture, and animal systems. Mitigating the effects of climatic stresses is crucial due to their influence on food production and livelihood security.

Extreme events like storms, cyclones, and landslides are increasingly affecting South Asian countries due to temperature and rainfall variations. Destructive cyclones have severely impacted millions of people worldwide, with the super cyclone in 1999 in Orissa causing extensive loss of life and property (Ahluwalia and Malhotra, 2006). Similarly, the coastal state of Andhra Pradesh experienced significant damage during the Hud-Hud cyclone in 2014.

Melting glaciers in the Himalayan regions pose future challenges for India. Rapid glacier melting due to rising temperatures threatens the freshwater supply, with implications for survival (Bajracharya et al., 2007). Satellite data reveals alarming rates of retreat, with the Gangotri Glacier retreating more than three times faster in the past 30 years compared to the previous 200 years (Rao, 2007).

1.3. Summary of CSA technologies and practices in India

Climate change is indeed a significant threat to the farming community, and addressing its impact is crucial for sustaining agriculture. To mitigate the effects of various climatic vulnerabilities such as drought, floods, heatwaves, cold waves, etc., Climate-Smart Agriculture (CSA) technologies have been demonstrated on farmers' fields. CSA encompasses a range of approaches that aim to adapt agriculture to changing climatic conditions and make it more resilient. These technologies and practices fall into several categories:

1. **Natural Resource Management Technologies:**
    - **Soil and Water Conservation Technologies:** These practices help retain soil moisture and prevent soil erosion. Techniques may include contour farming, terracing, and the use of cover crops.
    - **In-Situ Moisture Conservation Practices:** These methods focus on retaining moisture within the soil, reducing evaporation, and enhancing water availability to crops. Examples include mulching and reduced tillage.
    - **Rainwater Harvesting:** Capturing and storing rainwater for agricultural use during dry periods helps in maintaining water availability for crops.
    - **Groundwater Recharge:** Techniques like constructing percolation tanks and recharge pits help replenish underground aquifers, ensuring a more stable water supply.

2. **Crop Production Technologies:**
   - **Climate-Resilient Crops:** Developing and cultivating crop varieties that are tolerant or resistant to drought, floods, pests, and diseases can help ensure stable yields despite changing weather conditions.
   - **Crop Diversification:** Growing a variety of crops can reduce the risk associated with climate-related stresses, as different crops may respond differently to adverse conditions.
   - **Intercropping:** Planting multiple crops in close proximity can provide benefits such as improved soil health, pest management, and better resource utilization.
   - **High-Value Cropping:** Focusing on crops with higher market value can enhance farmers' income and provide a buffer against climate-related losses.
   - **Protected Cultivation:** Greenhouses and other protected cultivation methods shield crops from extreme weather conditions and pests, allowing for year-round production.
   - **Improved Nutrient Management Strategies:** Precision nutrient management ensures that crops receive the nutrients they need for optimal growth, which can be particularly important during periods of stress.
   - **Tillage Practices:** Implementing reduced or no-till farming methods can improve soil structure, conserve moisture, and reduce erosion.

3. **Livestock Production Technologies:**
   - **Improved Livestock Breeds:** Breeding programs can develop livestock breeds that are more resilient to heat, drought, and diseases.
   - **Improved Feed and Fodder:** Developing nutritious and climate-resilient feed options ensures the health and productivity of livestock.
   - **Protective Shelter:** Providing shelter for livestock can protect them from extreme weather conditions, ensuring their well-being.

The adoption and implementation of these CSA technologies and practices can enhance the resilience of the farming community to climate change impacts. By promoting sustainable agricultural practices that conserve resources and adapt to changing conditions, CSA contributes to the long-term food security and livelihoods of farmers.

2. Purpose of CSA Inventory

The Climate Smart Agriculture (CSA) inventory provides a concise overview of CSA technologies and practices available in the country to mitigate the adverse impacts of climate change on agriculture. It serves as a valuable resource by identifying and compiling the best CSA technologies for smallholders from various sources. This inventory plays a critical role in the agricultural sector by facilitating the validation of these technologies through participatory research in identified locations and conducting cost-benefit analyses.

Furthermore, the development of strategies for scaling up CSA technologies, in conjunction with government programs, is essential. Such strategies enable stakeholders and policymakers to take effective steps towards wider adoption and implementation of these technologies, ultimately strengthening the resilience of agriculture to climate change.

A fundamental aspect of successful agricultural development in the context of climate change is ensuring that investments are underpinned by robust data regarding past and future climate risks. This data is crucial for promoting agricultural practices that are not only sustainable but also transformative in the face of climate variability and change.

Central to these efforts is the concept of climate resilience. In this context, resilience refers to an agricultural system's capacity to anticipate, prepare for, adapt to, absorb, and recover from the impacts of climate change and extreme weather events. Resilience-building can be achieved through the implementation of both short- and long-term climate mitigation and adaptation measures. Additionally, it requires transparent and inclusive participation from a wide range of stakeholders and actors in decision-making and management processes.

By emphasizing climate resilience and promoting the uptake of CSA technologies, the agricultural sector can better address the challenges posed by climate change and work towards a more sustainable and resilient future for agriculture and food security.

3. Methodology of CSA Inventory

Literature Review: In the pursuit of identifying climate-smart agricultural (CSA) technologies suited for India, an exhaustive and comprehensive literature review was meticulously undertaken. This encompassed a wide spectrum of sources, spanning published research papers to unpublished documents and grey literature. The aim was to reveal a rich array of both established and emerging CSA technologies tailored to the unique agricultural landscape of India.

Consultation: Information was obtained from research institutions about the promising CSA technologies developed thus far and also validated under on-farm situations. The pertinent CSA technologies were cherry-picked suiting to various agro-climatic zones across India. Inputs were also obtained from individual scientists from various agroecological regions of the country, distinguished scientists representing the NARIs, domain specialists from state-level agricultural departments, and visionary farmers who serve as the torchbearers of innovative practices were obtained. Following comprehensive dialogues and interdisciplinary exchange of ideas, following thorough deliberations, a curated selection of CSA technologies was done for each distinctive agro-geographic region.

In summary, the methodology employed in India's quest to identify CSA technologies echoes a symphony of intellectual rigor, interdisciplinary collaboration, and an enthusiastic commitment to enhancing agricultural resilience in the face of climate challenges. This harmonious approach endeavors to cultivate innovative solutions tailored to the multifaceted tapestry of India's agricultural expanse.

4. Concept and Pillars of CSA

Climate Smart Agriculture (CSA) is an approach that aims to address the challenges posed by climate change while simultaneously promoting sustainable agricultural practices (FAO, 2010). The key components of CSA are as follows:

1. **Sustainably Increasing Agricultural Productivity and Incomes:**
    - With the global population expected to reach 9 billion by 2050, there is an urgent need to provide nutritious food for all while using existing natural resources sustainably.
    - Increasing crop and animal productivity is essential to meet the growing demand for food. This is especially important for the 75% of the world's poor who depend on agriculture for their livelihoods.
    - Improved productivity not only enhances food security but also boosts the incomes of farmers, contributing to poverty reduction.
2. **Adapting and Building Resilience to Climate Change:**
    - Agriculture is highly vulnerable to the impacts of climate change, including droughts, floods, cyclones, and other extreme weather events.
    - CSA focuses on reducing vulnerability to climate-related risks and shocks by adopting climate-resilient technologies and practices.
    - Building resilience in agriculture involves enhancing the capacity of farmers and farming systems to adapt to changing climate conditions and recover from long-term stresses.
    - Climate-resilient practices not only contribute to agricultural resilience but also lead to increased production, food security, higher farmer incomes, and overall livelihood development.
3. **Reducing Greenhouse Gas Emissions:**
    - Agriculture, particularly cropland, is a significant source of greenhouse gas emissions, accounting for approximately 8% of global anthropogenic emissions of methane (CH_4) and 32% of nitrous oxide (N_2O).
    - To limit global warming to below 1.5°C and mitigate the effects of climate change on agriculture, it is crucial to reduce agricultural GHG emissions.
    - CSA promotes the adoption of climate-smart technologies and practices that help mitigate emissions. This includes reducing emissions per kilogram of food produced, preventing the clearing of agricultural land, and exploring methods to remove carbon from the atmosphere (Anonymous, 2021).

In summary, CSA represents a holistic approach to agriculture that seeks to address the challenges posed by climate change while ensuring sustainable food production, enhancing resilience, and reducing greenhouse gas emissions. By implementing CSA practices and technologies, agriculture can play a pivotal role in building a more sustainable and climate-resilient future.

Portfolio of CSA Inventory

The categorization of Climate Smart Agriculture (CSA) technologies into various segments based on their potential to withstand climate change is a crucial step in addressing the challenges posed by a changing climate (Nayak et al., 2020). Here's an overview of the different CSA categories:

5. **Weather-Smart Technology:** The increasing frequency of extreme weather events, such as floods and droughts, poses a significant threat to agricultural productivity and farm incomes. Weather-smart technologies focus on mitigating these risks and include:
   - Weather forecasts and early warnings
   - Weather-based crop agro-advisory
   - Crop insurance
   - Adjustments in planting times
   - Stress-tolerant crop varieties
   - Diversified cropping systems
   - Off-farm income sources
6. **Water-Smart Technology:** Climate change is expected to result in increased water stress, affecting agriculture, which is a major user of freshwater resources. Water-smart practices in agriculture encompass:
   - On-farm and off-farm irrigation management
   - Rainwater harvesting
   - Groundwater recharge
   - Watershed management
   - Participatory irrigation management
   - Techniques like aerobic rice and the System of Rice Intensification (SRI)
   - Improved irrigation methods (e.g., check basin, drip irrigation, sprinkler irrigation)
   - Soil moisture conservation practices (e.g., mulching, contour bunding)
7. **Nutrient-Smart Technology:** The modern agricultural practices that rely on high-yielding crop varieties often demand substantial nutrient inputs. Nutrient-smart technologies aim to optimize nutrient use efficiency and reduce greenhouse gas emissions. Examples include:
   - Integrated nutrient management
   - Real-time and site-specific nitrogen management
   - Green manuring
   - Organic manures
   - Growing legumes in rotations
   - Biofertilizers

8. **Carbon-Smart Technology:** Agricultural practices that either enhance carbon sequestration in the soil-plant-microbe-human continuum or minimize the release of carbon gases into the atmosphere are considered carbon-smart (CS). Examples include:
    - Minimum tillage (MT)
    - Zero tillage (ZT)
    - Crop residue management
    - Agroforestry
9. **Energy-Smart Technology:** Energy efficiency is linked to greenhouse gas emissions, making energy-smart technologies important. These technologies aim to improve productivity with higher energy use efficiency. Examples include:
    - Conservation agriculture (CA)
    - Zero tillage (ZT)
    - Solar-operated machinery (e.g., solar pumps, solar sprayers)
10. **Knowledge-Smart Technology:** New knowledge plays a vital role in reducing climate-related risks and enhancing farmers' ability to adopt CSA practices on a large scale. Examples include:
    - Cropping system intensification
    - Integrated farming systems
    - Ecology-specific crop varieties
    - Information and communication technology (ICT) in extension services
    - Climate-smart villages
    - Village knowledge centers (VKCs)

To effectively target CSA practices, it's essential to consider the specific climate-stressed regions within the country. For instance:

- Drought-prone regions like Maharashtra, Karnataka, Andhra Pradesh, Telangana, Rajasthan, and Gujarat can benefit from the scaling up of drought and heat-tolerant CSA technologies.
- Flood-prone areas, including Assam, Meghalaya, Sikkim, Uttarakhand, parts of Uttar Pradesh, and Kerala, should focus on developing and implementing flood-tolerant crop technologies.

By tailoring CSA technologies to suit the unique climate challenges of each region, agriculture can become more resilient and sustainable in the face of climate change.

5. Brief Description of Individual Technology

Individual technologies are grouped into Natural Resource Management technologies, Crop production technologies, and Livestock production technologies and are further explained in brief.

Climate Resilient Natural Resource Management Technologies

1. Rainwater harvesting

Rainwater harvesting through the construction of permanent check dams is a crucial technology introduced by ICAR-CRIDA in Hyderabad at several locations in the country. This technology addresses water scarcity, enhances agricultural productivity, and builds resilience to climate change by capturing and storing rainwater. Here are key points about this technology:

Basic Features:

- Permanent check dams are built across streams or rivers to impound rainwater during rainfall events.
- The specifications of check dams can vary depending on project requirements and site conditions. They are generally low in height (1-5 meters) and can span from a few meters to several hundred meters in length.

Categorization of Technology:

- This technology primarily falls under the "water-smart" category of climate-smart agriculture, focusing on efficient and sustainable water resource management in agriculture.

Fig. 1 *Construction of check dam in Chitrakoot district of Bundelkhand region*

Suitability and Potential:

- This technology is suitable for regions with relatively high rainfall, especially in water-constrained areas like arid and semi-arid regions.
- The adaptability rate varies depending on factors such as water scarcity levels, rainfall patterns, and existing water management practices.
- Rainwater harvesting through check dams provides smallholder farmers with reliable access to water, enabling them to expand cropping seasons, diversify crops, and increase yields.

Benefits:

- Enhances water availability during dry spells, benefiting both kharif and rabi seasons.

- Replenishes groundwater levels, benefiting bore wells and open wells in the vicinity.
- Enables cultivation of rabi crops, resulting in higher yields and income.

Challenges:

- High initial investment required for construction.
- Demands technical expertise for identifying suitable locations, designing structures, and specifying construction details.

Scaling Up:

- The multiple benefits associated with this technology make it crucial for minimizing the impact of drought.
- Scaling up this technology would require greater investments in constructing check dams, which could come from government, corporate, or other sources.

Evidence of Benefit:

The construction of a check dam in Titihara village, Chitrakoot district, was carried out under the Technology Demonstration Component of the National Innovations in Climate Resilient Agriculture program. The check dam had the following specifications: it measured 45 meters in length, 4 meters in width, and 2 meters in height. The primary purpose of this check dam was to address irrigation challenges in the area, where the main sources of irrigation relied on nalas (small streams) and wells. The check dam was designed to capture and store runoff water, which could then be used for irrigation during both the kharif (monsoon) and rabi (winter) cropping seasons (Table 1).

Overall, the positive outcomes of constructing this check dam were as follows: the construction of the check dam in Titihara village demonstrated the potential of water management interventions to improve agricultural productivity, support sustainable groundwater recharge, and enhance the livelihoods of local farmers, especially in regions dependent on nalas and wells for irrigation.

Table 1 Impact of check dam in Titihara village of Chitrakoot district

Intervention	Crops		Yield (q/ha)		Net income (Rs/ha)	
Construction of check dam	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
	Green gram	Toria	12.1	15.0	53,650	25,000
	Sesame	Wheat	13.6	29.5	51,600	24,000
Farmers' Practice without check dam	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
	Pigeon pea	Fallow	6.5	-	14,000	-
	Jowar	Fallow	8.5	-	3,250	-

Rainwater harvesting through the construction of permanent check dams offers a sustainable solution to address water scarcity and boost agricultural productivity. However, overcoming the initial investment and technical challenges will be key to expanding its adoption and impact across regions facing water constraints.

Reference

Government of India, Ministry of Water Resources, Central Ground Water Board. (2017). *Manual on Artificial Recharge of Ground Water.*

2. Farm ponds for life-saving irrigation

Farm ponds, a technology demonstrated by ICAR-CRIDA in Hyderabad at several locations of the country, play a crucial role in addressing water scarcity, enhancing agricultural productivity, and promoting sustainable farming practices. Here are the key points about this technology:

Basic Features:

- A farm pond is a small-scale water storage facility created within or adjacent to agricultural fields.
- It collects and stores rainwater or runoff water for irrigation during periods of water scarcity.
- The size and capacity of farm ponds depend on local water requirements and availability.
- Proper design includes considerations for pond size, depth, and slope to maximize storage capacity and prevent erosion.
- Depending on soil conditions, a liner or soil sealing may be necessary to prevent excessive seepage.

Categorization of Technology:

- Farm ponds fall primarily under the "water-smart" category of climate-smart agriculture, focusing on efficient water resource management for increased productivity and resilience.

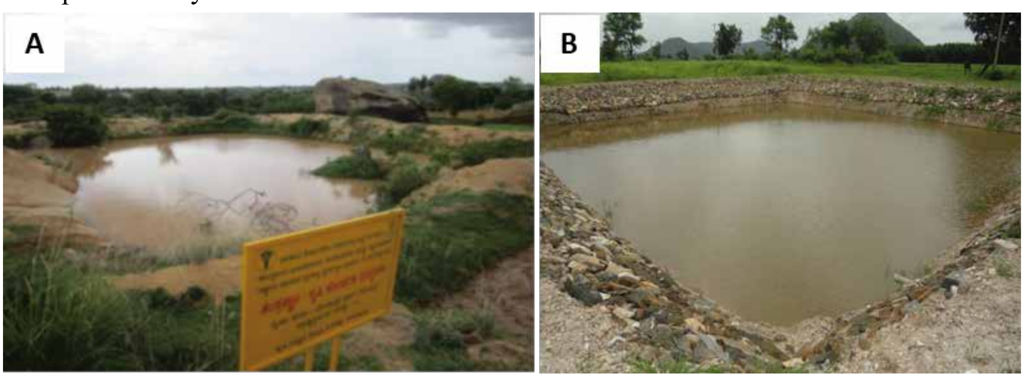

Fig. 2 *Farm Pond at Karnataka (A) and Telangana states (B)*

Suitability and Potential:

- Farm ponds are suitable for regions with erratic rainfall patterns, dry spells, and water scarcity, including arid and semi-arid areas.
- They are also valuable in hilly and sloping lands to capture runoff and prevent soil erosion.

Benefits:

- Enhance water availability for irrigation during dry spells.
- Increase crop yields, reducing vulnerability to water scarcity.
- Facilitate crop diversification, improving food security and income opportunities.
- Serve as valuable water sources for livestock.

Impact and Evidence of Benefit: Farm ponds, as demonstrated in several regions, have yielded tangible benefits with substantial economic returns. For instance, in Sonepur district of Odisha, farm ponds with a capacity of 675 cubic meters were constructed, enabling supplemental irrigation during dry spells. As a result, rice and green gram yields increased by up to 16% and 39%, respectively, compared to areas without irrigation. This translated to additional net returns of Rs. 6,820 and Rs. 4,600 per hectare over traditional farming practices.

In Kendrapara district, farm ponds played a crucial role in improving green gram yields. With supplemental irrigation from farm ponds, farmers achieved yields of 6.0 quintals per hectare, compared to just 4.3 quintals in areas without farm ponds. This translated to net returns of Rs. 14,200 with farm ponds, compared to Rs. 9,600 without them.

Similarly, in Jharsuguda district, farm ponds allowed for the cultivation of tomatoes. With the assistance of farm pond water, tomato yields surged to 428 quintals per hectare, compared to 242 quintals in areas without such facilities. This resulted in additional net returns of Rs. 1,69,000 per hectare compared to traditional practices, which netted Rs. 1,77,000.

Table 2 Drip irrigation for vegetables in different districts of Odisha

Districts	Intervention	Crop	Yield (q/ha)	Net returns (Rs. /ha)
Sonepur	Farm pond	Cauliflower	196	1,04,000
	Without farm pond		153	73,500
Kendrapura	Farm pond	Green gram	6.0	14,200
	Without farm pond		4.3	9,600
Jhaarsuguda	Farm pond	Tomato	428	3,46,000
	Without farm pond		242	1,77,000

These figures illustrate the substantial economic benefits that farm ponds bring to smallholder farmers. By providing access to consistent water sources, farm ponds empower farmers to diversify crops, extend cultivation seasons, and significantly increase their income, ultimately improving their economic well-being.

Challenges:

- High initial investment required for construction and infrastructure.
- Adaptability rates vary depending on local water availability, rainfall, and awareness.
- Limited access to finance can hinder adoption among smallholder farmers.

Scaling Up:

- Overcoming the initial investment barrier requires financial support, possibly through loans, grants, or subsidies.
- Access to technical expertise and extension services can help farmers design, construct, and manage farm ponds effectively.
- Increased awareness of the benefits of farm ponds can encourage their adoption, particularly among smallholders.

Farm ponds are a powerful tool in climate-smart agriculture, enabling smallholder farmers to mitigate the impact of water scarcity and improve their agricultural practices. Scaling up this technology involves addressing financial constraints, providing technical support, and raising awareness among farmers about its potential benefits.

Reference

Mishra, P. K., Rao, K. V., & Padmanabhan, M. V. (2010). Farm pond technology for semi-arid Alfisol region of Telengana in Andhra Pradesh. In *Rainwater Harvesting and Reuse through Farm Ponds: Experiences, Issues and Strategies* (Eds. Rao et al.), CRIDA, Hyderabad, pp. 170-174.

3. Desilting of community ponds

The technology of desilting community ponds was demonstrated by the ICAR-Central Research Institute for Dryland Agriculture (ICAR-CRIDA), located in Hyderabad, India. It is a methodical approach aimed at restoring and enhancing the water storage capacity of community ponds.

Basic Features of the Technology: Desilting community ponds involves the systematic removal of accumulated sediment, debris, and vegetation from the bottom of ponds. This process helps restore the pond's original storage capacity, which is crucial for water resource management. The techniques used for desilting can vary and are often tailored to the specific characteristics of each pond. Common methods include mechanical excavation, which employs excavators or dredgers, and manual labor, using shovels or buckets. Sometimes, a combination of both techniques is used for optimal results.

Fig. 3 *Community Pond before desilting (A), and after desilting (B)*

CSA Category: Desilting community ponds falls under the category of "Water Smart and Nutrient Smart Technology." This categorization highlights its focus on efficiently managing water resources and improving nutrient availability for agricultural purposes.

Intention/Focus: The primary intention of this technology is to augment the water storage capacity of community ponds. Its main focus is on ensuring a reliable water supply for agricultural irrigation, particularly during drought periods. By removing sediment and restoring ponds, it contributes to more sustainable agricultural practices.

Benefits: The benefits of desilting community ponds are substantial. They include:

- **Increased Water Storage Capacity:** Desilted ponds can store a larger volume of water, which is crucial during periods of low rainfall or unpredictable weather due to climate change.
- **Improved Agricultural Practices:** The additional water availability supports sustained irrigation, leading to enhanced crop growth, diversification, and higher yields.
- **Food Security:** Greater water availability positively impacts food security by supporting increased crop production.
- **Income Generation:** Enhanced agricultural productivity can lead to higher income for smallholder farmers.

Drawbacks/Limitations: Despite its advantages, desilting community ponds has some limitations, including:

- **Limited Effectiveness in Prolonged Water Scarcity:** In areas with chronic water scarcity, desilting alone may not fully meet irrigation demands during extended droughts.
- **Resource Accessibility:** Successful implementation relies on access to machinery, equipment, labor, and financial resources.
- **Dependence on Awareness and Participation:** The technology's success is contingent on farmer awareness and active involvement, which can be influenced by education and outreach efforts.

Suitability of the Technology:

Geographical Area: Desilting community ponds is suitable for regions with consistent or periodic water availability, either through rainfall or other water sources. It is especially relevant in areas prone to water scarcity or erratic rainfall patterns.

Cropping Pattern/Season: This technology is applicable throughout the cropping season, as it ensures a reliable water source for irrigation whenever needed.

Agro-ecosystem: Desilting is effective across various agro-ecosystems, making it versatile and adaptable to different agricultural environments.

Adaptability Rate: The overall adaptability of desilting community ponds is influenced by farmer awareness and understanding of its benefits. Training programs and awareness campaigns can significantly increase its acceptability. Farmers who recognize the positive impact of desilting on water storage capacity and agricultural productivity are more likely to embrace this technology.

Impact and Suitability to Smallholder Farmers and Women:

Desilting community ponds has a notable impact on smallholder farmers and women by:

- **Enhancing Agricultural Practices and Livelihoods:** The technology ensures a reliable water source for irrigation, directly benefiting agricultural practices and overall livelihoods.
- **Ensuring Reliable Water Sources for Irrigation:** This increased water availability supports smallholder farmers in sustaining their agricultural activities, ultimately leading to improved crop production.
- **Improving Crop Production, Food Security, and Income:** Smallholder farmers can irrigate their fields effectively, resulting in improved agricultural productivity. Increased water availability supports crop growth, diversification, and yield improvement, positively impacting food security and income generation.

Benefits/Success Story:

In specific villages such as D. Nagenahalli, Siddanuru, Mahalingapur, and Bilakundi, the impact of desilting community ponds is quantified as follows:

- **Increased Storage Capacity:** Desilting increased the storage capacity of village ponds up to 156,500 m^3 in D. Nagenahalli, 7,783 m^3 in Siddanuru, 4,392 m^3 in Mahalingapur, and 4,500 m^3 in Bilakundi.
- **Groundwater Level Rise:** The technology resulted in a significant increase in groundwater levels by 3 to 5 meters.
- **Direct Benefits to Farmers:** Approximately 188 farmers in these villages directly benefited from desilting initiatives.
- **Crop Yield Increases:** During dry spells, crop yield increases ranged from 25% to 54% when compared to un-irrigated plots.
- **Additional Net Returns:** Notable additional net returns per hectare were recorded, such as Rs. 29,400 per hectare for groundnut.

Table 3 Community ponds for supplemental irrigation in D. Naganahalli, Karnataka

District	Intervention	Crop	Crop yield (q/ha)	Net return (Rs./ha)
Tumkur	Desilting community pond	Groundnut	17	21870
	No desilting community pond		11	13980
Davanagere	Desilting community pond	Maize	58	59780
	No desilting community pond		39	40500
Gadag	Desilting community pond	Green gram	7	31240
	No desilting community pond		5	12580
Belagavi	Desilting community pond	Soybean	30	28900
	No desilting community pond		24	20850

Enabling Factors: Successful scaling up of desilting community ponds requires several factors:

- **Financial Support:** Government funding, grants, and support from development agencies can cover the expenses associated with machinery, equipment, labor, and other implementation costs.
- **Capacity Building:** Ongoing training and capacity-building programs are essential for ensuring the sustainable adoption of this technology.
- **Institutional Coordination:** Effective collaboration among various stakeholders, including government agencies, NGOs, local communities, and technical experts, is crucial.
- **Community Empowerment:** Active participation of the local community from the planning stage fosters a sense of ownership and sustains desilting initiatives.
- **Challenges:** Challenges in scaling up desilting community ponds include:
- **Prolonged Water Scarcity:** In some areas, the technology may face limitations in addressing the challenges posed by prolonged water scarcity.
- **Resource Accessibility:** Access to necessary resources, including machinery, equipment, labor, and funding, can be a hurdle.
- **Farmer Awareness and Participation:** Success hinges on farmer awareness and active participation, which may require education and outreach efforts.
- **Supportive Policies and Institutional Frameworks:** The presence of supportive policies and institutional frameworks is crucial for effective implementation and scaling up.

Desilting community ponds, classified as a "Water Smart and Nutrient Smart Technology," has emerged as a valuable solution for enhancing water storage capacity and promoting sustainable agricultural practices. While the technology offers significant benefits for smallholder farmers and women, its successful implementation relies on various factors, including farmer awareness, financial support, and community involvement. Addressing challenges and scaling up desilting initiatives necessitates collaborative efforts among stakeholders, ultimately contributing to improved agricultural practices, food security, and income generation.

Reference

NITI Aayog. (2022). *Standard Operating Procedure for Restoration and Rejuvenation of Ponds.* Government of India.

4. Sandbag check dams

Sandbag check dams are temporary structures constructed using sandbags or geotextile bags filled with sand or soil. They are typically used in water management and soil conservation practices to control erosion, retain sediment, and manage water flow in rivers, streams, and gullies. These check dams are built by stacking sandbags in a strategic manner across the watercourse, creating a series of small reservoirs that slow down the velocity of water and facilitate sediment deposition. The construction of sandbag check dams involves placing a row of sandbags along the desired alignment of the dam. The bags are tightly packed and stacked in a stepped or pyramid-shaped pattern, ensuring stability and strength. The top of the dam is often covered with additional protective layers such as geotextile fabric or gravel to prevent erosion and enhance longevity.

Fig. 4 *Sand bank check dam at Jharkhand*

The dimensions of a sandbag check dam may vary depending on the specific requirements of the site and the water flow conditions. The height of a sandbag check dam should be determined based on the expected water flow and the desired water level behind the dam. Typical heights can range from a few feet to around 10-15 feet (1-5 meters), but it can be adjusted based on the specific circumstances. The width of the sandbag check dam is determined by the desired stability and strength of the structure. The spacing between individual sandbags is important for stability and effectiveness. Sandbags should be placed in a staggered pattern to create a continuous barrier.

Sandbag check dams for water harvesting are a smart technology demonstrated by ICAR-CRIDA in Hyderabad. By constructing sandbag check dams, water flow can be controlled and managed effectively. These structures help retain water during periods of rainfall or high water flow, increasing water availability and reducing the risk of water scarcity during drought periods.

Fig. 5 *Vegetable cultivation with supplementary irrigation*

Sandbag check dams are most suitable in areas with appropriate soil conditions for bag stability and proper compaction. The soil should have enough cohesion to hold the bags in place and resist erosion. Additionally, the hydrological characteristics of the site, such as the flow rate and sediment load, should be compatible with the intended purpose of the check dam. Sandbag check dams are typically suitable for small to medium-scale applications, such as gully stabilization, erosion control, and temporary water management. They are commonly used in situations where quick and temporary measures are needed, such as emergency flood control or construction site management.

The adaptability rate of sandbag check dams varies depending on the specific region, community, and project context. It can be enhanced by addressing various factors and tailoring the approach to the specific needs, capacities, and preferences of the communities. By incorporating participatory approaches, providing technical support, and demonstrating the benefits, the likelihood of adoption can be increased, leading to wider implementation and utilization of sandbag check dams.

Sandbag check dams could have significant impacts on smallholder farmers, including women, by providing them with various benefits related to water management and soil conservation. Sandbag check dams help in retaining water and slowing down its flow, which increases water availability for irrigation purposes. With enhanced water availability, farmers can irrigate their crops more effectively, leading to improved agricultural productivity and increased crop yields. Sandbag check dams act as barriers that help control erosion and prevent sedimentation in downstream areas. By reducing the speed of water flow, these dams allow sediment to settle behind them, preserving fertile soil and preventing its loss due to erosion. This is particularly beneficial for smallholder farmers who often have limited access to resources for soil conservation.

In Umarani village of Nandurbar, eight high-intensity rainfall events of more than 25 mm per day occurred between June and September in 2018-19. These rainfall events helped harvest water multiple times in the sandbag check dam with a storage capacity of 14,800 m3. The harvested water percolated into the soil, leading to an improvement in the groundwater level by 5 to 10 feet in surrounding wells. Pre-sowing and supplemental irrigation were provided for chickpea crops, resulting in a significant improvement in yield up to 16.25 quintals per hectare, which is 45% more than the farmers' practice (Table 4). The sandbag check dam benefited 20 farmers covering a 10-hectare area in the rabi season.

Table 4 Sandbag Check Dam for Pre-sowing Irrigation for Rabi Crops in Nandurbar District of Maharashtra

Crop	Intervention	Yield (q/ha)	Improvement compared to farmers' practice (%)	Net return (Rs/ha)	B:C ratio
Chickpea	Farmers' practice	11.2	45	38,500	1.4
	Demo	16.3		65,700	2.3

Availability of resources and financing options significantly influence the uptake of sandbag check dams. Access to affordable or subsidized materials such as sandbags, geotextile bags, and locally available fill material is important. Additionally, financial support in the form of grants, loans, or government subsidies can help smallholder farmers overcome financial barriers and implement the technology. Building awareness among communities about the benefits and effectiveness of sandbag check dams is crucial for their uptake. Conducting workshops, training programs, and information campaigns can help educate community members about the technology, its applications, and its potential impact on water management and soil conservation. Involving local communities from the planning stage to implementation and maintenance is essential for successful uptake. Engaging community members in decision-making processes, considering their knowledge and perspectives, and addressing their specific needs and concerns can enhance ownership and increase the likelihood of adoption.

Reference

Kumar, S. (2012). *Sandbag Check Dam – a case of successful mobilization of community resources against climate variability.* Zonal Project Directorate, Zone-II, Kolkata. 22 pages.

5. Compartmental bunding

Compartmental bunding is an effective agricultural land management technique developed/introduced/compiled by the Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary, India. This technique is used to conserve moisture and enhance productivity in arid and semi-arid regions. It involves constructing interconnected compartments or bunds within agricultural fields to control water runoff, prevent soil erosion, and retain rain or irrigation water within the compartments.

Fig. 6 *Compartmental bunding for rabi sorghum in Pune district, Maharashtra*

The primary goal of compartmental bunding is to create micro-watersheds within larger agricultural fields, allowing for improved moisture conservation and utilization. By capturing and holding water within each compartment, it provides a localized water supply for crops, reducing water loss through runoff and evaporation. The construction process involves digging small channels or trenches along the land's contours to define the boundaries of each compartment. The excavated soil is then used to build low earthen bunds or ridges, which serve as physical barriers to trap water within each compartment.

Compartmental bunding aligns with water-smart technology, as it contributes to water conservation by reducing runoff and promoting water infiltration into the soil. Capturing and storing rainwater within compartments increase soil moisture levels and groundwater recharge.

This technique is most suitable for regions with limited water resources or erratic rainfall patterns, where optimizing water availability for crops is crucial. It is most effective on slopes ranging from gentle to moderate, typically recommended for slopes with gradients of up to 5% to 10%, and is best suited for sandy and loamy soils. Constructing compartmental bunds along contour lines helps capture and retain water, preventing downhill flow and promoting soil infiltration. It's particularly beneficial in areas prone to soil erosion, as the bunds act as physical barriers, preserving topsoil and soil fertility.

The adaptability rate of compartmental bunding depends on factors like its effectiveness in addressing specific soil and water conservation needs, alignment with local farming practices, and the availability of necessary resources, machinery, and awareness.

For smallholder farmers and women, compartmental bunding offers several advantages. By ensuring localized water supply for crops, it reduces water stress and enhances crop growth, resulting in increased yields and improved food security. Additionally, it prevents soil erosion, protecting valuable topsoil and supporting sustainable agriculture.

In Jalgaon K.P village of Pune district, Maharashtra, compartment bunding was applied for sorghum cultivation in the rabi season. Different compartment sizes, such as 5x5 m and 10x10 m, were found to be best practices for efficiently managing in-situ moisture content in vertisols. This significantly increased grain yield, water use efficiency, and water productivity. The implementation of compartmental bunds covered a 32 ha area, benefiting 80 farmers in 2018-19. These bunds were constructed in August, enabling the harvest of rainfall and uniform moisture conservation across the land. As a result, sorghum yields in the compartmental fields increased by 34% compared to without compartmental bunding (Table 5).

Table 5 Compartmental Bunding in Pune District of Maharashtra

Crop	**Intervention**	**Yield (q/ha)**	**Improvement compared to farmers' practice (%)**	**Net return (Rs/ha)**	**B:C ratio**
Sorghum	Farmers' practice	8.4	34	7,600	1.4
	Demo	15.7		15,480	1.7

To promote the adoption of compartmental bunding, it's essential to provide information and raise awareness about its benefits and techniques. Training programs, workshops, and extension services can educate smallholder farmers and offer guidance on implementation. Technical support and expertise from extension workers, agricultural agencies, and NGOs are crucial for proper bund construction and contour mapping.

Challenges in scaling up compartmental bunding include land tenure insecurity and fragmented land ownership. Farmers may hesitate to invest in land management without secure land tenure. Additionally, ongoing maintenance and upkeep of bunds are vital for long-term effectiveness, and lack of knowledge, resources, or community engagement in maintenance activities can reduce the technique's impact.

Reference

Patil, S. L., & Nalatwadmath, S. K. (2008). *Compartmental bunding for in situ rainwater conservation in medium to deep black soils.* Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary.

6. Raised bed planting of mustard

Raised bed planting of mustard is an innovative agricultural technique demonstrated by ICAR-CRIDA in Hyderabad. It aims to enhance water use efficiency and optimize crop productivity, with a focus on the widely cultivated oilseed crop, mustard (*Brassica* spp.). This technique involves creating raised planting beds with improved soil structure, enhanced drainage, and reduced water loss, resulting in efficient water utilization and improved crop performance.

Raised Bed Planting Process:

- Raised planting beds: Typically, 15-30 cm tall and 1-1.5 meters wide.
- Formation: Beds are shaped by ridges or mounds with furrows in between.
- Mustard seeds are directly sown on raised beds.
- Cost: Raised bed planter - approximately Rs. 40,000; Field preparation - about Rs. 2,000 per hectare.

Fig. 7 Raised bed planting in mustard in Baghphat and Muzaffarnagar districts

Alignment with Water-Smart Technology:

- Prevents soil erosion by providing defined planting areas with controlled drainage.
- Retains soil nutrients, reducing nutrient loss and enhancing soil fertility.
- Incorporates organic matter (e.g., compost or manure) to improve soil health, water holding capacity, and nutrient availability.

Suitability:

- Limited water resources or frequent drought conditions.
- Poorly drained soils or regions prone to waterlogging.
- Organic farming practices.
- Smallholder farmers with limited land resources.

Benefits:

- Improved water use efficiency.
- Enhanced soil conditions.
- Increased crop productivity.
- Water-saving potential (reduced runoff and evaporation).
- Results: Reduced irrigation frequency, 17-20% savings in irrigation water, reduced thinning and weeding costs, and increased yields (21-22%).

Table 6 Impact of Raised Bed Planting in Baghpat and Muzaffarnagar Districts

Location	Intervention	Yield (q/ha)	Cost of cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)
Baghpat	Flatbed planting	14.8	20,250	52,360	31,860
	Raised bed planting	17.9	19,750	67,650	47,900
Muzaffarnagar	Flatbed planting	16.5	20,700	58,350	37,650
	Raised bed planting	20.2	20,875	71,595	50,720

Promoting Adoption:

- Providing farmers with information and training.
- Educational programs, agricultural extension services, and knowledge sharing.
- On-farm demonstrations and field trials.
- Motivating farmers through positive results.

Challenges:

- Upfront investments in infrastructure and equipment.
- Financial limitations.
- Resistance to change among farmers accustomed to traditional practices.
- Need for training and support to transition to this innovative approach.

Overall, raised bed planting of mustard represents a promising approach to sustainable agriculture, benefiting both smallholder farmers and the environment. It contributes to improved food security, increased income generation, and efficient utilization of water resources, making it a valuable addition to modern agricultural practices.

Reference

Directorate of Research (AGRI) Assam Agricultural University. (2017). *Technical Bulletin on Raised Bed Planter for Kharif Pulse Cultivation in Assam.*

7. Low-cost polyhouse

Technology Developed/Introduced/Compiled by: National Horticulture Board, Ministry of Agriculture, Government of India.

A low-cost polyhouse is a greenhouse structure constructed with affordable materials, designed to create a controlled environment for plant growth while mitigating the impact of extreme weather conditions. These structures are scalable, allowing farmers to maximize land usage efficiently. They are particularly well-suited for cultivating high-value crops like vegetables, herbs, and flowers, where maintaining precise environmental conditions is critical for optimal growth and quality. The approximate cost for constructing a 100 square meter polyhouse is approximately Rs. 7,500.

Fig. 8 *Low-cost polyhouse for vegetable seedlings in Ganjam and Kendrapara districts of Odisha*

Alignment with Weather-Smart Technology: Low-cost polyhouses are classified as weather-smart technology. They serve as a physical barrier, safeguarding crops against adverse weather conditions, pests, and diseases. These structures provide protection from extreme temperatures, frost, wind, hail, and heavy rain, reducing the risk of crop failure and yield loss.

Suitability:

- Scalable for small land holdings.
- Ideal for regions prone to extreme weather conditions (heavy rain, wind, temperature fluctuations).
- Precise environmental control for high-value crops.
- Extended growing season by regulating temperature and preventing frost.
- Effective pest and disease management.

Adaptability and Acceptance:

- Variable based on local context, farming practices, economic conditions, and support systems.

Benefits for Smallholder Farmers:

- Protects against extreme weather events, ensuring consistent yields.
- Extends growing seasons for year-round cultivation and increased profitability.
- Reduces pesticide use through pest and disease control.
- Enhances water use efficiency.
- Empowers women by offering income generation opportunities.

Practical Demonstrations:

- Profitable off-season nursery production in a 50-square-meter low-cost polyhouse.
- Successful cultivation of high-value off-season vegetables during winter, commanding higher market prices.

Promoting Adoption:

- Technical training and knowledge sharing are essential for farmers to understand polyhouse principles, construction, and management.
- Ensuring affordability and availability of construction materials is crucial.
- Providing financial support through subsidies, grants, microcredit, or low-interest loans.
- Offering training programs, extension services, and demonstrations to build technical capacity.
- Addressing socio-cultural factors through community engagement and awareness campaigns to gain acceptance.

Low-cost polyhouses, developed by the National Horticulture Board, Ministry of Agriculture, Government of India, represent a valuable technology for smallholder farmers. They offer protection against extreme weather, extend growing seasons, reduce pesticide use, and empower women in agriculture. Promoting their adoption through training, affordability, and awareness campaigns can significantly benefit both farmers and the agricultural sector.

Reference

National Horticulture Board, Ministry of Agriculture, Government of India. (2011). *Technical Standards for Naturally Ventilated, Fan Pad House, and Shade Net House.*

8. Crop residue mulching

Crop residue mulching is an agricultural technique employed to conserve soil moisture and enhance vegetable production, particularly in hilly regions. It involves covering the soil surface with remnants of previous crops, such as stalks, leaves, and plant materials. In hilly areas, soil erosion and water runoff are prevalent due to the sloped terrain. Crop residue mulching mitigates water loss through evaporation by creating a protective layer on the soil surface. It slows down water runoff, allowing for better soil infiltration and retention of moisture for vegetable crops. This technique enhances soil moisture content, availability of water for crops, moderates soil temperature, and shields vegetable roots from temperature stress. The approximate cost of spreading grass mulch in one hectare is about Rs. 2,000-2,500.

Alignment with Water-Smart and Nutrient-Smart Technologies: Crop residue mulching aligns with both water-smart and nutrient-smart technologies. It shields soil from erosion caused by wind and water, acts as a physical barrier reducing raindrop impact, minimizes surface runoff, and curtails soil nutrient loss. Furthermore, it conserves soil moisture by reducing evaporation.

Fig. 9 *Crop residue mulching for cucumber in HP*

Suitability:

- Effective in dry and arid regions with limited water resources.
- Enhances moisture retention and water infiltration in sandy soils.
- Controls soil erosion on hilly or erodible land.
- Suppresses weed growth, reducing the need for herbicides.

Adaptability and Acceptance:

- Adoption rate depends on farmers' awareness and knowledge of mulching benefits.
- Training and educational programs can increase adoption.

Benefits for Smallholder Farmers:

- Conserves soil moisture, especially in areas with water scarcity.
- Extends growing seasons by moderating soil temperature.
- Enhances soil structure, nutrient retention, and sustainable agriculture.
- Reduces weed competition and the need for herbicides.
- Low-cost technique utilizing locally available organic materials.

Practical Demonstration:

- Grass residue mulching in cucumber cultivation in Hamirpur, Himachal Pradesh.
- Improved cucumber yield by 7% during stress years and 5% during normal years.
- Additional net returns of Rs. 9,000 and Rs. 7,000 per hectare in stress and normal years, respectively, compared to traditional practices (Table 7).

Table 7 Crop residue mulching for cucumber in Himachal Pradesh

District	Situation	Technology	Crop Yield (q/ha)	Net income (Rs/ha)
Hamirpur	Stress year (2018)	Grass residue mulching	144	76,000
		Farmers' practice	135	67,000
	Normal year (2019)	Grass residue mulching	155	87,000
		Farmers' practice	148	80,000

Promoting Adoption:

- Ensuring accessibility to mulch materials is crucial.
- Adaptation of mulching practices to local conditions, including climate and cropping systems.
- Identifying alternative mulch sources and promoting sustainable production.
- Developing labor-saving techniques, such as mechanized mulch application.

Crop residue mulching, demonstrated by ICAR-CRIDA in Hyderabad, is a valuable technique for conserving soil moisture, preventing erosion, and enhancing crop productivity. It aligns with water-smart and nutrient-smart technologies, making it suitable for regions with limited water resources and sloped terrains. Increasing awareness, ensuring material accessibility, and adapting techniques to local conditions are key to widespread adoption, benefiting smallholder farmers and sustainable agriculture.

Reference

Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. (2016). *Manual for Drought Management.*

9. Trench cum bund

Trench cum bunding is an innovative soil and water conservation technique aimed at improving soil moisture storage in agricultural fields. This method involves the construction of trenches and bunds (ridges) along the contour of the land. Its primary objective is to capture and store rainwater, preventing runoff and facilitating its infiltration into the soil. A trench is dug along the contour, often at the upper end of the field, and the excavated soil is used to create a bund or ridge downstream from the trench. The trench collects rainwater, allowing it to percolate into the soil, while the bund acts as a barrier, holding water within the field, promoting infiltration, and reducing erosion. The depth and width of the trench and the height of the bund can vary based on soil type, slope, and specific land conditions.

Alignment with Water-Smart Technology: Trench cum bunding falls under the water-smart technology category as it captures and stores rainwater, promoting water conservation.

Suitability:

- Ideal for sloping or undulating terrains prone to soil erosion and runoff.
- Beneficial in regions with limited rainfall or erratic precipitation patterns.
- Effective in various soil types, including sandy, loamy, or clayey soils.

Fig. 10 *Trench cum bunds for soil moisture conservation and to increase crop yield*

Factors Affecting Adaptability:

- Availability of resources, including labor, tools, and materials, significantly impacts adoption.
- Adequate awareness and knowledge among farmers enhance adaptability.

Benefits for Smallholder Farmers:

- Efficient water management, reducing the need for frequent irrigation.
- Effective soil erosion control, retaining soil fertility.
- Suitable for areas with limited access to irrigation facilities.

Practical Implementation:

- Trench cum bunds implemented in various villages across Karnataka, benefiting 596 farmers.
- Increased yields of pigeon pea, groundnut, and maize by 25% to 31%.
- Additional net returns of Rs. 12,380 to Rs. 22,490 per hectare compared to traditional practices (Table 8).

Table 8 Impact of trench cum bunds for soil moisture conservation and to improve crop productivity in Karnataka

District	Intervention	Crop	Crop Yield (q/ha)	Net return (Rs./ha)
Tumkuru	TCB (Trench cum bund)	Groundnut	15	33,780
	Without TCB		12	21,400
Chikkaballapur	TCB	Pigeon pea	27	48,685
	Without TCB		21	26,195
Davangere	TCB	Maize	47	28,900
	Without TCB		39	15,800
Belagavi	TCB	Maize	58	35,900
	Without TCB		44	20,250

This table showcases the impact of trench cum bunds on crop yield and net returns in different districts of Karnataka, illustrating the benefits of this soil and water conservation technique.

Promoting Adoption:

- Creating awareness through training programs, workshops, and farmer field schools.
- Facilitating farmer-to-farmer knowledge sharing.
- Government policies supporting soil and water conservation practices can encourage adoption.

Challenges and Solutions:

- Insecure land tenure can hinder long-term investment; access to affordable credit or government support can help.
- Periodic maintenance requirements necessitate regular cleaning and repair of bunds and trenches.

Trench cum bunding, demonstrated by ICAR-CRIDA in Hyderabad, is a valuable technique for conserving soil moisture, reducing erosion, and enhancing crop productivity. Its alignment with water-smart technology makes it suitable for regions with sloping terrain and limited water resources. Promoting awareness, facilitating resource accessibility, and government support can aid in widespread adoption, benefiting smallholder farmers and sustainable agriculture.

Reference

Dhyani, B. L., Dogra, P. K., Nirma, Sharma, G. C., & Sharma, S. N. (2016). Development and Management of Model Watersheds under New Guidelines. *ICAR – Indian Institute of Soil and Water Conservation, Dehradun*, 112 p.

10. Rice transplanter

Basic Features of the Technology: The Rice Transplanting Technology involves the use of a mechanized rice transplanter consisting of a prime mover, transmission, engine, float, lugged wheels, seedling tray, seedling tray shifter, pickup fork, and pickup fork cleaner. It has dimensions of 2410 mm in height and 2130 mm in width. The field capacity of a power tiller-mounted rice transplanter typically ranges from 0.2 to 0.5 hectares per hour. This technology enables efficient and timely planting of rice seedlings in flood-prone areas, overcoming the challenges of waterlogged conditions.

CSA Category: The technology fits under the category of energy-smart technology.

__Fig. 11__ Utilization of Rice Transplanter for timely sowing of crops in Kushinagar district

Main Focus/Benefits:

- Significantly reduces labor required for manual transplanting, increasing efficiency and saving time.
- Facilitates timely planting in flood-prone areas, optimizing growing conditions.
- Climate-resilient approach, enabling farmers to cope with unpredictable flooding.
- Reduces physical burden on women, empowering them in rice cultivation.

Drawbacks/Limitations:

- Initial investment cost can be a barrier for smallholder farmers.
- High operational costs including fuel, maintenance, and spare parts.
- Limited availability and accessibility of rice transplanters in remote areas.
- Customization to local contexts and infrastructure constraints needed for successful scaling up.

Suitability of the Technology:

Geographical Area: Flood-prone areas and regions facing labor shortages.

Cropping Pattern/Season: Rice cultivation during the monsoon season.

Agro-Ecosystem: Suitable for diverse soil types and agro-ecosystems.

Adaptability Rate:

Adoption may be influenced by regional preferences and existing practices. More common on larger farms with limited labor availability. Smallholder farmers adopt to reduce labor requirements.

Impact and Suitability to Smallholder Farmers and Women:

The technology significantly reduces labor requirements and allows timely planting, benefiting smallholder farmers with limited access to labor. It empowers women by reducing physical burdens and enabling more active participation in rice cultivation.

Benefits/Success Story:

In the Amwakhash cluster of Kushinagar district, rice transplanters were used for transplanting 15-20 days-old seedlings. Farmers achieved additional benefits of Rs. 7,474 and Rs. 15,801 per hectare and a yield improvement of 6.5% and 13.6% during the stress year and normal year, respectively. It reduced the cost of cultivation by Rs. 4,000-5,000 per hectare (Table 9).

Table 9 Impact of Paddy transplanter on Rice in Kushinagar District

Intervention	Yield (q/ha)	Gross Income (Rs./ha)	Net Income (Rs./ha)	Benefit-Cost Ratio (B:C Ratio)
Stress year (2014)				
Rice transplanter machine	45.83	76,079	54,364	2.50
Manually transplanting	43.0	72,250	46,890	1.84
Normal year (2013)				
Manually Transplanting	55.1	91,466	73,499	4.09
Rice transplanter machine	48.5	80,510	57,698	2.52

Enabling Factors:

- Government support programs, subsidies, grants, and low-interest loans.
- Agricultural machinery rental services.
- Cooperative initiatives.

Challenges in Scaling Up:

- High initial investment costs.
- Operational costs including fuel and maintenance.
- Limited availability and accessibility in remote areas.
- Customization and adaptation to local contexts are needed.

Rice Transplanting technology is a valuable innovation for rice cultivation in flood-prone areas. It significantly reduces labor requirements, empowers women, and enables timely planting, ultimately leading to increased yields and income for farmers. While initial adoption challenges exist, government support and infrastructure development can facilitate its wider uptake, contributing to more resilient and productive rice farming practices.

Reference

Chaitanya, N. V., Arunkumar, S., Bhanu, G., Akhilesh Kumar, S. G., & Avinash Babu, K. N. V. S. (2018). Design of Rice Transplanter. *Journal of Materials Science and Engineering, 377*.

11. Tank silt application for soil moisture conservation

Basic Features of the Technology: Tank silt, also known as pond silt or sediment, is the organic and inorganic material accumulated at the bottom of tanks or ponds. It is rich in organic matter. The technology involves excavating tank silt from water harvesting structures and applying it to farmland. The approximate cost of tank silt application is Rs. 12,000 per acre. The application of tank silt improves the physical, chemical, and biological properties of the soil and enhances its water-holding capacity.

CSA Category: The technology fits under the categories of water-smart and nutrient-smart technology.

***Fig. 12** Tank silt application for soil moisture conservation*

Main Focus/Benefits:

- Enhances soil's water-holding capacity, making efficient use of available water resources.
- Particularly suitable for areas with water scarcity and sandy or poorly drained soils.
- Improves moisture availability and nutrient content of the soil, contributing to better yields and plant health.

Drawbacks/Limitations:

- Awareness and knowledge among farmers play a significant role in adoption.
- Adoption depends on local context, such as the availability of tanks with silt.
- Requires campaigns, education, and training for widespread adoption.

Suitability of the Technology:

Geographical Area: Suitable for areas with water scarcity and tank or pond availability.

Cropping Pattern/Season: Applicable to various cropping patterns and seasons.

Agro-Ecosystem: Beneficial for improving soil quality in diverse agro-ecosystems.

Adaptability Rate: Adoption is influenced by awareness and local context. Availability of tanks with silt encourages adoption. Education and training programs can increase acceptability.

Impact and Suitability to Smallholder Farmers and Women:

The technology enhances soil's ability to retain water, benefiting smallholder farmers in water-scarce regions. It is cost-effective and utilizes local resources, making it accessible to farmers with limited financial resources. Moreover, it empowers women by increasing their involvement in agricultural activities.

Benefits/Success Story:

In D. Nagenahalli and Melkunda villages of Tumkuru and Kalaburagi districts, 5000 tons of tank silt were applied to a 24-hectare area, benefiting 63 farmers in 2018. The tank silt application improved soil properties and water-holding capacity, leading to increased moisture availability. Finger millet and pigeon pea crops in silt-applied fields resulted in additional yields of 3 and 4 quintals per hectare, respectively, and net returns of Rs. 6,470 and Rs. 25,610 per hectare over traditional practices (Table 10).

Table 10 Impact of application of tank silt in Karnataka

District	Intervention	Crop	Crop Yield (q/ha)	Net Return (Rs./ha)
Tumkuru	Silt Application	Finger Millet	14	20,750
	Farmers' Practice		11	14,280
Kalaburagi	Silt Application	Pigeon Pea	20	47,500
	Farmers' Practice		16	21,890

Enabling Factors:

- Awareness campaigns and education programs.
- Knowledge sharing through farmer networks.
- Community participation and ownership.

Challenges in Scaling Up:

- Limited awareness and knowledge among farmers.
- Adoption depends on the availability of tanks with silt.
- Need for education, training, and campaigns to promote adoption.

Tank Silt Application for Soil Improvement is a valuable technology for enhancing soil quality and moisture retention, especially in water-scarce regions. It empowers smallholder farmers, particularly women, and contributes to improved crop yields and income. To scale up adoption, awareness campaigns, education, and community participation are essential components of successful implementation.

Reference

Osman, M. (2008). *Recycling of Tank Silt for Improving Soil and Water Productivity in Rainfed Areas.* Central Research Institute for Dryland Agriculture, Hyderabad.

12. Laser land levelling

Basic Features of the Technology: Laser land leveling is an agricultural technique that creates a uniform and level field surface using laser-guided equipment. This precision technology improves water use efficiency by ensuring even distribution of irrigation water. It begins with a field survey to identify high and low spots. Laser equipment, typically mounted on a tractor or grading machinery, levels the field by removing high areas and filling low spots. The result is a smooth and even field surface conducive to efficient water distribution.

Fig. 13 *Laser land levelling in Pratapgarh district of Uttar Pradesh*

CSA Category: Laser land leveling falls under water-smart, nutrient-smart, and energy-smart technology.

Main Focus/Benefits:

- Enhances water use efficiency by uniformly distributing irrigation water.
- Reduces water wastage due to uneven terrain and runoff.
- Improves soil health and nutrient management.
- Minimizes soil erosion and nutrient loss.
- Suitable for fields with uneven topography.

Drawbacks/Limitations:

- High upfront cost for equipment and services.
- Limited access to laser-guided equipment in rural or remote areas.
- Need for trained operators and ongoing technical support.

Suitability of the Technology:

Geographical Area: Suitable for various geographical areas, particularly where water management is crucial.

Cropping Pattern/Season: Applicable to diverse cropping patterns and seasons.

Agro-Ecosystem: Beneficial for improving soil quality in different agro-ecosystems.

Adaptability Rate: Adoption depends on farmers' awareness and knowledge of the technology. Availability of rental services or cooperative arrangements can enhance adoption rates, especially among smallholder farmers with limited resources.

Impact and Suitability to Smallholder Farmers and Women:

Laser land leveling creates a more uniform field surface, benefiting smallholder farmers by increasing productivity and crop yields. It optimizes water use efficiency, making efficient use of limited water resources. This technology empowers women by involving them in food production and water management.

Benefits/Success Story:

In Uttar Pradesh, laser land leveling reduced the number of irrigations to 1-2 and saved 17-20% of irrigation water compared to traditional practices. It also reduced the cost of thinning and weeding operations and increased yields by 21 to 22% compared to conventional practices (Table 11).

Table 11 Impact of raised bed planting in Baghpat and Muzaffarnagar Districts

Location	Intervention	Yield (q/ha)	Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)
Baghpat	Flatbed Planting	14.8	20,250	52,360	31,860
	Raised Bed Planting	17.9	19,750	67,650	47,900
Muzaffarnagar	Flatbed Planting	16.5	20,700	58,350	37,650
	Raised Bed Planting	20.2	20,875	71,595	50,720

Enabling Factors:

- Awareness campaigns and education programs.
- Access to technical support, training, and capacity building.
- Availability and accessibility of laser-guided equipment, maintenance, and repair services.

Challenges in Scaling Up:

- High upfront costs for equipment and services.
- Limited access to laser-guided equipment in rural areas.
- Need for trained operators and ongoing technical support.

Laser Land Leveling is a precision technology that improves water use efficiency and soil health, particularly in areas with uneven terrain. It benefits smallholder farmers by increasing productivity and empowering women in agriculture. To scale up adoption, awareness campaigns, education, and technical support are essential components of successful implementation. Access to laser-guided equipment and related services also plays a crucial role in the technology's widespread adoption.

Reference

Bhat, R., & Sharma, M. (2010). *Extension Bulletin on Laser Leveller for precision land levelling for judicious use of water in Punjab.* Directorate of Extension Education, Punjab Agricultural University, Ludhiana.

13. Micro irrigation systems

Basic Features of the Technology: Micro irrigation involves precise water delivery through drippers, sprinklers, foggers, or other emitters placed on the surface or subsurface of the land. Water is applied directly near the root zone of crops, increasing water use efficiency. Drip irrigation provides water drop by drop, while sprinkler irrigation sprinkles water in lower heights at various directions. These systems significantly enhance water productivity and can be customized to suit different crops and water quality.

CSA Category: Micro irrigation falls under the category of climate-smart agriculture (CSA) known as water smart technology.

Fig. 14 *Micro irrigation systems*

Main Focus/Benefits:

- Efficient water use with over 90% water use efficiency in drip and over 80% in sprinkler irrigation.
- Suitable for various crops and agro-ecosystems.
- Maximizes water use efficiency, minimizing losses from evaporation and runoff.
- Conserves water resources, vital for regions facing water scarcity.
- Improves crop yields, food security, and smallholder farmers' income.

Drawbacks/Limitations:

- High upfront costs for equipment and installation.
- Limited access to micro irrigation technology in remote areas.
- The need for supportive policies, incentives, and financing mechanisms.

Suitability of the Technology:

Geographical Area: Suitable for areas with limited water resources or facing water scarcity.

Cropping Pattern/Season: Applicable to diverse cropping patterns and seasons.

Agro-Ecosystem: Beneficial for various agro-ecosystems.

Adaptability Rate: Micro irrigation has shown high adaptability and acceptability among farmers. It provides consistent water supply, improving crop productivity, particularly for smallholder farmers with limited water access.

Impact and Suitability to Smallholder Farmers and Women:

Micro irrigation technology significantly improves crop yields, income, and livelihoods of smallholder farmers. Its water-efficient nature is especially beneficial for farmers facing water scarcity. Women, who play essential roles in agriculture, can benefit from increased productivity and efficient water management.

Benefits/Success Story with Yield/Cost-related Data:

In Amravati district of Maharashtra, the application of harvested rainwater to cotton through drip irrigation resulted in a 29% higher yield than traditional flood irrigation methods. Additionally, it saved 57% of irrigation water. Chickpea yields were 40% higher with sprinkler irrigation compared to farmers' practices. Micro irrigation proved effective in utilizing harvested water, benefiting 218 farmers covering an area of 130 ha (Table 12).

Table 12 Utilization of harvested water for micro-irrigation in cotton and chickpea crops of Amravati district, Maharashtra

Crop	Intervention	Yield (q/ha)	Improvement compared to farmers' practice (%)	Net return (Rs/ha)	B:C ratio
Cotton	Farmers' practice	26.25	29	15,200	1:1.4
	Demo (Drip)	33.75		35,500	1:1.9
Chickpea	Farmers' practice	15.63	40	48,600	1:1.7
	Demo (Sprinkler)	21.87		65,960	1:2.6

Enabling Factors:

- Supportive policies and incentives.
- Capacity-building, technical support, and knowledge dissemination.
- Availability and accessibility of quality irrigation equipment.
- Collaborations among technology providers and suppliers.

Challenges in Scaling Up:

- High upfront investment costs.
- Limited access to technology in remote areas.
- Need for innovative financing mechanisms and cost-effective system designs.

Micro Irrigation, encompassing drip and sprinkler irrigation, is a water-smart technology that maximizes water use efficiency, benefiting crop yields, food security, and smallholder farmers' livelihoods. To scale up adoption, supportive policies, incentives, financing mechanisms, and partnerships among stakeholders are essential components of successful implementation.

Reference

National mission on micro irrigation operational guidelines. (2010). Department of Agriculture and Cooperation. Government of India.

14. Artificial recharge structures

Basic Features of the Technology: Artificial recharge structures capture and store water during periods of high rainfall or excess water availability, which is then used for irrigation during water scarcity or drought. Rainwater harvesting techniques are employed to capture and direct rainfall runoff from rooftops, catchment areas, or surface water sources into storage systems. Common structures include ponds, tanks, reservoirs, and underground storage systems.

Fig. 15 *Artificial recharge structures*

CSA Category: This technology falls under the climate-smart agriculture (CSA) category of water smart technology.

Main Focus/Benefits:

- Enhances water productivity.
- Adapts to climate variability.
- Builds resilience in agricultural systems.
- Efficient water management.
- Supports climate-resilient agriculture practices.
- Suitable for areas with available water sources.
- Hydrogeological assessments and feasibility studies are crucial.

Drawbacks/Limitations:

- Suitability depends on hydrogeological characteristics.
- Water quality assessment may be required.
- Technical complexities in design and implementation.
- Financial challenges in scaling up.

Suitability of the Technology:

Geographical Area: Suitable where there is sufficient water available for capture and storage.

Cropping Pattern/Season: Applicable to various cropping patterns and seasons.

Agro-Ecosystem: Suitable for diverse agro-ecosystems.

Adaptability Rate: Artificial recharge structures benefit smallholder farmers during droughts by providing critical irrigation. These structures enhance farmers' resilience to climate variability and reduce food insecurity risks.

Impact and Suitability to Smallholder Farmers and Women:

Artificial recharge structures benefit smallholder farmers by replenishing groundwater resources, ensuring a reliable water supply for irrigation during droughts. This technology enhances smallholder farmers' resilience to climate variability and reduces the risk of food insecurity. Women, who play vital roles in agriculture, can benefit from increased productivity and water availability.

Benefits/Success Story with Yield/Cost-related Data:

In Karnataka, recharge structures increased groundwater levels by 20 to 25 feet, enabling pre-sowing and supplemental irrigations for finger millet, green gram, and chickpea crops during the rabi season. Crop yields increased by 33% to 60% compared to areas without recharge structures. The use of this technology resulted in additional net returns of Rs. 7,600 per ha in finger millet, Rs. 22,700 per ha in green gram, and Rs. 7,600 per ha in chickpea (Table 13).

Table 13 Impact of Artificial Recharge Structures in Karnataka

District	Intervention	Crop	Net Returns (Rs./ha)
Chikkaballapur	Recharge structure	Finger millet	21,350
	Without recharge structure		13,750
Gadag	Recharge structure	Green gram	35,280
	Without recharge structure		12,580
Belagavi	Recharge structure	Chickpea	26,400
	Without recharge structure		18,800
Kalaburagi	Recharge structure	Chickpea	26,850
	Without recharge structure		19,600

Enabling Factors:

- Awareness creation among farmers, water users, and communities.
- Capacity-building programs, training workshops, and knowledge-sharing.
- Technical expertise in hydrogeology, engineering, and water management.
- Collaboration with research institutions and experts.

Challenges in Scaling Up:

- Technical complexities related to hydrogeology and engineering design.
- Site-specific conditions and aquifer variability.
- Financial challenges in scaling up artificial recharge projects.

Conclusion:

Artificial Recharge Structures for Critical Irrigation are vital for enhancing water productivity, adapting to climate variability, and building resilience in agricultural systems. Successful implementation requires addressing site-specific conditions, technical complexities, and financial challenges, making collaboration and capacity-building crucial for scaling up this technology.

Reference

Government of India, Central Ground Water Board. (2017). *Manual on Artificial Recharge of Ground Water.*

15. Broad bed furrow technique

Basic Features of the Technology: BBF involves creating raised beds and furrows in between to optimize soil moisture retention, reduce erosion, and enhance crop productivity. It was developed to address water scarcity, soil erosion, and inefficient water use. Dimensions can vary based on crop, soil, and local conditions. Raised beds are 1 to 1.5 meters wide, 15 to 30 centimeters high, while furrows are 30 to 60 centimeters wide and 10 to 20 centimeters deep.

Fig. 16 *Use of BBF in Soybean for in situ moisture conservation in Jalna District*

CSA Category: BBF falls under water smart technology, aiming to improve soil health, prevent land degradation, enhance ecosystem services, increase agricultural productivity, and build resilience to climate change.

Main Focus/Benefits:

- Controls soil erosion.
- Enhances water management.
- Suitable for sloping or hilly areas.
- Captures and retains water.
- Improved water infiltration.
- Increases crop yields.
- Soil fertility and health improvement.

Drawbacks/Limitations:

- Adoption may vary by region.
- Initial investment costs.
- Resource constraints for smallholders.

Suitability of the Technology:

Geographical Area: Suitable for sloping or hilly areas prone to soil erosion.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Suitable for regions with high-intensity rainfall or uneven distribution.

Adaptability Rate: Adoption varies depending on region, farmer preferences, local practices, and support. More readily adopted in areas prone to soil erosion and in regions where water management is critical.

Impact and Suitability to Smallholder Farmers and Women:

BBF technology enhances crop productivity by improving water management and soil moisture retention. Smallholder farmers benefit from increased yields and food security due to improved water infiltration and soil health. Women, who play key roles in agriculture, can benefit from increased productivity and water availability.

Benefits/Success Story with Yield/Cost-related Data:

In Jalna, Maharashtra, BBF technology adoption led to increased soybean yields from 12.87 q/ha to 15.25 q/ha compared to traditional farming practices. Net income increased by Rs. 6,620 per ha, demonstrating the benefits of BBF (Table 15).

Table 14 Impact of Broad Bed Furrow on Soybean Yield in Jalna, Maharashtra

Intervention	Area (ha)	No. of Farmers	Crop Yield (q/ha)	Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)	B:C Ratio
Farmers' Practice (Without BBF)	4	10	12.87	30,120	38,625	8,505	1.28
Demo (Use of BBF in Soybean)	4	10	15.25	32,150	47,275	15,125	1.47

Enabling Factors:

- Awareness campaigns, farmer field schools, and training programs.
- Supportive policies and incentives.
- Availability and accessibility of BBF equipment.
- Government and local authority involvement.

Challenges in Scaling Up:

- Resource constraints for smallholders.
- Initial investment costs.
- Adoption variations by region.

Conclusion:

Broad Bed Furrow (BBF) Planting Technology is a sustainable approach to control soil erosion, enhance water management, and improve crop productivity. It is well-suited for sloping or hilly areas and regions with high rainfall variability. Successful adoption requires awareness campaigns, supportive policies, and addressing resource constraints for smallholders.

Reference

Dupare, B. U., & Billore, S. D. (2021). *Soybean Production: Package of practices and Technical Recommendations. Extension Bulletin No. 16.* ICAR-Indian Institute of Soybean Research Publication. pp: 50.

16. In-situ management of paddy straw using baler cum knotter

Basic Features of the Technology: After combine harvesting of paddy (rice) crops, straw is left on the field. This technology involves the use of a baler cum knotter machine to compress straw into bales for easy transport and storage. The machine consists of various components and is powered by the tractor's power take-off. One bale typically weighs 15-25 kg, and it takes about 1.0-1.5 hours to make bales from one acre of straw. This practice helps prepare the field for the next crop by removing the straw quickly.

Fig. 17 *Baler cum Knotter technology in Bathinda District*

CSA Category: This technology falls under the water and nutrient smart category of climate-smart agriculture.

Main Focus/Benefits:

- Manages post-harvest paddy straw effectively.
- Reduces air pollution from straw burning.
- Improves soil moisture retention.
- Enhances soil health and fertility.
- Provides opportunities for income generation.
- Suitable for regions with abundant paddy straw.

Drawbacks/Limitations:

- Initial investment costs.
- Requires availability and affordability of machinery.
- Adoption varies based on local factors.

Suitability of the Technology:

Geographical Area: Suitable in regions where rice is a major crop and paddy straw residue is abundant. Also relevant in drought-prone or water-scarce areas for in-situ straw management.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Suitable for regions where air pollution from straw burning is a concern.

Adaptability Rate: Adoption varies based on factors such as machinery availability, affordability, farmer awareness, and local practices. More readily adopted in areas with abundant paddy straw.

Impact and Suitability to Smallholder Farmers and Women:

This technology mitigates environmental issues associated with straw burning, reducing air pollution and contributing to soil conservation. It promotes sustainable soil fertility management, reduces the need for synthetic fertilizers, and provides opportunities for income generation. Smallholder farmers, including women, benefit from increased productivity, improved soil health, and diversified revenue streams.

Benefits/Success Story with Yield/Cost-related Data:

In areas like Ropar and Bathinda districts, adopting the baler cum knotter technology led to increased crop yields compared to traditional farming practices. Net income also improved, as shown in Table 15 below:

Table 15 Impact of Paddy Straw Management Using Baler Cum Knotter in Ropar and Bathinda Districts

Location	Intervention	Yield (q/ha)	Cost of Cultivation (Rs./ha)	Net Income (Rs/ha)	B:C Ratio
Ropar	Baler cum knotter	50.1	32,249	57,515	2.78
	Farmers' Practice	49.25	32,249	54,856	2.70
Bathinda	Baler cum knotter	58.7	23,295	84,713	3.6
	Farmers' Practice	53.5	31,542	66,898	2.1

Enabling Factors:

- Availability and accessibility of baler cum knotter machines.
- Affordable machinery through subsidies or loans.
- Awareness campaigns about the benefits of straw management.
- Supportive policies and incentives.
- Financing mechanisms that ease the financial burden.

Challenges in Scaling Up:

- Initial investment costs.
- Limited availability of machinery.
- Difficulty reaching remote areas.
- Cultural practices and traditional beliefs related to straw management.

In-situ Management of Paddy Straw Using a Baler Cum Knotter is a sustainable approach to managing post-harvest paddy straw effectively. It reduces air pollution, improves soil health, and provides income-generating opportunities. Adoption depends on machinery availability, affordability, and local factors. Strategies to promote this technology should focus on addressing these challenges and raising farmer awareness.

Reference

Murai, A. S., Bhadauria, P., Singh, V., Sadawarti, K., & Singh, R. (2020). *Promoting Climate Resilient Agriculture: Journey of 51 Climate Smart Villages.* ICAR- Agricultural Technology Application Research Institute, Zone-I, Ludhiana, Punjab. P-88.

17. Zero till wheat sowing by PAU happy seeder

Developed/Introduced/Compiled by: The Happy Seeder, a tractor-mounted machine, was introduced by Punjab Agricultural University, Ludhiana.

Basic Features of the Technology: The Happy Seeder is designed to trim and lift rice straw, sow wheat into bare soil, and mulch the sown area with the straw. It allows farmers to sow wheat immediately after rice harvest without burning the straw. The machine uniformly places and presses the chopped paddy straw in the inter-row area as mulch, promoting better germination, emergence, weed control, and higher yield. It covers 5-6 acres per day, costing approximately 2500-3000 Rs/ha. Custom hiring of the Happy Seeder is available at a rate of 1500 Rs/acre.

Fig. 18 *Sowing of wheat by happy seeder technology in Bathinda district*

CSA Category: This technology falls under the energy smart and water smart categories of climate-smart agriculture.

Main Focus/Benefits:

- Facilitates zero till wheat sowing after rice harvest.
- Preserves soil moisture and reduces evaporation.
- Minimizes soil erosion.
- Optimizes water use.
- Increases crop productivity and wheat yields.
- Empowers women in agriculture.

Drawbacks/Limitations:

- Initial investment in machinery.
- Adoption varies based on awareness and support.

Suitability of the Technology:

Geographical Area: Suitable for dryland or rainfed farming areas with limited water availability. Effective in regions with high soil erosion rates.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Relevant in areas where air pollution from straw burning is a concern.

Adaptability Rate: Adoption depends on factors such as machinery availability, affordability, farmer awareness, and local conditions. More readily adopted in regions with abundant rice straw.

Impact and Suitability to Smallholder Farmers and Women:

This technology leads to increased crop productivity, especially higher wheat yields. It conserves natural resources, including soil and water, which is crucial for smallholder farmers who rely on agriculture for food security and income. Additionally, it empowers women by requiring less physical labor compared to traditional tillage methods.

Benefits/Success Story with Yield/Cost-related Data:

The adoption of Happy Seeder in Bathinda district, Punjab, resulted in significant benefits, including reduced lodging rate, lower heat stress, and a 95% reduction in weed growth. The technology helped farmers achieve higher yields, additional income, and better net returns, as shown in Table 16 below:

Table 16 Impact of Happy Seeder on Wheat in Bathinda District of Panjab

Intervention	Year	Yield (q/ha)	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
Sowing with Happy Seeder	2021-22	46.5	27,982	93,697.5	69,697.5	3.42
Farmers' Practice		41.5	35,095	83,622.5	49,622.5	2.38
Sowing with Happy Seeder	2020-21	55.5	24,000	109,612	85,612	4.56
Farmers' Practice		51.7	33,000	102,205	69,205	2.09

Enabling Factors:

- Availability and accessibility of Happy Seeder machines.
- Affordable machinery through subsidies or loans.
- Awareness programs and training sessions.
- Availability of quality seeds and inputs.
- Supportive policies and incentives.

Challenges in Scaling Up:

- Initial investment costs.
- Limited availability of machinery.
- Farmer awareness and knowledge.
- Regional variations in adoption.

Zero Till Wheat Sowing with Happy Seeder is a sustainable approach that enables farmers to sow wheat immediately after rice harvest without straw burning. It conserves soil moisture, reduces erosion, optimizes water use, and increases crop productivity. Adoption depends on machinery availability, affordability, and awareness. Strategies to promote this technology should focus on addressing these challenges and raising farmer awareness.

Reference

Singh, J., Grover, J., Singh, A., Kumar, R., Marwaha, B., Chandel, R., Chhina, R. S., Sharma, K., Sharma, A., Kumar, A., Murai, A. S., Lohan, S. K., Singh, M., Narang, M., Manes, G. S., & Singh, M. (2018). *Manual on Happy Seeder (Technology for in-situ management of paddy residue).* ICAR-ATARI, Zone-1, PAU Campus, Ludhiana, Punjab. P.20.

18. Residue incorporation by reversible mould plough

Developed/Introduced/Compiled by: The Residue Incorporation of Paddy Straw technology is aimed at addressing the environmental and soil health issues associated with the burning of paddy straw.

Basic Features of the Technology: This technology involves the incorporation of paddy straw residue into the soil using a reversible mould board plough. The plough is designed to work in all types of soil and can perform functions such as soil breaking, raising, and inversion. It has a field capacity of covering 0.3 ha per hour. The process of residue incorporation enhances the physical qualities of the soil, leading to increased crop output.

Fig. 19 *Paddy straw management through Reversible mould plough in Bathinda district*

CSA Category: The Residue Incorporation of Paddy Straw falls under the water, carbon, and nutrient smart categories of climate-smart agriculture.

Main Focus/Benefits:

- Improves soil fertility by increasing organic matter content and nutrient availability.
- Enhances water-holding capacity of the soil.
- Increases crop productivity and yields.
- Reduces air pollution from straw burning, improving air quality.
- Supports food security and income generation for smallholder farmers.

Drawbacks/Limitations:

- Adoption varies based on awareness and support.
- Limited access to machinery and equipment.

Suitability of the Technology:

Geographical Area: Suitable for paddy cropping systems where straw residue is generated. Particularly beneficial for soils with low organic matter content.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Suitable for areas where air pollution from straw burning is a concern.

Adaptability Rate: Adoption depends on factors such as machinery availability, affordability, farmer awareness, and local conditions. The level of awareness and knowledge about the benefits of residue incorporation and the negative impacts of straw burning is crucial.

Impact and Suitability to Smallholder Farmers and Women:

This technology improves soil fertility, nutrient availability, and water-holding capacity, leading to increased crop productivity and higher yields. Smallholder farmers, who often have limited access to external inputs such as fertilizers, benefit from these improvements, contributing to food security and income generation. Reduced air pollution from straw burning improves air quality and human health, benefiting communities living near paddy fields.

Benefits/Success Story with Yield/Cost-related Data:

Incorporation of paddy straw using a reversible mould board plough resulted in significant benefits. This included an improved yield of 13.6% over conventional methods, along with additional returns, as shown in Table 17 below:

Table 17 Impact of Paddy straw incorporation on Wheat yield in Bathinda district

Intervention	Yield (q/ha)	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
Reversible MB Plough	58.75	35,000	116,031.3	81,031.25	2.5
Farmers' Practice	51.25	33,000	101,218.8	68,218.75	2.0

Enabling Factors:

- Supportive policies and regulations discouraging straw burning.
- Financial incentives or subsidies for residue incorporation machinery.
- Availability and accessibility of machinery and equipment.
- Field demonstrations and successful case studies to create awareness.

Challenges in Scaling Up:

- Limited access to machinery and equipment.
- High costs and lack of availability.
- Inadequate infrastructure.
- Limited awareness and understanding among farmers.

The Residue Incorporation of Paddy Straw technology offers a sustainable solution to the environmental and soil health issues associated with straw burning. It enhances soil fertility, increases crop productivity, and reduces air pollution. Successful adoption depends on addressing challenges related to machinery access and raising awareness among farmers about the benefits of residue incorporation. Supportive policies and incentives can further promote its uptake.

Reference

Singh, A. K., Alagusundaram, K., Kumar, Ashwani, Singh, Rajbir, Sehgal, V. K., Chahal, V. P., Singh, K. K., Mahal, J. S., & Singh, S. K. (2019). *In-situ Crop Residue Management: Key Outcome and Learning.* Division of Agricultural Extension, ICAR, New Delhi. 30 pp.

19. Ridge and furrow cultivation method

Developed/Introduced/Compiled by: The Ridge and Furrow Method is aimed at optimizing water management and addressing soil erosion challenges in hilly regions.

Basic Features of the Technology: This method involves creating raised beds or ridges with furrows in between to optimize growing conditions and water management on sloping terrain. The raised beds act as barriers to reduce soil erosion, while the furrows serve as water channels for efficient water distribution and drainage. The ridger plough equipment is used for ridge and furrow formation, and its cost of preparation is approximately Rs. 2,200 per hectare.

Fig. 20 *Ridge and furrow method for high value vegetable cultivation in hilly regions*

CSA Category: The Ridge and Furrow Method falls under the "Water Smart Technology" category of climate-smart agriculture.

Main Focus/Benefits:

- Optimizes water management in hilly regions.
- Reduces soil erosion by slowing down water runoff.
- Improves soil conservation and nutrient availability.
- Enhances water infiltration and reduces waterlogging.
- Supports efficient water use and crop productivity.

Drawbacks/Limitations:

- Adoption depends on specific landscape characteristics.

- Challenges in maintaining uniform bed heights and furrow depths.
- Requires proper water management.

Suitability of the Technology:

Geographical Area: Highly suitable for hilly regions with sloping terrain where water runoff and soil erosion are concerns.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Particularly beneficial for terraced landscapes in hilly or mountainous regions.

Adaptability Rate: Adaptability depends on factors such as landscape characteristics, soil type, and local agricultural practices. Familiarity with other soil and water management techniques can influence adoption.

Impact and Suitability to Smallholder Farmers and Women:

The Ridge and Furrow Method optimizes water management, improves soil health, and enhances nutrient availability. These factors contribute to increased crop productivity, benefiting smallholder farmers who rely on agriculture for food security and income generation. Smallholder farmers, especially those in hilly regions prone to soil erosion, can benefit from reduced soil loss and improved water use efficiency. This method also supports high-value vegetable cultivation, which can diversify income sources for smallholders, including women.

Benefits/Success Story with Yield/Cost-related Data:

In the demonstration of the Ridge and Furrow Method for bottle gourd cultivation in Mann Panchayat village of Hamirpur, Himachal Pradesh, significant benefits were observed. The bottle gourd crop grown using the ridge and furrow system showed increased resilience to moisture stress during dry spells and achieved higher yields compared to conventional flatbed methods. During stress and normal years, the ridge and furrow system resulted in increased bottle gourd yields by 16 q/ha and 10 q/ha, respectively, compared to farmers' practice. This translated to additional net returns of Rs. 12,500 per hectare and Rs. 16,000 per hectare during stress and normal years, respectively.

Table 18 Impact of Ridge and Furrow System for Bottle Gourd in Hamirpur District, Himachal Pradesh

District	Situation	Technology	Crops	Crop Yield (q/ha)	Net Income (Rs/ha)
Hamirpur	Stress year (2018)	Ridge and Furrow	Bottle gourd	258	1,91,000
		Farmers' practice		242	1,75,000
	Normal year (2019)	Ridge and Furrow		265	1,98,000
		Farmers' practice		255	1,88,000

Enabling Factors:

- Supportive landscape characteristics (sloping terrain).
- Opportunities for terraced landscapes.
- Improved water management and reduced soil erosion.
- Diversified crop production.

Challenges in Scaling Up:

- Specific landscape requirements.
- Maintaining uniform ridge and furrow dimensions.
- Proper water management.
- Awareness and understanding among farmers and extension workers.

Other Relevant Information:

Environmental Impact: Ridge and furrow systems have environmental benefits by reducing soil erosion and improving water use efficiency. This leads to enhanced soil conservation and potentially cleaner waterways in hilly regions.

Training and Awareness: Providing farmers with technical training on the ridge and furrow method is essential for its successful uptake. Training programs should cover aspects such as ridge construction, furrow management, crop spacing, and water management techniques. Agricultural extension services, NGOs, and research organizations can facilitate awareness and knowledge dissemination.

Challenges in Adoption: Lack of awareness and understanding about the ridge and furrow method among farmers and extension workers can be a significant challenge. Farmers may face difficulties in properly implementing the technique, achieving uniformity in bed heights and furrow depths, and managing water flow. Continuous technical support and monitoring can help address these challenges.

Reference

Upare, B.U. and Billore, S.D. (2021). Soybean Production: Package of practices and Technical Recommendations. Extension Bulletin No. 16. ICAR-Indian Institute of Soybean Research Publication. Pp: 50.

20. Desilting of drainage channel

Basic Features of the Technology: Desilting involves removing accumulated sediment, debris, and vegetation from drainage channels to restore their carrying capacity and efficiency. Proper desilting ensures the quick disposal of runoff and prevents water stagnation, especially during heavy rainfall or periods of high-water flow. The dimensions of drainage channels, including width, depth, and slope, play a crucial role in their effectiveness.

CSA Category: Desilting of Drainage Channels falls under the "Water Smart Technology" category of climate-smart agriculture.

Fig. 21 *Desilting of drainage channel in Dhubri district of Assam*

Main Focus/Benefits:

- Efficient water management.
- Prevention of water stagnation.
- Reduction of flood-related issues.
- Enhanced agricultural productivity.
- Reduced waterlogging and flood damage.

Drawbacks/Limitations:

- Resource-intensive in terms of equipment and labor.
- Land tenure and ownership complexities in shared drainage channels.

Suitability of the Technology:

Geographical Area: Suitable in areas prone to water stagnation, low-lying fields, flood-prone regions, and locations with inadequate natural drainage systems.

Cropping Pattern/Season: Adaptable to various cropping patterns and seasons.

Agro-Ecosystem: Particularly beneficial in flood-prone and low-lying agricultural areas.

Adaptability Rate: Farmer's acceptance depends on their perception of the technology's direct benefits, such as improved water drainage, reduced waterlogging, and enhanced crop yields. Increased awareness can positively influence farmer adoption.

Impact and Suitability to Smallholder Farmers and Women:

Desilting of drainage channels enhances water drainage, reduces waterlogging, and mitigates flood-related risks. These benefits directly contribute to improved agricultural productivity, which is crucial for smallholder farmers. Smallholders, especially those in flood-prone areas, can benefit from reduced crop damage and increased yields. The technology is accessible and effective, making it suitable for women's participation in agricultural activities.

Benefits/Success Story:

In Udmari Pt – IV village of Dhubri district, Assam, the desilting of a 900-meter drainage channel was undertaken to enhance water carrying capacity and prevent prolonged flooding of fields during the kharif season. Prior to desilting, crop losses due to flooding ranged from 20% to 100%. Desilting improved water drainage, allowing timely rice cultivation during the kharif season and minimizing flash floods during summer rice cultivation. This technology helped minimize crop damage and resulted in additional net returns ranging from Rs. 5,000 to Rs. 23,000 per hectare compared to fields without desilting. The drainage channel was also utilized for transporting produce.

Enabling Factors:

- Improved water drainage.
- Reduced waterlogging and flood risk.
- Enhanced crop productivity.
- Affordable and effective technology.

Challenges in Scaling Up:

- Resource constraints (equipment, machinery, labor).
- Complexities in shared drainage channel ownership.
- Land tenure issues.

Other Relevant Information:

Environmental Impact: Desilting of drainage channels has environmental benefits by preventing water stagnation, reducing soil erosion, and improving water management in agricultural areas.

Technical Knowledge and Training: Providing farmers with technical knowledge and training programs is essential for successful technology adoption. Extension services, farmer field schools, and demonstration plots can facilitate knowledge dissemination and skill-building.

Challenges in Adoption: Lack of awareness and understanding among farmers and extension workers can hinder adoption. Maintaining uniform desilting practices and proper water management are continuous challenges that require support and monitoring.

Reference

Asian Development Bank (ADB). (2011). Operation and Maintenance of Flood Control Drainage and Irrigation Systems.

https://www.adb.org/sites/default/files/publication/157581/operation-maintenance-flood-control-drainage-irrigation-systems.pdf

Climate Resilient Crop Production Technologies

21. Drought-tolerant crop varieties

Developed/Introduced/Compiled by: Drought-Tolerant Crop Varieties were developed by scientists from ICAR institutes and SAUs across India. These varieties are aimed at mitigating the challenges posed by low rainfall, frequent dry spells, and drought conditions in various regions of the country.

Basic Features of the Technology: Drought-tolerant crop varieties have been developed for various cereals, pulses, oilseeds, and commercial crops. These varieties are characterized by their ability to withstand drought stress and low moisture conditions while maintaining high yield potential.

Table 19 Drought-tolerant crop varieties

Drought-tolerant varieties	
Rice	Sahabhagi Dhan, Vandana, Anjali, Satyabhama, DRR Dhan 42 (IR64 Drt 1), DRR Dhan 43, Birsa Vikas Dhan 203, Birsa Vikas Dhan 111, Rajendra Bhagwati, Jaldi Dhan 6-, Swarna Shreya, DRR-42, DRR-44, Inglongkiri
Maize	Pusa Hybrid Makka 1, HM 4, Pusa Hybrid Makka 5, DHM 121, Buland, Bajaura Makka, Early Composite and Girija, KH 517, Vyas, Proagro 4640, Plant gene (2465), Proline (3440) and Polo Gold
Sorghum	CSH 19 R, CSV 18, CSH 15R, Phule Suchitra, Parbhani-Moti, CSV-27, GS-23
Pearl Millet	HHB 67 improved, GHB 757, GHB 719, Dhanshakti, HHB 234, Mandor Bajra Composite 2, HHB-226, RHB-177, Pusa Composite 443, (ICTP-8203),
Chickpea	Vijay, Vikas, RSG 14, RSG 888, ICCV 10, Pusa 362, Raj Vijay 203, Akash, Digvijay, JG-11, BGD-103, JAKI-9218
Lentil	DPL62, KLB320, K75, PL8 and PL5
Garden pea	Vatika 10
Groundnut	Ajaya, Girnar 1, TAG-24, Kadiri 6, ICGV 91114,
Soybean	NRC 7, JS 95-60, MAUS-162

CSA Category: Development of drought-tolerant crop varieties falls under the "Weather Smart" and "Water Smart Technology" categories of climate-smart agriculture.

Main Focus/Benefits:

- Mitigation of drought stress.
- High yield potential under low rainfall and drought-prone conditions.
- Risk minimization and increased profits for farmers.

Drawbacks/Limitations:

- Dependence on the timely availability and accessibility of seeds.

Suitability of the Technology:

Geographical Area: Suitable for drought-prone areas across India.

Fig. 22 *Drought-tolerant varieties of sorghum (CSV-27) (A), pigeonpea (NA 1) (B), groundnut (Devi) (C), and wheat (DWR-2006) (D).*

Cropping Pattern/Season: Applicable to both Kharif and Rabi cropping seasons.

Agro-Ecosystem: Designed for low rainfall and drought-prone agricultural regions.

Adaptability Rate: The adoption of drought-tolerant crop varieties is cost-effective and user-friendly, making it highly acceptable among farmers. Significant numbers of farmers across the country have adopted this technology.

Impact and Suitability to Smallholder Farmers and Women:

Drought-tolerant crop varieties offer several benefits, including increased yields and returns, at a Low-cost. These varieties are easy to use, making them suitable for small, marginal, resource-poor farmers, and women farmers. The cost-effectiveness of adopting high-yielding varieties is a key driver of their adoption.

Benefits/Success Story with Yield/Cost-related Data:

In Pune, Maharashtra, a drought-tolerant sunflower variety called Phule Bhaskar was demonstrated. It resulted in a 27% higher grain yield (10.8 q/ha) compared to the farmers' practice of hybrids (8.5 q/ha). Additionally, it recorded increased net income (Rs. 24,840/ha) and a benefit-cost ratio (BC ratio) of 3.00.

Table 20 Performance of drought-tolerant sunflower variety Phule Bhaskar under rainfed condition

Intervention	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net income (Rs/ha)	B:C ratio
Farmers practice: Hybrids	8.50	14550	19550	2.34
Improved variety: Phule Bhaskar	10.80	12460	24840	3.00

Enabling Factors:

- Low-cost technology.
- Increased yield potential and returns.
- Farmer-friendliness.

Challenges in Scaling Up:

- Timely availability and accessibility of seeds to farmers.
- Dependence on agricultural departments for seed distribution.

Other Relevant Information:

Environmental Impact: Drought-tolerant crop varieties contribute to environmental sustainability by reducing the risk of crop failure due to drought conditions. They promote efficient water use and can help conserve soil and water resources.

Technical Knowledge and Training: While the adoption of drought-tolerant crop varieties is relatively simple, providing farmers with technical knowledge and training can further enhance their ability to make the best use of these varieties.

Challenges in Adoption: Ensuring the timely availability of drought-tolerant seeds to farmers, with the support of agricultural departments, is a critical challenge for widespread adoption of this technology.

References

Development of Flood and Drought Resistant Seeds (2015), Ministry of Agriculture & Farmers Welfare, Government of India,

https://pib.gov.in/newsite/PrintRelease.aspx?relid=123999

22. Flood-tolerant rice varieties

Developed/Introduced/Compiled by: Flood/Submergence-Tolerant Crop Varieties have been developed by scientists from ICAR institutes and SAUs across India to address the challenges posed by floods and submergence in crop fields. These varieties are designed to withstand high rainfall and flooding conditions.

Basic Features of the Technology: Flood/submergence-tolerant crop varieties are specifically bred to endure prolonged flooding and high-rainfall events. They are aimed at mitigating the significant losses incurred by farmers due to crop inundation and lodging caused by floods.

Table 21 Flood-tolerant varieties

Flood/ submergence tolerant varieties	
Rice	Swarna Sub-1, Sambha Mahsuri Sub-1, Varshadhan, Gayatri, Sarla, Pooja, Prateeksha, Durga, JalaMani, CR Dhan 505, CR Dhan 502, Jalnidhi, Neerja, Jaladhi 1, Jaladhi 2, Hemavathi, Bina-11, Jalasree, Jalkuwanri, Sawrna Sub 1, Bahadur Sub 1, Ranjith sub -1, Panindra, Dipholu, Padumani, Luit

CSA Category: Development of flood/submergence-tolerant crop varieties falls under the "Weather Smart Technology" category of climate-smart agriculture.

Main Focus/Benefits:

- Mitigation of flood-related crop losses.
- High yield potential under flood-prone conditions.
- Low-cost intervention.
- Particular benefit to marginalized and resource-poor farmers.

Fig. 23 Cultivation of flood-tolerant rice varieties Padumini (A), and Swarna Sub -1 (B)

Drawbacks/Limitations:

- Dependence on the timely availability and accessibility of seeds.

Suitability of the Technology:

Geographical Area: Suitable for flood-prone areas, especially in northeastern states of India.

Cropping Pattern/Season: Primarily applicable to Kharif cropping season.

Agro-Ecosystem: Suitable for cultivation in high rainfall and flood-prone agricultural regions.

Adaptability Rate: The adoption of flood/submergence-tolerant crop varieties is cost-effective and particularly beneficial for resource-poor and marginalized farmers. Farmers have widely accepted this technology due to its simplicity and Low-cost.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of flood/submergence-tolerant crop varieties has demonstrated significant yield improvements, particularly in flood-prone areas. These varieties are easy to adopt and cost-effective, making them suitable for small, marginal, resource-poor farmers, and women farmers. Marginalized groups, such as Scheduled Castes and Tribes, stand to benefit the most from this technology, as they often cultivate in flood-prone regions.

Benefits/Success Story with Yield/Cost-related Data:

In Odisha, the Swarna-Sub1 variety significantly outperformed the non-submergence-tolerant Swarna variety when fields were flooded for seven to fourteen days. Swarna-Sub1 showed a production advantage over Swarna of about 64 kilograms per hectare for every additional day of flooding, resulting in an overall 10.5% increase in total rice production compared to plots where Swarna-Sub1 was not planted. The production loss that was avoided during ten-day floods was 628 kg per hectare, a yield advantage of 45% over Swarna. Importantly, Swarna-Sub1 can also be planted in years when there are no floods because there was no discernible difference in yield between the two types in areas without flooding.

In Assam, the demonstration of the Swarna Sub-1 variety resulted in increased yields and returns over the local practice under flooded conditions.

Table 22 Performance of flood-tolerant rice variety Swarna Sub-1 in flood-affected areas of Assam

Intervention	**Yield (q/ha)**	**Cost of cultivation (Rs. /ha)**	**Gross income (Rs. /ha)**	**Net income (Rs. /ha)**	**BCR**
Farmers' practice	21.5	25,000	30,100	5,100	1.20
Swarna Sub-1	53.0	38,000	74,200	36,200	1.95

Enabling Factors:

- Low-cost intervention.
- Yield improvements.
- Simplicity of changing crop varieties for flood tolerance.

Challenges in Scaling Up:

- Timely availability and accessibility of seeds remain major challenges in scaling up this technology. Integrating flood/submergence-tolerant seed varieties into seed supply chains can facilitate its wider adoption.

Other Relevant Information:

Environmental Impact: Flood/submergence-tolerant crop varieties contribute to environmental sustainability by reducing the risk of crop failure due to floods and improving overall crop resilience in flood-prone regions.

Technical Knowledge and Training: While the adoption of flood/submergence-tolerant crop varieties is relatively simple, providing farmers with technical knowledge and training can further enhance their ability to make the best use of these varieties.

Challenges in Adoption: Ensuring the timely availability of flood/submergence-tolerant seeds to farmers, with the support of agricultural departments, is a critical challenge for widespread adoption of this technology.

Reference

Development of Flood and Drought Resistant Seeds (2015), Ministry of Agriculture & Farmers Welfare, Government of India,

https://pib.gov.in/newsite/PrintRelease.aspx?relid=123999

23. Salt-tolerant crop varieties

Developed/Introduced/Compiled by: Salt-Tolerant Crop Varieties have been developed by scientists from ICAR institutes and SAUs to address the challenges posed by soil salinization in agriculture. These crop varieties are specifically bred to withstand high salt concentrations in soils, enabling successful crop cultivation in salt-affected areas.

Basic Features of the Technology: Salt-tolerant crop varieties are designed to thrive in saline-affected soils, where regular crop varieties would typically struggle due to the adverse effects of salt stress. They offer the potential to sustain agricultural productivity in regions with soil salinity issues.

Table 23 Salt-tolerant crop varieties

Salt-tolerant varieties	
Rice	CSR-36, CSR-43 and CSR-46
Wheat	KRL-210 and KRL-213
Barley	NDB 943
Mustard	CS-58 and CS 60

CSA Category: Development of salt-tolerant crop varieties falls under the "Nutrient Smart Technology" category of climate-smart agriculture.

A B C

Fig. 24 *Cultivation of salt-tolerant varieties of rice (A), wheat (C), and mustard (B)*

Main Focus/Benefits:

- Mitigation of salt stress in crop plants.
- Increased crop yields in salt-affected soils.
- Low-cost intervention.
- Suitable for resource-poor and marginalized farmers.

Drawbacks/Limitations:

- Dependence on the timely availability and accessibility of seeds.

Suitability of the Technology:

Geographical Area: Suitable for salt-affected regions, particularly in North India, including parts of Uttar Pradesh.

Cropping Pattern/Season: Primarily applicable to both Kharif and Rabi cropping seasons.

Agro-Ecosystem: Suited for salt-affected agricultural areas across various regions in India.

Adaptability Rate: The adoption of salt-tolerant crop varieties is cost-effective and particularly beneficial for resource-poor and marginalized farmers. Farmers have widely accepted this technology due to its simplicity and Low-cost.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of salt-tolerant crop varieties has demonstrated significant yield improvements, particularly in salt-affected areas. These varieties are easy to adopt and cost-effective, making them suitable for small, marginal, resource-poor farmers, and women farmers. The technology has shown promise in helping marginalized farmers increase their yields and income.

Benefits/Success Story with Yield/Cost-related Data:

In Uttar Pradesh, salt-tolerant wheat varieties, KRL-210 and KRL-213, were demonstrated in salt-affected villages. These varieties were capable of withstanding sodic conditions due to their built-in resistance to sodic ions. They achieved yield advantages of up to 59% compared to the traditional variety PBW-373. The salt-tolerant varieties resulted in higher net income of Rs. 25,675 and a B:C ratio of 1.73 compared to the farmer's variety PBW-373 during the year 2018-19.

Table 24 Performance of salt-tolerant wheat varieties in salt-affected regions of Uttar Pradesh

Intervention	Yield (q/ha)	Cost of cultivation (Rs. /ha)	Net income (Rs. /ha)	B:C ratio
KRL-210	34	34900	25500	1.60
KRL-213	32	34900	25675	1.73
Farmers practice: PBW-343	22	34700	3250	1.09

Enabling Factors:

- Low-cost intervention.
- Yield improvements.
- Simplicity of changing crop varieties for salt tolerance.

Challenges in Scaling Up:

- Timely availability and accessibility of salt-tolerant seeds remain major challenges in scaling up this technology. Collaboration with agricultural departments for distributing salt-tolerant seeds can facilitate wider adoption.

Other Relevant Information:

Environmental Impact: Salt-tolerant crop varieties contribute to environmental sustainability by allowing productive crop cultivation in salt-affected lands, thereby reducing pressure on prime agricultural lands and freshwater resources.

Technical Knowledge and Training: While the adoption of salt-tolerant crop varieties is relatively simple, providing farmers with technical knowledge and training can further enhance their ability to make the best use of these varieties.

Challenges in Adoption: Ensuring the timely availability of salt-tolerant seeds to farmers remains a critical challenge for widespread adoption of this technology, which can be resolved through coordinated efforts with agricultural departments.

References

Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country have developed salt-tolerant varieties. Especially Central Soil Salinity Research Institute (CSSRI) worked tremendously on salt-tolerant crop varieties suitable for salt-affected soils.

24. Heat-tolerant wheat varieties

Developed/Introduced/Compiled by: Heat-tolerant wheat varieties have been developed by the Indian Institute of Wheat and Barley Research (IIWBR) to address the challenges posed by rising temperatures during wheat growth phases. These varieties are bred to thrive in high-temperature conditions, ensuring consistent grain production even in the face of global warming.

Basic Features of the Technology: Heat-tolerant wheat varieties are designed to withstand high temperatures during the grain-filling period, which is crucial for wheat production. They exhibit strong stem strength, lodging tolerance, and resistance to various diseases, making them suitable for cultivation in regions prone to heat stress.

***Fig. 25** Cultivation of heat tolerant varieties*

CSA Category: Development of heat-tolerant wheat varieties falls under the "Weather Smart Technology" category of climate-smart agriculture.

Main Focus/Benefits:

- Improved wheat yield under high-temperature conditions.
- Enhanced resistance to diseases and lodging.
- Suitable for early sowing.
- Addresses the challenges of heat stress, ensuring food security.

Drawbacks/Limitations:

- Timely availability and accessibility of seeds remain a challenge.

Suitability of the Technology:

Geographical Area: Recommended for irrigated timely sown conditions in various regions, including Punjab, Haryana, Delhi, Rajasthan, Western U.P., Jammu and parts of Himachal Pradesh and Uttarakhand.

Cropping Pattern/Season: Suitable for Rabi cropping season.

Agro-Ecosystem: Ideal for irrigated wheat growing conditions.

Adaptability Rate: With increasing temperatures each year, these heat-tolerant wheat varieties have gained popularity among farmers. They offer a solution to the challenges posed by rising temperatures, ensuring consistent crop performance and increased income for farmers.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of heat-tolerant wheat varieties is a low-cost and simple intervention, making it accessible to smallholder farmers and women farmers. These varieties enable farmers to achieve good yields and returns even under heat waves.

Benefits/Success Story with Yield/Cost-related Data:

During the crop season 2021-22, the varieties DBW187 and DBW222 exhibited heat tolerance and achieved yield gains of 3.6% and 5.4%, respectively, compared to HD-3086 (Source: AICRP on Wheat and Barley progress report, 2020-21 & 2021-22).

Enabling Factors:

- Low-cost intervention.
- Improved wheat yield and resistance to heat stress.
- Public and private partnerships for seed production and distribution.

Challenges in Scaling Up:

- Timely availability and accessibility of seeds remain a challenge, but the IIWBR is working with private companies to promote these varieties.
- Integration into ongoing development programs like the National Food Security Mission (NFSM) is recommended for scaling up these heat-tolerant technologies.**References:** ICAR- Indian Institute of Wheat and Barley Research, https://iiwbr.icar.gov.in/varieties-of-wheat/

Promoting a Heat-Resistant Variety of Wheat, 2022, Ministry of Agriculture & Farmers Welfare, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1882246

25. Cold stress-tolerant crop varieties

Developed/Introduced/Compiled by: Cold-tolerant crop varieties have been developed by ICAR institutes and State Agricultural Universities (SAUs) to address the challenges posed by low non-freezing temperatures on various crops. These varieties are bred to thrive in cold conditions, ensuring consistent crop performance even in lower temperature environments.

Basic Features of the Technology: Cold-tolerant crop varieties are designed to withstand low temperatures, especially below 10–15°C, which can otherwise cause injury and reduce crop yields. They exhibit traits that allow them to perform well in cold stress conditions, reducing losses and increasing returns for farmers.

Table 25 Cold stress-tolerant crop varieties

Cold stress-tolerant varieties	
Rice	Bhrigudhan, HPR2143, HPR1068, RP2421, Palam, Basmati-1, Bhrigudhan, Varun Dhan, Gizza-14, K-39, K-343, K-448, Pant Dhan11, NE Megha Rice 1, NE Megha Rice 2
Wheat	RSP561, Shalimar wheat-I, Buland
Barley	NBHS352
Chickpea	PDG 4
Mustard	KBS-3, RGN-73, DRMRIJ-31
Soybean	RGN-73

CSA Category: Development of cold-tolerant crop varieties falls under the "Weather Smart Technology" category of climate-smart agriculture.

Main Focus/Benefits:

- Improved crop yields even under lower temperature conditions.
- Mitigation of losses due to chilling temperatures.
- Suitable for cold-hit regions, enhancing food security.

Fig. 26 *Cultivation of cold-tolerant mustard variety DRMRIJ-31 in Jodhpur*

Drawbacks/Limitations:

- Timely availability and accessibility of seeds may be a challenge.

Suitability of the Technology:

Geographical Area: Suitable for cold-prone regions in India, including Himachal Pradesh, Uttarakhand, Jammu, Kashmir, Rajasthan, Ladakh, and Northeastern states.

Cropping Pattern/Season: Suitable for Rabi cropping season.

Agro-Ecosystem: Ideal for cultivation under cold temperature conditions in India.

Adaptability Rate: Cold-tolerant crop varieties are a low-cost and straightforward intervention, making them accessible to small and marginal farmers and women farmers. Farmers have adopted these varieties to increase yields and returns, especially in areas prone to cold stress.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of cold-tolerant crop varieties is a low-cost and straightforward technology, making it widely accessible to smallholder farmers and women farmers. These varieties enable farmers to achieve higher yields and profits even in cold-prone areas.

Benefits/Success Story with Yield/Cost-related Data:

In Jodhpur district, the improved cold-tolerant mustard variety DRMRIJ-31 demonstrated increased yields and net returns over the local farmers' practice (NRCDR-2).

Table 26 Performance of Improved Cold-Tolerant Mustard Variety DRMRIJ-31

Intervention	Yield (q ha^{-1})	Cost of Cultivation (Rs. ha^{-1})	Net Income (Rs. ha^{-1})	B:C Ratio
Farmers' Variety: NRCDR-2	14.03	15,680	33,425	1:3.13
Improved Variety: DRMRIJ-31	19.74	16,300	52,790	1:4.23

Enabling Factors:

- Low-cost intervention.
- Improved crop yields in cold conditions.
- Public and private partnerships for seed production and distribution.

Challenges in Scaling Up:

Timely availability and accessibility of seeds may be a challenge, but raising awareness about cold-tolerant varieties and integrating them into seed supply chains can help overcome this challenge.

Reference

Mandapaka, Maheswari, Sarkar, Basudeb, Vanaja, Maddi, Rao, Mathukumalli, Prasad, J.V.N.S, Mathyam, Prabhakar, Gajjala, Ravindra, Venkateswarlu, Bandi, Choudhury, P, Yadava, DK, Bhaskar, Shreeram, & Alagusundaram, K. (2019). Climate Resilient Crop Varieties for Sustainable Food Production under Aberrant Weather Conditions.

https://www.researchgate.net/figure/Crop-Varieties-Suitable-for-Cultivation-under-Cold-Stress_tbl4_331731142

26. Short-duration drought-escaping crop varieties

Developed/Introduced/Compiled by: Short-duration and drought-escaping crop varieties have been developed by ICAR institutes and State Agricultural Universities (SAUs) to address the challenges posed by drought conditions. These varieties have shorter growth cycles, allowing them to complete their life cycles in 4 to 6 weeks, making them well-suited to arid and semi-arid tropics where droughts are common.

Basic Features of the Technology: Short-duration and drought-escaping crop varieties enable farmers to mitigate the impact of drought by completing their life cycles quickly. These varieties are well-suited for areas prone to drought and have predictable growth patterns, ensuring higher crop yields even in early-season droughts.

Table 27 Short-duration and drought-escaping varieties of crops

Short-duration and drought-escaping varieties	
Rice	DRR-42, DRR-44, Jogesh, Mandakini, SahbhagiDhan, Shusk, NDR 97, NDR 2064, 2065, NDR 3112
Wheat	PBW-373, K-7903, HD-2967
Maize	GM-6, Proline, Bajaura Makka, girija,
Finger millet	ML-365
Chickpea	JAKI-9218, BRG 4, GNG-1581
Greengram	TARM-1, IPM-02-03, Samrat, SML 668, IPM -2-3, PDM 139
Blackgram	PU-31, Shekhar-2, Azad Urd 2, Azad Urd 3
Pigeonpea	BDN-711
Cowpea	Sadabahar, Kasi Kanchan
Soybean	MAUS-158, Phule Sangam (KDS-726), JS-9305

CSA Category: Development of Short-duration and drought-escaping crop varieties falls under the "Weather Smart" and "Water Smart" technology categories of climate-smart agriculture.

Main Focus/Benefits:

- Higher crop yields in early-season drought conditions.
- Quick maturity of crops to escape drought.
- Suitable for drought-prone regions, enhancing food security.

Drawbacks/Limitations:

- Timely availability and accessibility of seeds may be a challenge.

***Fig. 27** Cultivation of Short-duration and drought-escaping finger millet (var. ML-365)*

Suitability of the Technology:

Geographical Area: Suitable for drought-prone areas of India, including Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Maharashtra, Uttar Pradesh, etc.

Cropping Pattern/Season: Suitable for both Kharif and Rabi cropping seasons.

Agro-Ecosystem: Ideal for cultivation in frequently drought-prone areas of arid and semi-arid tropics.

Adaptability Rate: The adoption of Short-duration and drought-escaping crop varieties is a low-cost and effective intervention, making it highly appealing to farmers in drought-prone areas. The technology has gained significant adoption due to its ability to save time and provide high yields even in drought conditions.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of Short-duration and drought-escaping crop varieties is a low-cost and accessible technology, making it suitable for smallholder farmers and women farmers. These varieties offer the advantage of resilience to drought and can significantly increase yields and income.

Benefits/Success Story with Yield/Cost-related Data:

Finger millet ML-365 variety was demonstrated to minimize the impact of low rainfall and dry spells. Significant improvements in yield were observed, with increases of up to 36-39% compared to the local variety. ML-365 demonstrated resilience to dry spells, resulting in higher grain yields.

Table 28 Yield, Cost, and Income of ML-365 Rice During Drought Year in South Karnataka Region

Districts	Intervention	Yield (q/ha)	Cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)
Tumkur	Farmers' practice: GPU-28	10.5	20830	27300	6470
	Improved variety: ML-365	14.6	21650	37960	16310
Davanagere	Improved variety: ML-365	26.5	35000	65650	30650
	Farmers' practice: Local variety	22.5	36200	56750	20550

Enabling Factors:

- Low-cost intervention.
- Increased awareness about the benefits of Short-duration varieties.
- Availability of seeds through seed supply chains.

Challenges in Scaling Up:

- Ensuring timely availability and accessibility of seeds to farmers. This challenge can be addressed by integrating these varieties into seed supply chains and promoting awareness among farmers.

References

Indian Council of Agricultural Research (ICAR) institutes and state agricultural universities located in different parts of the country have developed many Short-duration crop varieties that are suitable for cultivation in drought-prone districts.

27. Intercropping

Developed/Introduced/Compiled by: Intercropping is a well-established agricultural practice that involves growing two or more crops in close proximity. ICAR institutes and State Agricultural Universities (SAUs) have suggested specific intercropping interventions based on crop and season suitability to maximize yield and minimize risks.

Basic Features of the Technology: Intercropping is a farming practice aimed at increasing yields on a given piece of land by utilizing resources and ecological processes that might otherwise go unused by a single crop. It is a climate-smart technology falling under the "Energy Smart" category.

Table 29 Intercropping systems suitable for different states

Examples	Suitable states
soybean + pigeonpea (8:2)	Karnataka, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamilnadu
cotton + pigeonpea (8:2)	Karnataka, Andhra Pradesh, Gujarat
green gram + pigeonpea (2:1)	Karnataka, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamilnadu
maize + pigeonpea (6:1)	Karnataka, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamilnadu, Uttar Pradesh
finger millet + pigeon pea (4:1)	Karnataka, Andhra Pradesh, Tamilnadu
kodo millet + pigeon pea (10:2)	Karnataka, Andhra Pradesh, Tamilnadu
maize + soybean (2:1)	Madhya Pradesh, Karnataka, Andhra Pradesh, Tamilnadu, Uttar Pradesh
cotton + pigeon pea (4:2)	Karnataka, Andhra Pradesh, Gujarat

CSA Category: Intercropping systems fall under the "Energy Smart" category of climate-smart agriculture.

Fig. 28 *Intercropping Greengram + Pigeonpea (2:1) and Maize + Pigeonpea (6:1)*

Main Focus/Benefits:

- Maximizing yield on limited land.
- Efficient utilization of resources.
- Minimizing risks associated with single-crop farming.
- Pest and weed control.
- Nutrient enrichment of the soil.

Drawbacks/Limitations:

- Intercropping may require more field preparation.
- Compatibility and synergy between crops must be considered.
- Farmers need knowledge and training to implement effective intercropping systems.

Suitability of the Technology:

Geographical Area: Suitable for arid and semi-arid regions of India, including Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh, etc.

Cropping Pattern/Season: Applicable to both Kharif and Rabi cropping seasons.

Agro-Ecosystem: Best suited for arid and semi-arid regions of India.

Adaptability Rate: Intercropping has gained popularity among farmers, especially in regions with limited arable land. Farmers recognize the economic benefits of maximizing land productivity through intercropping systems.

Impact and Suitability to Smallholder Farmers and Women:

Intercropping has effectively maximized production on limited arable land, benefiting smallholder farmers with smaller land holdings. It has also increased farmers' income by creating additional revenue streams from their farms. This intervention is particularly suitable for small farmers with limited land resources.

Benefits/Success Story with Yield/Cost-related Data:

In S. Raguttahalli village, during the years 2014, 2016, and 2018, when there was a deficit of 50%, 34%, and 42% rainfall respectively, a Groundnut + Pigeon pea (10:2) intercropping system was demonstrated. This was aimed at minimizing the impact of dry spells and enhancing resilience. The intercropping system recorded higher net returns compared to sole groundnut cultivation.

Table 30 Productivity of Groundnut + Pigeon pea (8:2) intercropping in Tumkuru district

Intervention	Yield (q/ha)	Cost of Cultivation (Rs./ha)	Gross Returns (Rs./ha)	Net Returns (Rs./ha)
Groundnut + Pigeon pea BRG-2	15.3	18,000	34,500	16,500
Groundnut	13.0	17,600	26,000	8,100

Enabling Factors:

- Low-cost intervention.

- Increased awareness and knowledge about intercropping systems.
- Availability of suitable crop pairings for intercropping.

Challenges in Scaling Up:

- Farmer knowledge and training are essential for implementing effective intercropping systems. This can be addressed through field demonstrations, field days, agricultural fairs, etc.

References

Indian Council of Agricultural Research (ICAR) institutes and state agricultural universities located in different parts of the country have recommended location specific intercropping systems for maximizing yield and returns.

28. Drum seeding of rice

Developed/Introduced/Compiled by: In regions with small and marginal land holdings and hilly terrain, where draft animals and human labor are the primary sources of power for agricultural production due to low mechanization levels, the need for simple, suitable, and efficient machines or implements is crucial to improve agricultural efficiency. The transplanting of rice seedlings, a labor-intensive and expensive operation, can be replaced by direct seeding, reducing labor requirements by over 20% in terms of working hours.

Basic Features of the Technology: Drum seeding of rice in flooded soils is a water-smart technology. It allows farmers to directly sow pre-germinated rice seeds in the field, eliminating the need for nursery raising and transplantation.

Fig. 29 *Drum seeder technique of summer rice in Dhubri district*

CSA Category: This technology falls under the "Water Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Reducing labor-intensive transplanting.
- Saving on transplanting costs.
- Efficient use of water.
- Timely sowing, especially in areas prone to flash floods.
- Reducing the risk of flooding.
- Potential for earlier harvest.
- Suitable for regions with heavy weed infestation.

Drawbacks/Limitations:

- Weed management is a challenge.
- Requires effective use of weedicides.
- May not be suitable for areas with excessive weed pressure.

Suitability of the Technology:

Geographical Area: Suitable for paddy-growing regions in various states, including Karnataka, Andhra Pradesh, Tamil Nadu, Punjab, Haryana, and the northeastern states of India.

Cropping Pattern/Season: Applicable to Kharif, Rabi, and Summer cropping seasons.

Agro-Ecosystem: Suitable for regions where the sowing period is critical and not suitable for nursery raising, making the drum seeder technique an effective alternative.

Adaptability Rate: The drum seeder technique has gained popularity among farmers because it significantly reduces transplanting costs and labor requirements. Farmers have recognized the economic benefits of this intervention.

Impact and Suitability to Smallholder Farmers and Women:

The drum seeder technique has effectively reduced the drudgery of human labor and can be successfully implemented in farmers' fields. It eliminates the need for raising a nursery and transplanting seedlings, making it suitable for small and marginal farmers. Additionally, it allows for quicker crop establishment, potentially shortening the crop duration by 7-10 days compared to traditional practices.

Benefits/Success Story with Yield/Cost-related Data:

The adoption of the drum seeder technique led to effective water use and timely planting. Flash floods during Oct-Nov, which traditionally delayed summer rice sowing, could be overcome with the drum seeder technique. This reduced the quantity of seeds required and minimized cultivation costs by approximately Rs. 6,000-10,000 per hectare. Furthermore, rice yields increased by up to 14%, resulting in additional returns of Rs. 14,850 per hectare compared to normal planting.

Table 31 Performance of direct-seeded rice by drum seeder

Intervention	Yield (q/ha)	Cost of Cultivation (Rs./ha)	Gross Returns (Rs./ha)	Net Returns (Rs./ha)
Traditional method	33.5	40,650	50,250	9,600
Drum seeder technique	38.4	33,150	57,600	24,450

Enabling Factors:

- Cost savings in labor and transplanting.
- Efficient water use.
- Timely sowing to avoid flooding.
- Potential for earlier harvest.
- Suitability for small and marginal farmers.
- Technological simplicity.

Challenges in Scaling Up:

- Effective weed management is crucial.
- Awareness and training of farmers are needed.
- Availability and accessibility of drum seeder machines.
- Promoting the use of weedicides where necessary.

References

Krishi Vigyan Kendra, Chittoor, Andhra Pradesh had developed drum seeder for direct sowing of the pregerminated paddy seeds which will save lot of time, resource and energy.

Direct seeding in rice using drum- seeder, KVK, Chittoor, Andhra Pradesh https://www.aesanetwork.org/direct-seeding-in-rice-using-drum-seeder/#:~:text=In%20response%20to%20these%20practical,first%20time%20during%20rabi%202006.

29. Use of CSR-BIO for rice

Sodic soils pose a significant challenge to crop productivity, even after reclamation. The use of chemical fertilizers, such as gypsum, increases the financial burden on farmers and has negative environmental impacts. At present, there are no efficient strains available for soils with a pH of more than 8.5. While several microbial isolates function effectively as bio-fertilizers and bio-control agents for soils with a pH of 7.0-8.5, they are highly location-specific and often rely on single potential isolates. In response to these challenges, ICAR- Central Soil Salinity Research Institute, Karnal, has developed CSR-BIO, a bio-growth enhancer that integrates dynamic microbial consortia (*Bacillus* spp. & *Trichoderma* spp.) with dynamic culture media to increase crop productivity in sodic soils. CSR-BIO is a low-cost method for multiplying salt-tolerant bio-growth enhancers to boost the production of agri-horticultural crops in both normal and sodic soils. It promotes crop growth due to its growth-promoting qualities, making it an affordable, cost-effective, and environmentally beneficial technology. It can be applied as seed treatment, seedling dip, or soil application.

Fig. 30 *Seed treatment and seedling dip of rice nursery with CSR-BIO in Kaushambi district*

CSA Category: This technology falls under the "Nutrient Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Enhancing crop yields in salt-affected soils.
- Microbial consortia with universal applicability.

- Higher shelf-life and lower production cost.
- Eco-friendly and cost-effective.
- Wide acceptability among farmers.
- Demonstrated yield increase in various crops.

Drawbacks/Limitations:

- Requires effective awareness and training.
- Availability and accessibility of CSR-BIO.
- Weeding may still be necessary in some cases.

Suitability of the Technology:

Geographical Area: Suitable for salt-affected regions of India, particularly in Uttar Pradesh.

Cropping Pattern/Season: Applicable to Kharif, Rabi, and Summer cropping seasons.

Agro-Ecosystem: Suitable for paddy growing areas affected by salt.

Adaptability Rate: CSR-BIO has gained wide acceptability among farmers across the nation and has been adopted in about 10,800 hectares of land, covering seven states and involving approximately 18,400 farmers.

Impact and Suitability to Smallholder Farmers and Women:

CSR-BIO is an eco-friendly, cost-effective, and highly economical technology. It has demonstrated yield increases in various crops, making it suitable for small and marginal farmers. Its simplicity and affordability make it easy for adoption.

Benefits/Success Story with Yield/Cost-related Data:

The adoption of CSR-BIO has resulted in an average yield increase of 19.75% across various crops. Notable yield increases include 15% in paddy, wheat, tomato, capsicum, okra, mango, and guava, 24% in ixora, banana, jasmine, and greenhouse tomato, and 22% in chili and garlic. The technology also contributed to an 18% yield increase in gladiolus and potato.

Table 32 Performance of rice with and without intervention under sodic conditions

Intervention	**Yield (q/ha)**	**Cost of Cultivation (Rs./ha)**	**Net Income (Rs./ha)**	**B:C Ratio**
Application of CSR-BIO formulation as seed treatment	33	19,195	24,571	2.2
Without CSR-BIO formulation	28	19,000	17,094	1.9

Enabling Factors:

- Cost savings and yield enhancement.
- Universal applicability of microbial consortia.
- Eco-friendly and low production cost.
- Farmer acceptability and wide adoption.
- Demonstrated success in various crops.

Challenges in Scaling Up:

- Effective awareness and training.
- Availability and accessibility of CSR-BIO.
- Integration with state development programs.
- Ensuring proper application and management in various crops.

References

ICAR- Central Soil Salinity Research Institute, Karnal, Haryana

https://cssri.res.in/technology/

30. Halo Azo and Halo PSB technology

A significant strategy for managing salt-affected soils and improving crop yields is soil reclamation. However, traditional reclamation methods often involve the use of chemical fertilizers, which can raise costs, reduce soil fertility, and contribute to greenhouse gas emissions. To address these challenges, ICAR- Central Soil Salinity Research Institute, Karnal, has introduced a substitute strategy involving the application of PGPR (Plant Growth Promoting Rhizobacteria) to enhance soil productivity and reduce the need for chemicals in sodic soils. This approach is particularly relevant because effective PGPR strains for sodic environments with soil pH levels higher than 8.5 are limited.

Halo Azo and **Halo PSB** formulations have been developed for increasing productivity under sodic conditions. Halo Azo contains highly effective, salt-tolerant nitrogen-fixing bacteria Azotobacter species, while Halo PSB contains highly efficient salt-tolerant strains of phosphorus-solubilizing bacteria. These formulations are well-suited for soils with pH in the range of 7.5 to 9.9. Inoculating with nitrogen-fixers can augment 10 to 15 kg N/ha, and phosphorus solubilizers can augment 15 to 20 kg P_2O_5/ha. The liquid formulations have a shelf life of over one year.


Fig. 31 *Seed treatment Halo Azo and Halo PSB culture in wheat crop*

CSA Category: This technology falls under the "Nutrient Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Enhancing crop yields in sodic soils.
- Reduced reliance on chemical fertilizers.

- Use of salt-tolerant microbial strains.
- Improved nutrient mobilization.
- Shelf-stable liquid formulations.
- Low-cost and easy adoption.

Drawbacks/Limitations:

- Awareness and training are essential for effective adoption.
- Availability and accessibility of Halo Azo and Halo PSB.
- Integration with existing farming practices.

Suitability of the Technology:

Geographical Area: Suitable for salt-affected regions of Uttar Pradesh and Haryana.

Cropping Pattern/Season: Applicable to Kharif and Rabi cropping seasons.

Agro-Ecosystem: Can be adopted in paddy-wheat growing areas affected by salt.

Adaptability Rate: A significant number of farmers have adopted this intervention due to its Low-cost and feasibility. Its simplicity and applicability in the field make it particularly suitable for small farmers and can be easily adopted by women farmers.

Impact and Suitability to Smallholder Farmers and Women:

This technology has demonstrated a positive impact, especially in salt-affected soils. It has resulted in an average yield improvement of 13% in wheat crops when compared to crops without the application of microbial cultures. The Low-cost and ease of use make it suitable for small and marginal farmers, and its adoption can contribute to improved income.

Benefits/Success Story with Yield/Cost-related Data:

In a village of Kaushambi district, Halo Azo and Halo PSB microbial cultures were demonstrated in wheat crops (variety KRL-210). The cultures were seed-treated before sowing, offering protection against pests. The nitrogen-fixing bacteria (*Azotobacter*) in Halo Azo produce indole acetic acid and siderophores for nutrient mobility. When applied to the soil, they fix nitrogen and make it available to the plant, promoting plant growth under salt stress. Halo PSB improves root development, nutrient uptake, and overall crop growth. The application of these microbes resulted in a yield improvement of up to 13% compared to crops without microbial culture.

Table 33 Performance of wheat in salt-affected soils with and without intervention

Intervention	Yield (q/ha)	Cost of Cultivation (Rs./ha)	Net Income (Rs./ha)	B:C Ratio
Application of Halo Azo and Halo PSB formulation as seed treatment	36	25,207	28,793	2.1
Without microbial culture formulation in wheat crop	32	25,007	22,993	1.9

Enabling Factors:

- Cost savings and yield enhancement.

- Use of salt-tolerant microbial strains.
- Low-cost and easy adoption.
- Farmer acceptability and adoption.
- Demonstrated success in improving crop yields.

Challenges in Scaling Up:

- Awareness and training are essential.
- Availability and accessibility of Halo Azo and Halo PSB.
- Integration with existing farming practices and extension services.

Reference

ICAR- Central Soil Salinity Research Institute, Karnal, Haryana

https://cssri.res.in/technology/

31. Direct seeded rice

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research institutes.

Traditional rice farming methods consume a significant portion (approximately 40%) of the world's irrigation water resources for rice production. However, with the challenges posed by climate change, water scarcity, urbanization, labor shortages, and shrinking arable land, new strategies and innovations in rice farming are essential to meet growing food demand and maintain food security. One such innovative approach is Direct Seeded Rice (DSR), which offers a more sustainable and economically feasible method of rice production.

DSR represents a departure from conventional rice farming practices, which involve raising seedlings in a nursery before transplanting them into flooded fields. Instead, DSR is a crop establishment system where rice seeds are directly sown in the field. It is considered one of the most efficient, sustainable, and economically viable rice production methods available today.

__Fig. 32__ Direct seeded rice cultivation in Faridkot district of Punjab

CSA Category: DSR technology falls under the "Water Smart" and "Energy Smart" categories of climate-smart agriculture.

Main Focus/Benefits:

- Faster planting and maturation.
- Conservation of resources, including water and labor.
- Compatibility with mechanization.
- Reduced greenhouse gas emissions.
- Employment opportunities.
- Reduced labor intensity and drudgery, making it attractive to young and female farmers.

Drawbacks/Limitations:

- Weed management challenges.
- Need for awareness and adoption of weed management practices.
- Integration with existing farming practices.

Suitability of the Technology:

Geographical Area: Suitable for rice-growing regions in Karnataka, Andhra Pradesh, Tamil Nadu, Odisha, West Bengal, Uttar Pradesh, Punjab, Haryana, Chhattisgarh, and other areas.

Cropping Pattern/Season: Applicable to both Kharif and Rabi cropping seasons.

Agro-Ecosystem: Pan India technology suitable for rainfed rice-growing areas.

Adaptability Rate: DSR technology has gained acceptance due to its ability to save labor, reduce costs, eliminate the need for nursery preparation, and improve soil physical conditions. Farmers, particularly smallholders, are gradually adopting DSR cultivation.

Impact and Suitability to Smallholder Farmers and Women:

DSR technology is highly suitable for smallholder farmers and women. It saves labor, reduces costs, eliminates the need for nursery preparation, and offers improved soil conditions for future crops. Additionally, DSR is less labor-intensive and less physically demanding, making it an appealing option for young and female farmers.

Benefits/Success Story:

In a case study from Punjab, a farmer named Gurpreet Singh adopted direct seeding of Basmati rice in 5 acres and traditional transplanted coarse rice in another 15 acres. The average yield of direct-seeded Basmati rice was 51 q/ha, while that of transplanted coarse rice was 46.3 q/ha. With DSR, the farmer saved about Rs 3,000 to Rs 4,000 per hectare in labor costs and reduced irrigation water consumption by seven irrigations. While herbicide applications were necessary, the overall benefits were significant, leading the farmer to double the area under direct-seeded Basmati rice in the following season.

Enabling Factors:

- Cost savings and yield improvement.
- Resource conservation (water, labor, and energy).
- Reduction in labor intensity and drudgery.

- Compatibility with mechanization.
- Appeal to young and female farmers.
- Acceptance and adoption by smallholders.

Challenges in Scaling Up:

- Effective weed management practices are essential.
- Awareness and training are required for adoption.
- Integration with existing farming practices.
- Upscaling and creating awareness through field demonstrations.

References

Indian Council of Agricultural Research https://icar.org.in/content/profitable-paddy-cultivation-through-direct-seeding-technology-rice-wheat-seeder

Indian Rice Research Institute (IRRI)

https://dsrc.irri.org/our-work/what-is-dsr

32. Strip cropping in soybean and pigeon pea

Strip cropping is an agricultural practice where crops are planted in parallel bands across a slope but do not follow contour lines. In this technique, close-growing crop species are alternated with one another in strips. Strip cropping is highly effective in controlling erosion, particularly in soils and topographies where it is well-suited. This practice also helps reduce surface runoff and encourages water infiltration into the soil, contributing to rainwater conservation compared to sole cropping. For example, strip cropping of soybean and pigeonpea in a 4:2 ratio is recommended to minimize runoff and increase water use efficiency. The width of the strips can vary from 7.6 meters to 23 meters.

Fig. 33 Strip cropping in soybean and pigeon pea

CSA Category: Strip cropping technology falls under the "Water Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Effective erosion control.
- Improved water infiltration.

- Conservation of rainwater.
- Enhanced soil health and fertility.
- Reduction of sedimentation.
- Improved water quality.
- Nitrogen fixation.
- Attraction of pollinators.

Drawbacks/Limitations:

- Secondary species in strip cropping may not bring additional income.
- Management challenges may arise.

Suitability of the Technology:

Geographical Area: Suitable for adoption in Madhya Pradesh, Maharashtra, Karnataka, and Andhra Pradesh.

Cropping Pattern/Season: Strip cropping is applicable as an agricultural practice.

Agro-Ecosystem: Particularly suitable for soybean and pigeon pea growing areas.

Adaptability Rate: Farmers have adopted strip cropping due to its numerous benefits, including soil erosion prevention, moisture retention, soil nutrient improvement, and increased profitability.

Impact and Suitability to Smallholder Farmers and Women:

Strip cropping is highly suitable for smallholder farmers as it is a low-cost intervention. It effectively conserves moisture and reduces runoff, benefiting farmers in regions with limited resources.

Benefits/Success Story:

In Takali (Bk.) village of Amravati district, Maharashtra, strip cropping of soybean and pigeon pea was implemented during the year 2018-19. Despite experiencing dry spells, the strip cropping system effectively conserved moisture. This resulted in a 48% increase in crop yield compared to sole cropping of soybean. The strip cropping method enhanced net returns by up to Rs. 36,400 per hectare, which was 79% more than the farmers' practice. Even in a normal rainfall year, strip cropping showed significant yield advantages and additional net returns.

Table 34 Performance of Strip cropping in soybean and pigeon pea

Intervention	Crop yield (q/ha)	Net income (Rs/ha)	Improvement compared farmers practice (%)	B:C ratio
Farmers' practice (Soybean)	19.5	46250	79	1.6
Demo (Soybean and pigeon pea (4:2) equivalent yield)	29.0	82650		2.2

Enabling Factors:

- Low-cost of the technology.
- Reduction of runoff and moisture conservation.

- Effective erosion control.
- Benefits in terms of soil health and fertility.
- Improved water infiltration.
- Enhanced profitability.

Challenges in Scaling Up:

- Awareness and training are required for effective adoption.
- Integration with existing farming practices.
- Coordination with state development programs and stakeholders.
- Dissemination through interface meetings and central programs.

References

Indian Council of Agricultural Research https://icar.org.in/content/profitable-paddy-cultivation-through-direct-seeding-technology-rice-wheat-seeder
Indian Rice Research Institute (IRRI)
https://dsrc.irri.org/our-work/what-is-dsr

33. Dryland horticulture

Dryland farming is crucial for India's food security, as 68% of cultivated land falls under dryland ecosystems, contributing 44% of total food production. These areas are vulnerable to water scarcity, drought, and degradation, which affect food security and livelihoods. Traditional crops often fall short of meeting these challenges. By selecting suitable crops, improved varieties, and modern production technologies, drylands can be made more productive. Horticultural crops have significant potential in dryland areas and can provide economic products, stabilize income during periods of rainfall deficit, and offer ecosystem services like habitat preservation, erosion prevention, water regulation, microclimate control, and soil fertility improvement. Introducing fruit trees such as Jamun, Mango, Tamarind, Cashew, and Amla can provide higher returns compared to annual crops during drought years. While initial establishment can be challenging due to moisture constraints, micro irrigation techniques can help establish dryland horticulture.

Fig. 34 *Dryland horticulture in Tumkuru and Chikkaballapur districts*

CSA Category: Dryland Horticulture falls under the "Water Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Improved income for farm families.
- Efficient utilization of land resources.
- Diversified income sources.
- Mitigation of challenges related to water scarcity and drought.
- Economic products.
- Ecosystem services.
- Stability of income during rainfall deficits.

Drawbacks/Limitations:

- Small farmers may face difficulties due to landholding size.
- Initial establishment challenges.

Suitability of the Technology:

Geographical Area: Suitable for adoption in arable lands of Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and other low rainfall areas in arid and semiarid tropics.

Cropping Pattern/Season: Annual crop pattern.

Agro-Ecosystem: Suitable for water-scarce lands in arid and semiarid regions.

Adaptability Rate: Considerable numbers of farmers have adopted dryland horticulture interventions and have realized the benefits, including improved income and productivity of their land.

Impact and Suitability to Smallholder Farmers and Women:

Dryland horticulture is suitable for smallholder farmers, although their adaptability rate may be relatively lower due to smaller landholdings. However, larger farmers can easily adopt this intervention and benefit from it in dryland areas. Sustained income can be generated from fruit tree species, making it a valuable option for farmers.

Benefits/Success Story:

Farmers are earning sustained income from fruit tree species. For example, Amla planted in 2011 began yielding fruits in 2015, providing a net income of Rs. 27,900 per hectare by selling 1,700 kg of Amla fruits at Rs. 19/kg. Tamarind trees planted in 2011 started fruiting in 2017, resulting in a net income of Rs. 23,400 by selling 260 kg of Tamarind at Rs. 90/kg. Dryland horticulture has provided higher income and stable returns for farmers, utilizing off-season precipitation and making it valuable for small landholders and areas with water scarcity.

Enabling Factors:

- Economic benefits and stability of returns.
- Utilization of off-season precipitation.

- Suitable crop selection.
- Improved varieties.
- Modern production technologies.
- Diversified income sources.
- Ecosystem services.

Challenges in Scaling Up:

- Initial establishment of dryland horticulture crops.
- Creating awareness about micro irrigation techniques.
- Providing subsidies to support adoption.
- Encouraging smallholders to adopt the technology.

Reference

Reddy, A. G. K., Renuka Rani, B., Samuel, J., Pushpanjali, Yadagiri, J., & Jamanal, S. K. (2022). *Natural Resource Management for Sustainable Dryland Horticulture*. ICAR-Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad & National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India. 124p.

https://www.manage.gov.in/publications/eBooks/Natural%20Resource%20Management%20for%20sustainable%20dryland%20%20horticulture.pdf

34. Catch crop after recession of flood water

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research institutes.

India experiences various climatic conditions, including heavy rainfall leading to floods that can severely impact crop production through complete submergence of fields. Rice is the only crop that can survive submergence but can still get damaged under extreme flood situations with water stagnation for more than 20 days. In some years, floodwaters recede by September, presenting an opportunity for a catch crop to minimize crop loss from the kharif season. Scientists have recommended planting crops like toria or onion as catch crops after the recession of floodwater before taking up wheat cultivation. This helps reduce losses due to floods and increases returns. Catch crops also play a role in reducing nutrient leaching from the soil following the main crop, scavenging available nitrogen and other nutrients. Cover crops like these prevent soil erosion and suppress weeds.

***Fig. 35** Cultivation of catch crop after recession of flood water*

CSA Category: Catch Crop Farming falls under the "Water Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Efficient utilization of water, nutrients, and time.
- Reduction of losses caused by floods.
- Increased returns.
- Reduction of nutrient leaching.
- Prevention of soil erosion.
- Suppression of weeds.

Drawbacks/Limitations:

- Limited adoption by farmers due to market demand.
- Requires timely planting.

Suitability of the Technology:

Geographical Area: Suitable for flood-prone areas, especially in the northeastern parts of India.

Cropping Pattern/Season: Kharif season.

Agro-Ecosystem: Suitable for flood-prone paddy-growing areas of India.

Adaptability Rate: A significant number of farmers have adopted this intervention, especially in northeastern states, where flood-prone areas are prevalent.

Impact and Suitability to Smallholder Farmers and Women:

Catch crop farming is well-suited for smallholder farmers as it helps reduce losses from floods and efficiently utilizes leftover nutrients, water, and time. It can also be adopted by women farmers without the need for special skills.

Benefits/Success Story with Yield/Cost-related Data:

In NICRA villages, farmers grow onions for green leaf during September after the recession of floodwaters. This late kharif crop allows for timely planting of rabi crops. With the variety Agrifound Dark Red, farmers achieved an average yield of 355 quintals per hectare of green leaf, selling it in the local market at Rs. 20/kg. This resulted in a net return of Rs. 5,50,000/ha with a B:C ratio of 4.43.

Enabling Factors:

- Economic benefits.
- Efficient resource utilization.
- Reduced flood-related losses.
- Environmental benefits.
- Suitable for smallholder farmers.
- Adoption by women farmers.

Challenges in Scaling Up:

- Market demand and crop choice.
- Timely planting.
- Integration with agricultural institutions and state departments for input provision.

References

Indian Council of Agricultural Research institutes located in different parts of the country had recommended cultivate catch crop after the recession of the flood water in flood-prone districts of the country.

35. Water saving aerobic rice

More than half of all irrigation water used in Asia is for rice, and 75% of the world's rice production comes from irrigated land. Aerobic rice cultivation, as an alternative to traditional flooded rice cultivation, focuses on reducing water usage while sustaining productivity. Aerobic rice can be rainfed or irrigated, using various methods like flash-flooding, furrow irrigation, or sprinklers. Unlike flooded rice, irrigation is not meant to submerge the soil but to bring the soil water content in the root zone up to field capacity.

Aerobic rice, particularly drought-tolerant varieties like MAS-26, is suitable for direct sowing, avoiding puddling and transplanting. It offers resistance to pests and diseases and has the potential to save 50% of water and 80% of seed requirements.

Fig. 36 *Cultivation of aerobic rice*

CSA Category: Aerobic Rice Cultivation falls under the "Water Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Efficient water use.
- Higher yields.
- Drought tolerance.
- Reduced greenhouse gas emissions.
- Resistance to pests and diseases.

Drawbacks/Limitations:

- Poor field maintenance can result in crop failure.

Suitability of the Technology:

Geographical Area: Suitable for drought-prone areas of India.

Cropping Pattern/Season: Kharif and Rabi seasons.

Agro-Ecosystem: Suitable for low rainfall areas prone to frequent dry spells.

Adaptability Rate: A considerable number of farmers have adopted this variety for aerobic rice cultivation, although creating awareness and promoting adoption remains essential.

Impact and Suitability to Smallholder Farmers and Women:

Aerobic rice cultivation, particularly with drought-tolerant varieties, benefits farmers by achieving higher yields even in drought years. It can be particularly suited for smallholder farmers in low rainfall areas and can be adopted by women farmers.

Benefits/Success Story with Yield/Cost-related Data:

Farmers growing aerobic rice with the variety MAS-26 achieved higher yields of 16% in a drought year (2018) compared to traditional practices. In a normal year (2020), the same variety obtained a higher yield of 22% along with lower water consumption compared to normal transplanting. The resilience achieved was 111% due to aerobic rice variety MAS-26 compared to farmers' practice.

Enabling Factors:

- Economic water use.
- Adaptation to future climate change.
- Lower water consumption.
- Higher yields.
- Drought tolerance.
- Reduced greenhouse gas emissions.

Challenges in Scaling Up:

- Convincing farmers about the technology, which can be addressed through field demonstrations and training programs.

Reference

University of Agricultural Sciences, Bengaluru

https://kvktumakuru2.icar.gov.in/addressing-drought-vulnerability-by-cultivation-of-aerobic-paddy-mas-26/

Climate Resilient Livestock/Animal Production Technologies

36. Supplementation of area-specific mineral mixture

The productivity of dairy cows relies on balanced feeding, ensuring they receive all essential nutrients required for their physiological functions. In India, animal nutrition practices have traditionally been based on locally available feed supplies, which often lack specific minerals and have lower bioavailability, leading to mineral deficiencies and metabolic disorders in dairy animals. To address this, area-specific mineral mixtures have been developed as a scientific approach to supplement the dietary needs of dairy animals. This supplementation starts during the early growth stage of dairy animals, including calves or heifers. Lactating animals receive 100-200g daily, growing and non-producing animals receive 50g daily, and calves receive 25g daily. It can be mixed with concentrate or with common salt (15-20g). The duration of feeding is adjusted based on individual animal health, mineral status, and dietary composition. Nutritive mineral supplementation helps improve growth rates in calves, increase milk production, reduce heat stress, enhance reproductive efficiency, reduce calving intervals, extend the productive life of animals, and improve immunity. It contributes to overall animal health and immunity, thereby sustaining productivity during periods of stress.

CSA Category: This technology falls under the "Nutrient Smart" category of climate-smart agriculture.

Main Focus/Benefits:

- Efficient nutrient supplementation.
- Improved growth, milk production, and reproductive efficiency.
- Reduced heat stress.
- Extended productive life of animals.
- Enhanced immunity and overall animal health.

Fig. 37 *Feeding area-specific mineral mixture to cow and buffalo*

Drawbacks/Limitations:

- Potential challenges in ensuring adoption among small-scale farmers.

Suitability of the Technology:

Geographical Area: Suitable for arid and semi-arid regions to reduce heat stress among cows and buffaloes.

Agro-Ecosystem: Formulated for different agro-climatic zones to address specific deficiencies and imbalances.

Adaptability Rate: This technology has received positive feedback from a significant number of farmers and has rapidly spread among them due to its direct impact on milk production and animal health.

Impact and Suitability to Smallholder Farmers and Women:

Area-specific mineral mixtures are a low-cost intervention, making them accessible to small-scale farmers. It has the potential to increase their income by improving the productivity and health of their dairy animals. Women farmers can also readily adopt this intervention as it does not require specialized skills.

Benefits/Success Story with Yield/Cost-related Data:

Farmers in Ahmednagar district, Maharashtra, reported reduced anoestrus, repeat breeding problems, and enhanced conception, milk production, and fat percentage in milk. Repeat breeding was reduced by 32%, and anoestrus virtually disappeared. Approximately 68% of crossbred cows conceived with the first insemination following mineral and vitamin mixture supplementation. Milk production increased by 6.0%, while fat content increased by 3.1%. Although supplementation increased feed costs by Rs. 306/cow, net income improved by Rs. 1074/cow over a two-month period.

Table 35 Influence of area-specific mineral mixture on milk yield

Treatment	**Milk production (L/day/cow)**	**Fat (%)**	**Gross returns (Rs/cow/60 days)**	**Net returns (Rs/cow/60 days)**
No mineral mixture supplementation	13.72	3.57	18,522	6410
Mineral mixture supplementation @50-60g/cow/day	14.53	3.68	20,051	7484

Enabling Factors:

- Efficient nutrient supplementation.
- Improved productivity and animal health.
- Cost-effective intervention.
- Accessibility of locally available mineral sources.

Challenges in Scaling Up:

- Ensuring adoption among small-scale farmers due to limited resources, knowledge, and financial constraints.
- Overcoming challenges related to knowledge dissemination and awareness creation.

Reference

The National Dairy Development Board (NDDB)

https://www.nddb.coop/sites/default/files/pdfs/Mineral_Mixture%5B1%5D.pdf

37. Preservation of green fodder as silage

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located across India and state agriculture universities of respective states.

Many parts of India regularly face severe moisture stress conditions that hinder the growth of field and fodder crops. This situation intensifies during drought periods, leading to a shortage of fodder, especially in the summer. Silage making is a technique used to conserve animal feed for times when feed availability is limited. The silage making process involves cutting fresh fodder into small particles (1-2 cm) with a moisture content of 65-70%, compacting it using a tractor or roller to achieve a packing density of at least 200-250 kg of fresh matter per cubic meter, and storing it in a well-drained area away from direct sunlight and rain. Proper fermentation and stabilization occur when the silage is stored for at least 40-45 days under controlled conditions where air cannot contact the silage.

The recommended daily feeding allowance of silage for dairy cattle is typically around 1.5-2.5% of the animal's body weight, although this can be adjusted based on factors such as silage quality, availability of other feed sources, and desired production levels.

CSA Category: Silage making can be categorized as a "Weather Smart" and "Nutrient Smart" technology since it ensures the availability of nutritious fodder during lean periods.

Fig. 38 *Silage preparation and feeding to cow*

Main Focus/Benefits:

- Preservation of animal feed during periods of scarcity.
- Increased milk output and improved dairying practices.
- Enhanced income generation, poverty reduction, and animal protein supply.
- Particularly beneficial for smallholder dairy farmers.

Drawbacks/Limitations:

- Requires proper storage and controlled fermentation.
- Availability of surplus plant biomass for silage preparation.

- Potential need for awareness and training among farmers.

Suitability of the Technology:

Geographical Area: Silage making is applicable throughout India, with increasing interest among dairy farmers in Maharashtra, Karnataka, Telangana, and Andhra Pradesh, where modern dairy farming practices have been introduced.

Agro-Ecosystem: This intervention is suitable for areas that frequently face fodder shortages during lean periods.

Adaptability Rate: Farmers have benefited from this low-cost technology, and it can be adopted whenever surplus plant biomass is available, ensuring higher quality stored fodder during scarcity periods. Farmers have prepared silage in bags and trenches as per their requirements.

Impact and Suitability to Smallholder Farmers and Women:

Silage making is a low-cost intervention and is easily adoptable by small farmers. The technology has been demonstrated to increase milk production, with milch animals showing an average increase of 0.5-1.0 liter of milk per day. Women farmers can also readily adopt this technology, as it requires minimal inputs and can be handled manually.

Benefits/Success Story with Yield/Cost-related Data:

In selected villages of Karnataka, feeding cows with silage resulted in a 9.54% higher milk yield and an 8.62% higher net income compared to farmers' practices. The availability of fodder during the off-season led to increased milk production and income.

Table 36 Effects of feeding silage to livestock on milk yield

Intervention	Milk production (L/day/cow)	Gross returns (Rs/cow/60 days)	Net returns (Rs/cow/60 days)
Farmers' practice	8.15	19560	16560
Silage making	9.01	21624	18124

Enabling Factors:

- Low-cost and farmer-friendly ensiling procedure.
- Simplicity and manual handling.
- Adaptability for handling and feeding as per demands.
- Increased milk production and income.
- Potential for promotion through ATMA, State Animal Husbandry Departments, NGOs, and milk cooperative societies.

Challenges in Scaling Up:

- Ensuring awareness and training for farmers.
- Availability of surplus plant biomass for silage preparation.

Reference

National Dairy Research Institute (NDRI), Karnal, Haryana, National Dairy Development Board (NDDB), Anand. An Effective way of conserving green fodder,

https://www.nddb.coop/sites/default/files/pdfs/Silage_Making%5B1%5D.pdf

38. Azolla meal as a protein supplement for cattle

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located across India and respective Krishi Vigyan Kendras (KVKs) in various districts for grassroots initiation.

Drought-prone regions of India often face a significant shortage of green fodder, which makes it challenging for farmers to afford concentrates for feeding dairy animals, resulting in lower milk production. Although the availability and preservation of green fodder can be enhanced during the rainy season, it must be supplemented with a proper protein diet to sustain milk production, especially among poor farmers. Azolla, a free-floating water fern, contains approximately 25% crude protein and essential minerals like iron, calcium, magnesium, as well as significant quantities of Vitamin A and Vitamin B12. It is recognized as a cost-effective and abundant protein source due to its ability to synthesize amino acids, providing diet flexibility and cost-effective cattle breeding.

Azolla can be initially combined with ordinary feed for the first week and then fed directly to animals once it becomes succulent.

Fig. 39 *Azolla cultivation*

CSA Category: Azolla cultivation can be categorized as both a "Weather Smart" and "Nutrient Smart" technology, as it ensures the availability of nutritious fodder during lean periods and provides a cost-effective protein source.

Main Focus/Benefits:

- Sustainable availability of feed as per farmer's requirements.
- High nutritional content and rapid multiplication rate.
- Livestock readily digest azolla due to its high protein content and low lignin concentration.
- Ideal for small farmers due to ease of cultivation, Low-cost, and immediate rewards.

Drawbacks/Limitations:

- Availability of water bodies or ponds for azolla cultivation.
- Requires initial knowledge and training for successful cultivation.

Suitability of the Technology:

Geographical Area: Azolla can be grown in ditches, ponds, and wetlands of warm temperate and tropical regions.

Agro-Ecosystem: This intervention is suitable for areas that frequently experience fodder shortages during lean periods. Azolla units can be established in rocky and rainfed areas where green feed for animals is scarce.

Adaptability Rate: The affordability of azolla as an alternative to concentrated feed has garnered the attention of farmers. Its ease of cultivation and Low-cost make it highly adoptable, especially among small and marginal farmers.

Impact and Suitability to Smallholder Farmers and Women:

Azolla cultivation has shown positive impacts, particularly in increasing milk production by 7.8% in crossbred cows. It has also improved milk fat percentage by 0.5-1.0% compared to traditional feeding practices. Establishing azolla units and conducting demonstrations have raised awareness among farmers about supplementing animal feed with protein-rich azolla, benefiting both smallholder farmers and women involved in dairy farming.

Benefits/Success Story with Yield/Cost-related Data:

In S. Raguttahalli village of Chikkaballapur district, the daily nutrient requirement of milch animals was met by supplementing their diet with fresh azolla ration at 200-1000g daily. Each azolla ring produced 5-6 kg of fresh azolla per day for four months during the lean period.

Table 37 Effects of azolla feed on milk yield of livestock

Intervention	**Milch breed**	**Ration of azolla**	**Milk production (L/day/cow) %**		**% increase in milk production**
			Farmers practice	Intervention	
Azolla protein	HF	200g/daily	18.0	19.5	7.6-7.8
	Jersey	200g/daily	14.0	15.2	

Enabling Factors:

- Affordability of azolla as an alternative to concentrates.
- Ease of cultivation and Low-cost.
- High protein content and rapid multiplication rate.
- Increased awareness among farmers through demonstrations and azolla unit establishment.

Challenges in Scaling Up:

- Availability of suitable water bodies or ponds for azolla cultivation.
- Initial knowledge and training requirements for successful cultivation.

References

Kumar, U., & Nayak, A. K. (2019). *Azolla Germplasms at NRRI: Conservation, Characterization and Utilization*. NRRI Research Bulletin No. 19, ICAR- National Rice Research Institute, Cuttack -753006, Odisha, India, pp 68. URL: https://icar-nrri.in/wp-content/uploads/2019/07/1.-NRRI_Research-Bulletin-No.-19.pdf.

Mooventhan et al. (2019). *Azolla: The super plant for sustainable feed production. Indian Farming, 69*(06), 26–27.

URL: https://nibsm.icar.gov.in/images/Azolla_The_super_plant_for_sustainable_feed_production.Indian_Farming.pdf.

39. Hydroponic fodder production

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) in collaboration with respective R&D institutions of the country and Krishi Vigyan Kendras (KVKs) in various districts.

The availability of green fodder for livestock is limited due to land constraints and water scarcity, making it challenging to produce sufficient green fodder throughout the year. The lack of quality fodder hinders livestock growth, production, and reproduction. Hydroponic fodder is grown in trays measuring 2x1 sq. ft with a planting density of approximately 1.5-2 kilograms of seeds per square meter. To prevent fungal growth in the growing fodder, trays are dipped in a 0.1-1.5% sodium hypochlorite solution for 1 hour before soaking the seeds in normal water. Green fodder can be harvested between 7 to 12 days after sowing, reaching a suitable height of around 25-35 centimeters. On average, 1.0 kg of seeds in a tray can produce up to 5.0 kg of fresh green fodder through hydroponics. Establishing hydroponic fodder production can lead to increased production, stable harvests of high-quality fresh green fodder year-round, and the potential for commercial-scale production.

CSA Category: Hydroponic fodder production falls under the "Water Smart" technology category. It ensures sufficient green fodder availability year-round, leading to increased milk yields for cattle and higher income for farming families.

Main Focus/Benefits:

- Stable and economical feed source for livestock.
- Suitable for areas with limited cultivable land and water.
- Improves cattle health, conception rates, and milk taste.
- Reduces feed requirements by 25% and labor costs.
- Low-cost and easy-to-manage intervention.

Fig. 40 *Hydroponic green fodder production*

Drawbacks/Limitations:

- Requires initial knowledge and training for successful cultivation.
- Availability of suitable water bodies or trays for hydroponic fodder production.

Suitability of the Technology:

Geographical Area: Hydroponic fodder production is suitable for arid and hilly regions, as well as areas with high population density where cultivable land and water resources are scarce.

Agro-Ecosystem: This technology can be highly beneficial in regions facing shortages of green fodder during various seasons.

Adaptability Rate: Farmers have widely accepted hydroponic green fodder due to satisfactory results. They find the fodder highly palatable, digestible, nutritious, and rich in protein compared to conventionally grown fodders. Farmers have reported improvements in cattle health, conception rates, reduced feed requirements, improved milk taste, and decreased labor costs.

Impact and Suitability to Smallholder Farmers and Women:

In Siddanuru village of Davangere district, feeding cattle with hydroponic maize fodder at 1 kg/day during summer months for crossbred cows resulted in a 14.6% increase in milk production and a 27% increase in income compared to feeding cattle with dry roughages only. The staggered sowing of fodder maize allowed continuous production and supply of green fodder to milch animals.

Benefits/Success Story with Yield/Cost-related Data:

The technology has shown positive impacts, including increased milk production, improved cattle health, and higher income for farmers.

Table 38 Milk yield of livestock supplemented with hydroponic fodder

Intervention	Milk yield (L / Day)	Cost of cultivation (Rs)	Net return (Rs)
Farmers' practice: sole dry roughage feeding	9.10	128	100
Supplementation of fodder maize along with Roughages	10.66	130	137

Enabling Factors:

- Low-cost and easy-to-manage features make it attractive to farmers.
- Promotion through National Livestock Mission, State Agricultural Universities (SAUs), and Krishi Vigyan Kendras (KVKs) can help reach more farmers.
- Trainings and demonstrations facilitate adoption.

Challenges in Scaling Up:

- Availability of suitable water bodies or trays for hydroponic fodder production.
- Initial knowledge and training requirements for successful cultivation.

References

ICAR Research Complex, Goa; Rajasthan University of Veterinary & Animal Sciences, Bikaner; Tamil Nadu Veterinary and Animal Sciences University, Chennai is working on hydroponic fodder production.

NAAS (National Academy of Agricultural Sciences). (2017). *Policy Paper No. 85 Hydroponic Fodder Production in India*. National Academy of Agricultural Sciences, New Delhi: 27p.

Hydroponics: A sustainable way of green fodder production. (2023). *Indian Farming*, 73(02), 02-05. URL: https://epubs.icar.org.in/index.php/IndFarm/article/view/130176.

40. Year-round fodder production

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) in collaboration with the Indian Grassland and Fodder Research Institute (IGFRI) and Krishi Vigyan Kendras (KVKs) in various districts.

In several rice and wheat-growing districts of India, milk productivity is very low (3.2 liters/day/animal) due to rainfall variability and poor health of milch animals. This can be attributed to continuous feeding of rice and wheat straw without the use of green fodder. Lack of grazing areas in villages during the rainy season, owing to waterlogging conditions, leads to fodder scarcity. Cultivating high-yielding, perennial fodder crop varieties such as Berseem (Vardhan and BL-10), Oat (Kent), Napier (NB-21), Sudan grass (MFSH-4), and Napier (NB -21) can help increase milk yield and net returns.

Fig. 41 *Year-round fodder cultivation*

CSA Category: Perennial fodder crop cultivation falls under the "Weather Smart" technology category. It leads to the production of green fodder during the off-season, ensuring a stable feed supply for livestock.

Main Focus/Benefits:

- Increased milk yield and net returns.
- Suitable for arid and semi-arid tropics with well-drained soils.
- Year-round fodder availability.
- Low-cost intervention.
- Can be adopted by small farmers.

Drawbacks/Limitations:

- Requires fertile land, reliable irrigation, and higher fertilizer doses.
- Labor-intensive due to daily harvesting.
- Challenges in the timely availability of agricultural inputs.
- Limited cultivable area for fodder crops.

Suitability of the Technology:

Geographical Area: The technology is suitable for sub-tropical and warm temperate regions of the country, particularly in arid and semi-arid tropics with well-drained soils.

Agro-Ecosystem: Perennial fodder cultivation provides year-round fodder for dairy animals, making it suitable for areas facing seasonal fodder scarcity.

Adaptability Rate: Farmers have widely adopted improved varieties of perennial fodder crops, resulting in increased green fodder production and milk yield. Improved varieties can be scaled up through collaboration with the Animal Husbandry Department.

Impact and Suitability to Smallholder Farmers and Women:

In Mahopar village of Gorakhpur district, improved varieties of Sorghum (HC-136) + Cowpea (BL-2) were sown as a mix and recorded 680 q/ha of green fodder in a short time. Sole sorghum during July to October recorded 520 q/ha of fodder yield (two cuttings) compared to the existing local variety (265 q/ha). Improved variety of berseem (Vardan) recorded a 26% higher fodder yield. Makkhan grass (NS-07) demonstrated its impact as a milk yield booster.

Table 39 Annual fodder yield, milk yield, and economic returns of year-round cultivation of fodder crops

Intervention	Annual fodder yield (q/ha)	Milk Yield (L/day)	Cost (Rs. /day/ animal)	Net income (Rs. /day/animal)
Sorghum + Cowpea-Berseem -Muiticut chari	1730	5.6	158	94
Sorghum-Oat-cowpea Napier	1240	4.8	151	65
Sorghum & Napier	766	3.6	121	41
Berseem (Vardhan)	710	3.4	118	35
Napier-Makkhan grass-cowpea	990	4.4	148	50

Benefits/Success Story with Yield/Cost-related Data:

The technology has shown positive impacts, including increased milk production, improved cattle health, and higher income for farmers.

Enabling Factors:

- Low-cost intervention.
- Collaboration with institutions like IGFRI and KVKs for promotion.
- Production of quality seeds and organizing demonstrations.
- Awareness creation among farmers for sustainable fodder production.

Challenges in Scaling Up:

- Dependence on fertile land and reliable irrigation.
- Labor-intensive daily harvesting.
- Timely availability of agricultural inputs.
- Limited cultivable area for fodder crops.

References

Indian Grassland and Fodder Research Institute (IGFRI), Jhansi; National Institute of Animal Nutrition and Physiology (NIANP), Bengaluru

ICAR-IGFRI (2021). Fodder Resources Development Plan for Uttar Pradesh, *ICAR-Indian Grassland and Fodder Research Institute,* Jhansi.

41. Composite fish culture

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and respective Krishi Vigyan Kendras (KVKs) in various districts for grassroots initiation.

Composite fish culture is a popular technique for maximizing fish yield in ponds and reservoirs. It involves a comprehensive management system, including pond preparation, stocking, fertilization, manuring, supplemental feeding, and periodic harvesting. This method promotes the co-culture of compatible and non-competing fish species, each occupying distinct feeding zones within the pond or reservoir. This strategy optimizes the utilization of available food resources in the water, leading to increased fish output per unit area and higher biomass. Common carp species like rohu, catla, and mrigal are often stocked together, with stocking densities ranging from 1,500 to 2,500 fingerlings per acre. Fishes are fed between 1% to 5% of their body weight per day through multiple feedings. Intensive fish farming, with higher stocking densities, may use pond areas ranging from 0.01 to 0.1 hectare.

CSA Category: Composite fish culture can be categorized as a "Water Smart" technology. It efficiently utilizes water resources for income generation.

Main Focus/Benefits:

- Efficient utilization of water resources.
- Increased fish yield and biomass.
- Diversified income source.
- Suitable for different agro-ecological zones.
- Adoption in high rainfall areas and community tanks.

Drawbacks/Limitations:

- Limited access to quality fingerlings or fish seed.
- Dependence on reliable hatcheries and nurseries.

4. ***Fig. 42*** *Composite fish culture*

Suitability of the Technology:

Geographical Area: Composite fish culture is suitable for different agro-ecological zones in India, making it adaptable to various regions.

Agro-Ecosystem: This technology can be adopted in areas with high rainfall and can be implemented in community tanks and village ponds where excess water accumulates, reducing production costs and increasing productivity.

Adaptability Rate: Farmers initially had poor knowledge of fish stocking density, size, and ratio, resulting in underutilization of available resources. On-site training and pond renovations made it more accessible for farmers, turning it into an additional income source.

Impact and Suitability to Smallholder Farmers and Women:

The technology can be easily adopted by small and marginal farmers due to its minimal investment requirements. It leads to improved production, income, and nutritional status for farmers.

Benefits/Success Story with Yield/Cost-related Data:

In water harvesting structures, water levels typically decrease after December, affecting fry growth. However, yearlings become table-size and can be harvested within six months of the culture period. Floating fish feed applied at 1% of the body weight of fish daily resulted in higher survival rates (94%) compared to traditional practices (65%). Fish yields of more than 6 q/ha were recorded, along with additional net income of more than Rs. 50,000.

Table 40 Performance of composite fish culture

Intervention	Survival rate (%)	Yield (q/ha)	Net returns (Rs)
Farmers' practice	65	20	40,000
Composite fish culture	94	26	90,000

Enabling Factors:

- Low-cost intervention.
- Collaboration with ICAR institutes and KVKs for promotion.
- Availability of training and renovation support.
- Diversified income source for farmers.

Challenges in Scaling Up:

- Ensuring access to quality fingerlings and fish seed.
- Maintaining reliable hatcheries and nurseries for seedstock.

Composite Fish Culture stands as a prime example of how scientific advancements in agriculture can empower smallholder farmers. By efficiently using available water resources, this technology enhances fish yield, provides a diversified income source, and improves the livelihoods of rural communities. However, addressing challenges related to access to quality fingerlings and maintaining reliable hatcheries is crucial for scaling up its adoption. As a "Water Smart" CSA technology, Composite Fish Culture contributes not only to food security but also to sustainable water resource management, making it a valuable addition to India's agricultural practices.

References

AICRP on Composite Fish Culture and Fish Seed Production under ICAR- Central Inland Fisheries Research Institute, Barrackpore, Kolkata and ICAR-Central Coastal Agricultural Research Institute, Goa

https://ccari.icar.gov.in/dss/inlandfish.html

42. Shelter management in dairy animals

Improved Low-Cost Housing for Dairy Animals, developed in collaboration between Indian Council of Agricultural Research (ICAR) institutes, the Animal Welfare Board of India, and Krishi Vigyan Kendras (KVKs), addresses the critical issue of heat stress in dairy cows. Extreme weather conditions can significantly impact milk production, quality, and cow health. This technology provides cost-effective shelter solutions for dairy animals, enhancing their well-being and overall productivity.

Heat stress is a leading cause of production loss in dairy cows, affecting attributes such as milk output, milk quality, and milk composition. Improved housing that provides a conducive environment for good health and protects animals from extreme weather conditions can help dairy cows perform to their genetic potential. The improved low-cost housing for dairy animals typically consists of asbestos sheets, wooden poles, and loose flooring. These housing structures come in various dimensions to cater to the needs of farmers based on their farm size and animal numbers. The houses are surrounded by compound walls of 3-4 feet in height to protect animals from heatwaves during the day. The housing can be constructed in an East-West direction to maximize natural light and provide optimal open space. Combined with proper cooling strategies and feeding programs, improved shelter can mitigate the negative effects of climatic stress and enhance milk quality and quantity.

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes in collaboration with the Animal Welfare Board of India and respective Krishi Vigyan Kendras (KVKs) in various districts for grassroots initiation.

Fig. 43 *Improved shelter to minimize heat stress in livestock*

CSA Category: The improved low-cost housing for dairy animals falls under the "Weather Smart" category as it provides shelter and protection to animals from extreme weather conditions, thereby improving animal health and productivity.

Main Focus/Benefits:

- Shelter to protect animals from extreme weather conditions.
- Enhanced animal health and productivity.
- Controlled breeding and reduced health risks.
- Energy conservation for meat and milk production.
- Reduced feed waste.
- Overall enhanced productivity.
- Support for nutrient recycling or soil fertilization.

Drawbacks/Limitations:

- Customization required for local conditions.

Suitability of the Technology:

Geographical Area: This intervention is suitable for arid and semi-arid regions of India.

Agro-Ecosystem: Suitable shelter management practices can be implemented in various agro-climatic zones across the country. Improved shelter can also act as a barrier in areas where cold stress is experienced during the winter season.

Adaptability Rate: Farmers have shown significant interest in adopting improved shelter technology, leading to higher returns. Many farmers have started constructing improved shelters based on recommendations.

Impact and Suitability to Smallholder Farmers and Women:

This technology can empower farmers to increase their income by providing protective shelter to their animals. Improved housing results in better feed intake, reduced cold stress during winter, increased milk productivity (16-29% per animal), and higher farmer income (around Rs. 25,000 per year).

Benefits/Success Story with Yield/Cost-related Data:

Improved shelter construction led to increased feed intake in buffaloes and reduced the entry of cold waves during winter. Milk productivity saw a significant increase of 16-29% per animal, resulting in higher farmer income of around Rs. 25,000 per year.

Table 41 Effect of improved shelter on milk productivity of livestock

Intervention	**Type of material used**	**Cost of Rearing (Rs. /animal/year)**	**Milk productivity (L/day/animal)**		**Net returns (Rs. /ha)**
			Cow	Buffalo	
With shelter	Asbestos Sheet with Iron rod	11,000 (Housing cost 5,000)	10.6	9.9	91,760
Without shelter	Open area	5000	7.5	7.8	62,000

Enabling Factors:

- Collaboration with ICAR institutes, Animal Welfare Board of India, and KVKs.
- Customization of shelter management practices to suit local conditions.
- Mitigation of heat stress challenges.
- Enhanced farmer skills and knowledge.

Challenges in Scaling Up:

- Variability in local conditions may require customization.

Improved Low-Cost Housing for Dairy Animals represents an impactful intervention in Indian agriculture. By mitigating the effects of heat stress and extreme weather conditions, it contributes to improved animal health, increased milk productivity, and higher farmer income. While challenges in customization and scalability exist, this "Weather Smart" CSA technology has the potential to transform dairy farming in arid and semi-arid regions, benefiting smallholder farmers and women in particular. It exemplifies the importance of innovative solutions in addressing climate-related challenges in agriculture.

References

The National Dairy Research Institute (NDRI), Karnal, Haryana brings out extensive research in collaboration with other research institutes, state agricultural universities, and dairy development agencies to disseminate knowledge and best practices in housing and shelter management for dairy animals.

43. Low-cost Mechang type poultry house

Low-Cost Mechang Type Shelter for Backyard Poultry, developed in collaboration with Indian Council of Agricultural Research (ICAR) institutes and state agriculture universities, addresses the vulnerability of backyard poultry to extreme weather conditions, especially in flood-prone areas. This technology introduces affordable shelters and improved poultry breeds, improving the livelihoods of smallholder farmers and empowering women in the process.

Backyard poultry farming is an accessible and valuable source of eggs and meat in rural areas, particularly for poverty alleviation. Many farmers practice open rearing of poultry birds without shelter, which can lead to high mortality due to submergence, especially during floods. Seasonal diseases also pose a risk in flood-prone regions. To mitigate these challenges, low-cost improved Mechang type shelters are introduced to protect poultry birds, and improved breeds like 'Vanaraja' are introduced in flood-prone districts of Assam. The low-cost Mechang shelter measures 8 ft x 5 ft with a 4 ft raised house and costs up to Rs. 3,500, making it affordable for farmers.

Fig. 44 *Rearing poultry in Mechang type poultry house in Manipur district*

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in various parts of the country and state agriculture universities of respective states.

CSA Category: The installation of low-cost Mechang type poultry houses falls under the "Weather Smart" category as it protects poultry birds from extreme weather conditions, including high rainfall and floods.

Main Focus/Benefits:

- Protection of poultry birds from floods and extreme weather.
- Reduction in bird mortality.
- Enhanced productivity through improved breeds.
- Low-cost and accessible technology.
- Contribution to poverty alleviation and improved food security.

Drawbacks/Limitations:

- Geographically limited to high rainfall and flood-prone areas.

Suitability of the Technology:

Geographical Area: This technology is suitable for adoption in the northeastern states of India.

Agro-Ecosystem: It is particularly suitable for high rainfall areas facing frequent floods.

Adaptability Rate: Farmers have shown a positive response to this intervention, as it helps alleviate poverty, improve financial stability, and enhance nutritional status.

Backyard poultry is often managed by farm women, providing them with a source of income.

Impact and Suitability to Smallholder Farmers and Women:

The technology is cost-effective for farmers, making it feasible for widespread adoption. Poultry rearing contributes to household food security, income generation, and employment opportunities, thereby contributing to poverty reduction. Farmers benefit even under climatic stresses, making it an attractive and low-risk option. The technology can be scaled up in larger areas with support from organizations like AAU, Animal Husbandry departments, National Livelihood Mission, and through Self-Help Groups (SHGs).

Benefits/Success Story with Yield/Cost-related Data:

This low-cost poultry house prevented inundation during floods, reducing bird mortality to 20% compared to 45% in local practices. Disease incidence also decreased to 25% compared to 85% in farmers' practices. The introduction of the improved breed 'Vanaraja' resulted in birds attaining a body weight of 2.5 kg/year with egg production of 110-120 per year. The improved shelter generated a net income of Rs. 2,580 per unit, compared to Rs. 300 per unit or even total failure due to floods in traditional practices.

Table 42 Economic analysis of Mechang type of poultry house

Intervention	Cost of rearing (Rs. /Unit (20 birds))	Gross return (Rs. /Unit (20 birds))	Net return (Rs. /Unit (20 birds)
Farmers' practice	1200	1500	300
Low-cost Mechang type shelter	1820	4,400	2,580

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- Affordable and low-cost technology.
- Positive impact on poultry health and productivity.
- Potential for poverty alleviation and improved food security.

Challenges in Scaling Up:

- Geographical limitation to flood-prone regions.

Low-Cost Mechang Type Shelter for Backyard Poultry is a prime example of a "Weather Smart" CSA technology tailored to specific geographic and climatic conditions. Its successful adoption in northeastern India demonstrates its potential for alleviating poverty, enhancing food security, and improving the livelihoods of smallholder farmers, particularly women. While its geographical scope is limited, its impact on poultry health, productivity, and income generation is significant, making it a valuable intervention in the context of climate-smart agriculture.

Reference

Central Agricultural University (CAU), Imphal, Manipur; College of Veterinary Science, Poultry Science, Assam Agricultural University in assistance with ICAR Research Complex for NEH Region, Meghalaya.

44. Deep litter system of housing for pigs

The Deep Litter System of Housing for Pigs, developed in collaboration with Indian Council of Agricultural Research (ICAR) institutes and state agriculture universities, addresses the challenge of heat stress in pig rearing. By providing a cost-effective and environmentally friendly housing solution, this technology enhances pig health and productivity, particularly in arid and semi-arid tropics.

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in various parts of the country and state agriculture universities of respective states.

Pigs have significant economic potential for farmers due to their high fecundity, efficient feed conversion, early maturity, and short generation interval. However, poor housing management often leads to heat stress in pigs. To address this issue, the deep litter system of housing was introduced for pigs, aiming to mitigate heat stress. In this system, pigs are reared on bedding consisting of sawdust (40%), paddy husk (20%), dry soil (20%), charcoal (10%), and dried tree leaves (10%), which costs about Rs. 3,600 per unit.

Fig. 45 *Rearing pigs in deep litter system of housing*

CSA Category: The deep litter system of housing for pigs falls under the "Weather Smart" category as it protects pigs from severe heat stress and provides a cost-effective, environmentally friendly solution.

Main Focus/Benefits:

- Mitigation of heat stress in pigs.
- Cost-effective and low-maintenance housing.
- Reduced environmental impact.
- Enhanced pig health and productivity.
- High-quality compost production from the bedding material.

Drawbacks/Limitations:

- Geographically limited to arid and semi-arid tropics.

- Requires proper construction and management practices.

Suitability of the Technology:

Geographical Area: This technology is suitable for adoption in arid and semi-arid tropics.

Agro-Ecosystem: Pig rearing in the deep litter system is particularly beneficial in upland areas of the northeastern region, providing additional income opportunities for tribal farmers.

Adaptability Rate: Farmers find the deep litter system to be less expensive, pig-friendly, and environmentally sustainable. It eliminates the need for effluent ponds and produces enriched manure that can be used as a natural fertilizer.

Impact and Suitability to Smallholder Farmers and Women:

This technology has the potential to enhance the livelihoods of smallholder farmers, particularly weaker sections of society. It offers better insulation against temperature fluctuations and helps maintain optimal environmental conditions for pig rearing.

Benefits/Success Story with Yield/Cost-related Data:

The deep litter housing system for pigs provides insulation against temperature fluctuations, reducing the impact of climatic stresses. It contributes to higher pig survival rates, adequate body weight gain, and minimized mortality. Additionally, it significantly reduces water consumption and enhances meat productivity, resulting in higher net income per pig. Compared to conventional concrete floor pig houses, the deep litter housing system resulted in several positive impacts:

- Higher daily body weight gain.
- Improved feed conversion ratio.
- Increased survival rate of pigs.
- Significantly reduced water requirement.
- Enhanced meat productivity (up to 36% increase).
- Higher net income per pig (Rs. 5,892).

Table 43 Productivity and profitability of deep litter system of housing for pigs

Intervention	Body weight gain in 12 months (kg/pig)	Water requirement (L)	Cost of rearing (Rs/unit)	Gross return (Rs. /pig)	Net return (Rs. /pig)
Farmers' practice	48	18	3,650	7,680	4,030
Deep litter housing system	65	4	4,508	10,400	5,892

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- Cost-effective and pig-friendly housing solution.
- Reduced environmental impact.
- Potential for increased income for farmers.

Challenges in Scaling Up:

- Requires proper training and capacity building for construction and management.
- Geographical limitation to specific regions.

The Deep Litter System of Housing for Pigs is a valuable "Weather Smart" CSA technology that offers significant benefits to pig farmers, especially smallholders. Its impact on pig health, survival rates, and income generation underscores its potential to improve livelihoods and enhance food security. While its adoption is geographically limited, its cost-effectiveness and environmental sustainability make it a promising intervention in the context of climate-smart agriculture. Proper training and support are essential for successful scaling up and widespread adoption.

Reference

ICAR Research Complex for NEH Region, Meghalaya in collaboration with National Research Centre on Pig (NRCP), Guwahati.

https://krishi.icar.gov.in/jspui/bitstream/123456789/72496/1/deep%20litter%20housing%20for%20pigs.pdf

45. Breed upgradation in goat for drought-prone areas

Livestock plays a crucial role in mixed farming systems and serves as an alternative source of income for many rural households. To ensure a stable income, mixed farming can be integrated with goat rearing. However, some native goat breeds exhibit low productivity compared to improved breeds in the country. To enhance meat productivity, particularly under stress conditions, various improved goat breeds have been introduced, including Beetal Buck, Black Bengal, Osmanabadi, Sangamneri, Barbari, and Kannaiadu, known for their high-quality chevon production. Additionally, several goat breeds such as Jamunapari, Beetal, Jakhrana, and Surti are renowned for milk production, while Changthangi, Chegu, and Gaddi show promise for fiber/pashmina production.

***Fig. 46** Osmanabadi and Sangamneri breed goats*

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

CSA Category: Breed upgradation for improved goat breeds can be categorized under "Weather Smart" technology, as these breeds are known for their productivity even under stress conditions.

Main Focus/Benefits:

- Enhancing meat, milk, and fiber production.
- Improved adaptability to varying climatic conditions.
- Reduced mortality rates and increased twinning.
- Enhanced income generation for rural communities.
- Mitigation of climate-related risks in livestock farming.

Drawbacks/Limitations:

- Limited geographical suitability.
- Variability in the success of breed upgradation programs.
- The need for awareness and extension services.

Suitability of the Technology:

Geographical Area: This technology is suitable for states like Uttar Pradesh, Haryana, Punjab, and Gujarat.

Agro-Ecosystem: Improved goat breeds can be domesticated in various agro-climatic zones, making them suitable for lowland, midland, and highland areas. They require lower investment and are adaptable to different rearing systems.

Adaptability Rate: The adoption of improved goat breeds has yielded positive results, with significant reductions in kid mortality and increases in twinning rates. Farmers in various regions have initiated commercial goat farming after witnessing the success of breed upgradation programs. This technology is especially beneficial for small and marginal farmers due to its Low-cost and high-income potential.

Impact and Suitability to Smallholder Farmers and Women:

The introduction of superior genetics from high-yielding meat goat breeds through crossbreeding or hybridization can significantly enhance meat production potential in local breeds like Osmanabadi and Sangamneri. This approach retains the desirable adaptive traits of local breeds while boosting productivity. Goat farming with improved breeds is well-suited for promoting food security among women and reducing poverty, as it can be easily managed by underprivileged individuals, including women and children, and provides essential nutrients even in remote areas.

Benefits/Success Story with Yield/Cost-related Data:

In Ahmednagar district, 13 improved breeds, including Osmanabadi and Sangamneri bucks, were introduced for breed upgradation. Approximately 766 local goats were upgraded to Osmanabadi and Sangamneri crosses, resulting in significant improvements:

- Kid mortality reduced by 62%.
- Twining rates increased by 313%.
- Live weight at 3, 6, and 9 months was higher in upgraded goats compared to local goats.
- Average daily weight gain of 87.4±2.88 g/day was observed.

This success led to the initiation of commercial goat farming by 12 farmers in the village, contributing to increased income despite low rainfall.

Table 44 Performances of improved breeds of goat in drought-prone areas

Details of Intervention	Breed	Birth weight of kids (kg)	Twinning (%)	Market weight (kg)	Income (Rs. Per goat)
Farmers practice (Local breeds)	Non-descriptive	2.1±0.26	23.0	19.8±1.76	4950.00
Improved breeds	Osmanabadi and Sangamneri	2.2±0.14	72.0	28.6±1.14	7150.00

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- High adaptability of improved goat breeds.
- Low-cost intervention with high-income potential.
- Significant economic benefits for farmers.

Challenges in Scaling Up:

- Geographical limitations.
- Variability in success rates.
- The need for awareness campaigns and extension services.

The introduction of improved goat breeds for breed upgradation has shown promising results in terms of enhanced productivity and income generation for smallholder farmers. This technology offers a viable pathway to mitigate climate-related risks in livestock farming and promote food security, particularly among marginalized communities. To scale up these efforts, increased awareness, capacity building, and extension services will be crucial in promoting the benefits of breed upgradation programs to farmers across different regions.

Reference

Osmanabadi Goat Field unit, NARI, Phaltan, Maharasthra, Sanganmeri Goat field unit, MPKV Rahuri, Maharasthra under the guidance of ICAR-All India Co-Ordinated Research Project on Goat Improvement.

https://pcgoatcirg.icar.gov.in/osmanabadi/pdf_download/NARI_Goat%20management%20tips.pdf

46. Breed upgradation in cows with Gir and Sahiwal breeds

Technology Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

In India, the dairy industry predominantly relies on indigenous dairy animals, often raised in low-input, low-output systems. Among these indigenous cattle breeds, the Gir and Sahiwal breeds are highly regarded for their milk production, resilience, and adaptability to tropical conditions. Gir cows, renowned for their hardiness and disease resistance, have an average milk yield of 1,590 liters per lactation, which can be further improved with better practices. Sahiwal cattle are considered one of India's best milch cattle breeds, with lactation yields ranging from 1,600 to 2,750 liters. However, local breeds in certain regions yield lower milk productivity. To address this issue, KVK Kalahandi initiated artificial insemination (AI) using Sahiwal and Gir bull semen on oestrus-synchronized cows, following the recommendations of OUAT (Orissa University of Agriculture and Technology).

CSA Category: Genetic development and breed improvement for enhanced milk production can be categorized under "Weather Smart" technology, as it focuses on improving resilience and productivity in tropical climates.

Main Focus/Benefits:

- Improved milk yield and productivity.
- Enhanced disease resistance and adaptation to hot tropical climates.
- Reduced maintenance costs.
- Higher quality milk production.
- Promotion of sustainable use and conservation of cow genetic resources.

Fig. 47 *Pregnancy diagnosis and artificial insemination in Odisha*

Drawbacks/Limitations:

- Requires awareness and training for farmers.
- Challenges in adoption by small and marginal farmers.
- May involve initial investment in AI and breed improvement.

Suitability of the Technology:

Geographical Area: Gir and Sahiwal cattle breeds are particularly suitable for arid and semi-arid tropics.

Agro-Ecosystem: These breeds are known for their milk output, resilience to illness, tolerance of hot tropical climates, low maintenance costs, and high-quality milk ingredients. They are well-suited for regions facing climatic stress.

Adaptability Rate: A significant number of farmers have benefited from the introduction of improved Gir and Sahiwal breeds. The increased yield and income have attracted more farmers to adopt these breeds. Improved shelter management and nutrient management have further contributed to favorable conditions for better milk production. Small and marginal farmers can easily adopt these improved breeds, as the cost of insemination is lower than purchasing improved cattle breeds. Farmers are also generating income by selling improved breeds of adult cattle.

Impact and Suitability to Smallholder Farmers and Women:

The adoption of Gir and Sahiwal breeds has resulted in an improvement in milk productivity by more than 20% (1.5-2.0 liters per day) compared to traditional practices. Farmers in villages are increasingly raising these improved breeds, primarily due to the cost-effectiveness of insemination compared to buying improved cattle. The income generated from selling improved adult cattle has further improved the economic well-being of smallholders. The increased milk yield is beneficial for household food security and income generation, especially among women and marginalized communities.

Benefits/Success Story with Yield/Cost-related Data:

In villages served by KVK Kalahandi, around 70-80% of farmers now raise improved Gir and Sahiwal breeds. The adoption of these breeds has led to significant improvements:

- Milk productivity increased by more than 20% (1.5-2.0 liters per day) compared to traditional practices.
- Farmers are attracted to the Low-cost of insemination compared to purchasing improved cattle.
- Farmers are earning more than Rs. 30,000 by selling improved adult cattle.

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- High adaptability of improved Gir and Sahiwal breeds.
- Low-cost insemination compared to purchasing improved cattle.
- Significant economic benefits for farmers.

Challenges in Scaling Up:

- Awareness and training are essential for farmers to understand the traits and advantages of improved breeds.
- Adoption by small and marginal farmers may require additional support and incentives.
- Initial investment in AI and breed improvement may be a barrier.

The introduction of improved Gir and Sahiwal cattle breeds for breed improvement has demonstrated significant potential for enhancing milk production and income generation in regions facing climatic stress. This technology offers a sustainable pathway to improve food security and alleviate poverty, particularly among marginalized communities. Scaling up these efforts will require increased awareness, training, and capacity-building programs to promote the benefits of breed improvement and encourage widespread adoption by farmers across different regions.

Reference

National Dairy Research Institute (NDRI), Karnal, Central Institute for Research on Cattle (CIRC), Meerut

https://circ.icar.gov.in/division.php?DId=25&RMFlag=1

47. Breed upgradation in poultry

Developed/Introduced by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

Backyard poultry production plays a vital role in generating family income, particularly for rural women in India. However, indigenous bird breeds often have low egg and meat production, such as 70 to 80 eggs per bird per year. The potential for backyard poultry productivity can be significantly enhanced through improved chicken varieties and better management practices.

CSA Category: This intervention falls under "Weather Smart" technology, as it introduces improved poultry breeds that are adapted to stress conditions.

Main Focus/Benefits:

- Improved productivity of both meat and eggs.
- Adaptation to stress conditions.
- Reduced mortality rates.
- Employment generation for rural youth.
- Enhanced food security and income opportunities.

***Fig. 48** Rearing of improved breeds of poultry*

Drawbacks/Limitations:

- Initial investment required for setting up poultry houses.
- Necessary training and capacity-building for farmers.
- Challenges related to chick availability and mortality rates.

Suitability of the Technology:

Geographical Area: Kadaknath and Vanaraja breeds have evolved in indigenous agro-ecological conditions and are well-suited to the local environment.

Agro-Ecosystem: These breeds are recommended for adoption in areas facing climatic stress. They exhibit resistance to extreme weather conditions, such as summer heat and cold winters, and can thrive in challenging environments, including basic housing, limited management, and nutrition.

Benefits/Success Story with Yield/Cost-related Data:

- Farmers have readily adopted these improved poultry breeds, leading to increased employment opportunities for rural youth.
- The feedback from farmers indicates several advantages, including faster growth of birds, larger-sized eggs, resilience to diseases, minimal space and workforce requirements, and a reasonable investment.
- Kadaknath fetches a higher market price, exceeding Rs. 1,500 per bird.
- A benefit-cost ratio of more than 4.0 has been achieved with improved breeds.
- For Vanaraja chicks, the net income from 10 birds through egg and meat sales was Rs. 13,240, compared to Rs. 5,900 from local chicks.

Impact and Suitability to Smallholder Farmers and Women:

The introduction of improved Kadaknath and Vanaraja poultry breeds has significantly impacted smallholder farmers and women:

- High acceptability among farmers, even under high-temperature conditions.
- Increased income opportunities for rural women.
- Enhanced food security and nutrition through improved meat and egg production.
- Empowerment of rural women through income generation and employment.

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- Adaptability of improved poultry breeds to local conditions.
- Positive feedback from farmers.
- Increased demand for meat and eggs.

Challenges in Scaling Up:

- The need for awareness and training for farmers.
- Initial investment required for setting up poultry houses.
- Addressing challenges related to chick availability and mortality rates.

The introduction of improved Kadaknath and Vanaraja poultry breeds has significantly enhanced backyard poultry productivity, providing rural women with increased income opportunities. These breeds exhibit adaptability to climatic stress conditions, low space and workforce requirements, and resilience to diseases. The positive impact on farmers' livelihoods, income, and food security highlights the potential for scaling up these interventions. To achieve broader adoption, continued awareness, training, and support for addressing challenges will be essential.

Reference

ICAR-Directorate of Poultry Research, Hyderabad, Telangana and College of Veterinary Science and Animal Husbandry, Nanaji Deshmukh Pashu Chikitsa Vigyan Vishwa Vidyalaya Jabalpur, Madhya Pradesh in collaboration with KVK Jhabua, Madhya Pradesh.

http://pdonpoultry.org/pdpnew/index.php?option=com_content&view=article&id=101&Itemid=47

https://atarijabalpur.icar.gov.in/upload/publication/Kadaknath%20Farming%20for%20Farmers%E2%80%99%20Livelihood%20and%20Empowerment.pdf

48. Improved pig breeds for flood-prone areas

Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

Pig farming is a significant source of protein and income in rural areas of India, particularly in the northeastern region. However, traditional small-scale pig farming faces challenges such as floods, which can hinder production. To address this, improved pig breeds, including Hampshire cross and native breed Ghungroo, were introduced to farmers. Hampshire exhibits better growth rates, while Ghungroo can produce more offspring, making them suitable for flood-prone areas.

CSA Category: This intervention is categorized under "Weather Smart" technology, as it introduces improved pig breeds suitable for flood-prone areas.

Main Focus/Benefits:

- Improved pig breeds for enhanced growth and reproduction.
- Increased self-sufficiency and food security.
- Raised income levels for rural communities.
- Utilization of pig manure for farming.
- Low-external-input activity that relies on local feed resources and household waste.
- Particularly advantageous for smallholders and tribal groups.



***Fig. 49** Rearing of improved breeds of pigs in Assam*

Drawbacks/Limitations:

- Farmers may need training in improved breeding and management practices.
- Economic constraints and inbreeding can hinder pig performance.
- Adequate nutrition and health care are essential for optimal results.

Suitability of the Technology:

Geographical Area: Pig rearing is concentrated in Jharkhand and northeastern states, with a particular focus on Assam.

Agro-Ecosystem: These improved pig breeds are well-suited for adoption in high rainfall and flood-prone areas. The technology is ideal for small landowners looking for profitable and less labor-intensive pig farming, which can improve cash returns and capital.

Benefits/Success Story with Yield/Cost-related Data:

- Improved pig breeds, like the Hampshire cross, have demonstrated better returns in flood-prone areas. The boar achieved a body weight of 65.8 kg in 12 months, a 48% improvement compared to non-descriptive breeds.
- Hampshire cross pigs have fetched higher returns, with Rs. 6,900 per pig.
- Ghungroo sows have a larger litter size, resulting in the potential to earn Rs. 30,000 for 10 piglets on average through their sale.

Table 45 Performance of improved breeds of pigs in flood-prone areas

Intervention	Body weight at 12 months (kg)	Cost of rearing (Rs. /animal)	Gross return (Rs. /animal)	Net return (Rs. /animal)
Non-descriptive breed	44.6	3200	7200	4000
Hampshire cross breed (HS)	65.8	3500	14000	6900

Impact and Suitability to Smallholder Farmers and Women:

The introduction of improved pig breeds has had a significant impact on smallholder farmers and women:

- Pig farming provides nutritional and economic benefits, including the conversion of household waste into fertilizer.
- Small farmers and marginalized groups can easily adopt these improved breeds with minimal investment.
- Pig farming offers early returns compared to other livestock, with higher live weights fetching better returns.
- Income is also generated through the sale of piglets.
- Pig farming is labor-efficient and relies mostly on women's labor for upbringing.

Enabling Factors:

- Collaborative efforts with ICAR institutes and state agriculture universities.
- Local adaptability of improved pig breeds.

- Local market demand for improved breeds.
- Training programs focused on breeding techniques, nutrition, and health management.
- Supportive policies to promote improved pig breeding.

Challenges in Scaling Up:

- Training and capacity-building for farmers.
- Economic constraints and inbreeding.
- Adequate nutrition and health care for pigs.
- Adoption of improved breeding practices.

The introduction of improved pig breeds, such as Hampshire cross and Ghungroo, has proven to be a valuable intervention for pig farming in flood-prone areas of northeastern India. These breeds enhance growth, reproduction, and income opportunities for smallholder farmers and women. Training programs and supportive policies can facilitate the broader adoption of improved pig breeding practices, further benefiting rural communities and food security.

Reference

Assam Agricultural University, Khanapara, Guwahati (Assam) with support of All India Coordinated Research Project (AICRP) on Pig centres.
https://aicrp.icar.gov.in/pig/publications/research-highlights/

49. Breed upgradation of sheep in drought-prone areas

Developed/Introduced/Complied by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

Sheep breeding plays a crucial role in livestock production, providing essential products like meat and milk. India boasts a rich diversity of sheep breeds, but traditional non-descriptive sheep often produce lower yields than improved crosses, resulting in reduced income for farmers. To address this issue, the Nimbkar Agricultural Research Institute (NARI), Mumbai, developed the NARI Suwarna strain of Deccani sheep. These sheep have the FecB gene, allowing ewes to produce twin lambs, and they exhibit faster growth and larger size compared to Deccani sheep. Crossbreeding with local sheep enhances lamb production.

Fig. 50 *Rearing improved breeds of sheep in drought-prone areas*

CSA Category: This intervention falls under "Weather Smart" technology as it focuses on upgrading sheep breeds for drought tolerance, offering nutritional stability and insurance to farmers during agricultural failures.

Main Focus/Benefits:

- Introduction of NARI Suwarna sheep for improved lamb production.
- Enhanced twinning rate and income for farmers.
- Adaptability to dry conditions in northwestern and southern peninsular regions.
- Significant response from farmers due to low maintenance and increased production rates.
- Predominantly reared by women, landless, marginal farmers, and small-scale farmers.

Adaptability Rate:

- High adaptability of NARI Suwarna sheep to dry and semi-arid regions.

Drawbacks/Limitations:

- Investment in training and animal management practices required.
- Streamlining feed supplement supply can reduce production costs.
- Scalability requires on- and off-campus training, demonstrations, and collaboration with local stakeholders.

Suitability of the Technology:

Geographical Area: NARI Suwarna sheep are adaptable to dry conditions in the northwestern and southern peninsular regions of India.

Agro-Ecosystem: These improved sheep breeds are suitable for domestication in drought-prone semi-arid regions.

Benefits/Success Story with Yield/Cost-related Data:

- Introduction of NARI Suwarna sheep resulted in a substantial increase in twinning rates (37-51%) and higher income (35-45%) for farmers.
- NARI Suwarna ewes can produce milk to raise twin lambs to a weaning weight of 13-15 kg each in 3-4 months with minimal supplementary feeding.
- Flock size increased by 22% compared to local breed flocks within a year.
- Farmers earned an additional income of Rs. 2,45,000 by selling ram lambs.
- Improved animal management practices reduced mortality to zero in the improved breed flocks compared to local sheep.

Table 46 Improved breeds of sheep in drought-prone areas

Intervention	No. of pairs	Before upgradation			No. of upgraded (October 2018)				Income generated from sale of rams
		Total	Male	Female	Total	Male	Female	Mortality	
NARI Suwarna	12	24	10	14	52	28	24	0	115000
Local breed	12	24	10	14	38	22	16	2	85500

Impact and Suitability to Smallholder Farmers and Women:

The adoption of NARI Suwarna sheep has had a significant impact on smallholder farmers, particularly women:

- Increased income to farm families with low investment.
- Technology adoption led to the expansion of improved breed populations in drought-prone districts.
- Trainings, demonstrations, and animal health camps have facilitated technology adoption.
- Collaboration with local stakeholders, Farmer's Producing Organizations (FPOs), and sheep-rearing farmers can further promote this activity in districts prone to drought.

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- Local adaptability of improved sheep breeds.
- High adaptability of NARI Suwarna sheep to dry and semi-arid regions.
- Increased twinning rates and income generation.
- Streamlined supply of feed supplements.
- Enhanced animal management practices.

Challenges in Scaling Up:

- Initial investment in training and capacity-building.
- Ensuring consistent feed supplement supply.
- Expanding adoption through on- and off-campus training, demonstrations, and collaborations with local stakeholders.

The introduction of NARI Suwarna sheep has brought about significant improvements in lamb production, income generation, and resilience for farmers in drought-prone areas. This technology showcases the potential for enhancing smallholder livelihoods through improved animal breeds and management practices. Scaling up this intervention requires continued training, demonstrations, and collaborative efforts with local stakeholders to ensure its success in addressing agricultural challenges and promoting food security.

Reference

Nimbkar Agricultural Research Institute, Maharashtra, India
https://nariphaltan.org/suwarna.pdf

50. Breed upgradation in duck

Developed/Introduced/Compiled by: Indian Council of Agricultural Research (ICAR) institutes located in different parts of the country and state agriculture universities of respective states.

Ducks are a significant alternative poultry species for egg and meat production, offering several advantages such as year-round production, large-sized eggs, disease resistance, and adaptability to various rearing systems. The Khaki Campbell duck breed, known for its exceptional egg-laying abilities and adaptability to diverse climates, including the northeastern regions of India, is particularly valuable. These ducks are capable of withstanding both hot and cold temperatures, making them suitable for areas with fluctuating weather patterns. Adult Khaki Campbell ducks weigh around 2.2-2.4 kg and reach sexual maturity in 19-20 weeks, with an annual egg production potential of about 250-340 eggs, each weighing approximately 60-68 g. Small-scale farmers, often with marginal incomes, commonly raise ducks as a secondary source of income, maintaining relatively small flocks with a sex ratio of 1:5. Broody ducks or hens are responsible for hatching duck eggs.

***Fig. 51** Rearing Improved duck breed Khaki Campbell in districts of Assam*

CSA Category: This intervention aligns with "Weather Smart" technology, as Khaki Campbell ducks are adapted to withstand diverse climatic conditions, providing an opportunity for income generation and improved livelihoods for farmers.

Main Focus/Benefits:

- Introduction of Khaki Campbell ducks for enhanced egg production.
- Adaptability to different temperature and climatic conditions.
- Superior egg quality, valued in the market, offering income generation opportunities.
- Foraging abilities, reducing feed costs for farmers.
- Diversification of income sources for small and marginal farmers.

Drawbacks/Limitations:

- Initial investment in acquiring Khaki Campbell ducks and related training.
- Adoption and successful integration into existing farming practices require knowledge and resources.
- Sustainable duck farming practices can help reduce reliance on synthetic fertilizers and promote soil fertility.

Suitability of the Technology:

Geographical Area: Khaki Campbell ducks are widely adaptable to various regions of India, including the northeastern regions, coastal areas of southern India, and parts of central India.

Agro-Ecosystem: These breeds are suitable for domestication in semi-arid regions.

Benefits/Success Story with Yield/Cost-related Data:

- Khaki Campbell ducks introduced in Assam showed promising results. After three months, Khaki Campbell ducks had an average weight of 1.7 kg and produced 170-200 eggs per year per bird. In contrast, local ducks only reached a maximum weight of 1.4 kg and laid 60 eggs annually per bird.
- Khaki Campbell ducks exhibited faster egg production, with an average age of first egg laying at 120 days compared to 165 days for the local breed.
- At 6 months, Khaki Campbell ducks had an average body weight of 2.2-2.5 kg, while local ducks weighed 1.9-2.0 kg.
- The improved breed contributed to an additional income of Rs. 2,850 per 10 birds through meat sales and Rs. 3,400-4,000 from egg sales per bird, resulting in a 103% increase in daily income from the sale of ducks.
- Duck manure enriched soil fertility, reducing the need for synthetic fertilizers and promoting sustainable farming practices.

Table 47 Performance of Khaki Campbell over local breed in Assam district

Intervention	**Cost of rearing (Rs. / ha)**	**Gross return (Rs. / ha)**	**Net return (Rs. /animal)**
Local duck breed	1600	3000	1400
Khaki Campbell duck breed	2000	4850	2850

Adaptability Rate: Overall and Farmer's Acceptability:

Khaki Campbell ducks have demonstrated remarkable adaptability to diverse climatic conditions, making them suitable for various regions in India. Farmers have shown a positive response to the introduced breed due to their ability to withstand different temperatures and climatic conditions in diverse regions.

Impact and Suitability to Smallholder Farmers and Women:

Khaki Campbell ducks have had a positive impact on smallholder farmers, particularly women:

- Improved egg production and diversified farming systems.
- Reduced dependence on external feeding inputs.
- Stable source of income, contributing to better livelihoods for farm families.
- Proper utilization of duck manure enriches soil fertility and supports sustainable farming practices.
- Availing training programs, resources, and technical assistance from state animal husbandry departments and KVKs ensures the sustainability of duck farming operations.

Enabling Factors:

- Collaboration with ICAR institutes and state agriculture universities.
- Adaptability of Khaki Campbell ducks to diverse climates.
- Opportunities for income generation and business growth.
- Reduced feed costs through foraging abilities.

- Diversification of income sources for small and marginal farmers.

Challenges in Scaling Up:

- Initial investment in acquiring Khaki Campbell ducks and related training.
- Adoption and integration into existing farming practices require knowledge and resources.
- Ensuring sustainable duck farming practices and soil enrichment through manure utilization.

The introduction of Khaki Campbell ducks has provided smallholder farmers, especially women, with an opportunity to improve their livelihoods through enhanced egg production and diversified income sources. These ducks, known for their adaptability and foraging abilities, offer the potential for reduced feed costs and sustainable farming practices. The successful adoption of this technology requires ongoing training, resources, and technical support, highlighting the importance of collaboration with local stakeholders and government agencies in promoting food security and improved livelihoods.

Reference

ICAR- Central Avian Research Institute, Bareilly, Uttar Pradesh
https://cari.icar.gov.in/varieties_deve.php; https://cari.icar.gov.in/

6. Conclusions and Recommendations

In India, various organizations have made significant efforts to develop technologies that can mitigate the impact of climatic stress in different agricultural situations. However, choosing the appropriate technology for a specific situation depends on several factors, including the existing production systems, available resources, the type of stress being faced, and the resources accessible to farmers. The selection of suitable technology for a given situation should be a participatory process involving all stakeholders and considering the practicality from the farmers' perspective.

To effectively spread promising climate-smart technologies and reach a larger number of farmers, investments are essential, and necessary resources must be mobilized. In India, numerous government programs are already in place with the goal of increasing productivity, combating land degradation, improving water use efficiency, addressing micronutrient deficiencies, promoting watershed development, implementing site-specific nutrient management, and reclaiming alkali/saline soils, among others. To reach a broader audience of farmers and reduce the impact of climatic stresses, it is crucial to integrate Climate-Smart Technologies (CSTs) into these ongoing programs.

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List of CSA Technologies

Sl. No.	CSA Technology
Climate Resilient Natural Resource Management Technologies	
1	Rainwater harvest
2	Farm ponds for life saving irrigation
3	Desilting of community Ponds
4	Sandbag check dams.
5	Compartmental bunding
6	Raised bed panting of mustard
7	Low-cost polyhouse
8	Crop residue mulching
9	Trench cum bund
10	Rice transplanter
11	Tank silt application for soil moisture conservation
12	Laser land levelling
13	Micro irrigation systems
14	Artificial recharge structure
15	Broad bed furrow technique
16	In-situ management of paddy straw using baler cum knotter
17	Zero till wheat sowing by PAU happy seeder
18	Residue incorporation by reversible mould plough
19	Ridge and furrow cultivation method
20	Desilting of drainage channel
Climate Resilient Crop Production Technologies	
21	Drought-tolerant crop varieties
22	Flood-tolerant rice varieties
23	Salt-tolerant crop varieties
24	Heat tolerant wheat varieties
25	Heat tolerant wheat varieties
26	Short-duration drought-escaping crop varieties
27	Intercropping
28	Drum seeding of rice
29	Use of CSR-BIO for rice
30	Halo Azo and Halo PSB technology
31	Direct seeded rice
32	Strip cropping in soybean and pigeon pea
33	Dryland horticulture
34	Catch crop after recession of flood water
35	Water saving aerobic rice

Climate Resilient Livestock/Animal Production Technologies	
36	Supplementation of area-specific mineral mixture
37	Preservation of green fodder as silage
38	Azolla meal as a protein supplement for cattle
39	Hydroponic fodder production
40	Year-round fodder production
41	Composite fish culture
42	Shelter management in dairy animals
43	Low-cost Mechang type poultry house
44	Deep litter system of housing for pigs
45	Breed upgradation in goat for drought-prone areas
46	Breed upgradation in cows with Gir and Sahiwal breeds
47	Breed upgradation in poultry
48	Improved pig breeds for flood-prone areas
49	Breed upgradation of sheep in drought-prone areas
50	Breed upgradation in duck

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