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Scalable climate resilient technologies

in diverse rainfed agro-ecologies

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Climate change poses significant challenges for developing nations like India, particularly in rainfed agriculture, which is highly sensitive to climatic variables such as rainfall and temperature. Climate vulnerability include erratic rainfall, extreme weather events, heat stress and cold stress, all of which affects crop yields, food security, and rural livelihoods. India's smallholder farmers, who comprise 86% of the agricultural sector, are especially vulnerable to climate-induced stresses such as floods, droughts, heatwaves, cold waves and dry spells. Projections indicate a potential decrease in crop productivity over period leading to economic losses. Agriculture also contributes to global greenhouse gas emissions. This highlights the prerequisite of climate-resilient agricultural (CRA) practices that enhance the rainfed agro-ecosystem ability to adapt to climate challenges while minimizing environmental impact. CRA practices which includes soil moisture conservation, tank silt application, climate stress cropping systems and varieties, integrated farming systems and livestock interventions focus on improving productivity, ensuring food security, and increasing the resilience of rural communities. In addition to adaptation to climate vulnerabilities, these practices also have mitigation co-benefits and provide ecosystem services.

Keywords: Adaptation, Climate resilient agriculture, Climate vulnerability, Mitigation

CLIMATE change is a major global challenge, particularly for developing countries like India. It significantly affects agriculture, impacting crop yields and human health. Additionally, it influences water availability and overall food security. In India, the major challenge of climate change is rainfall variability, which causes frequent dry spells, floods and drought. Reduction in summer monsoon rainfall, and more frequent and intense extreme weather events (such as landslides, cyclones, floods, hailstorms, and droughts) have been observed in recent decades affecting agricultural productivity. Furthermore, the increase or decrease in temperature is also a major concern. Intergovernmental Panel on Climate Change (IPCC) has reported a mean increase of global temperature by 0.74°C in the past century, with a projected further increase of 1.8–4°C by 2100. The impact of climate change is more significant in rainfed regions comprising of 86% resource poor small and marginal farmers which further aggravates the situation. Climate change could potentially decrease the crop productivity in India by 4.5–9% annually during the 2020–2039.

Agriculture is not only a victim of climate change but it is a contributor to climate change since agriculture is a significant source of greenhouse gas emissions (19.6% of total emissions) (FAOSTAT). Hence, the agricultural practices which increases the capacity of the system to respond to various climate-related disturbances by resisting or tolerating the damage and recovering quickly (adaptation practices) are need of the hour. Besides adaptation, these practices should also have low environmental impact, in addition to mitigation potential (reduction in GHG emissions and increase in carbon sequestration). These practices with both adaptation and mitigation potential are climate resilient agricultural practices (CRA) which enhances crop productivity to contribute to higher income, food security and improve livelihoods of rural communities.

It is essential to explore, develop, and scale up location-specific climate-resilient technologies to tackle the challenges posed by climate change in rainfed agro-ecosystems. These challenges include droughts, dry spells, uneven rainfall distribution, soil erosion, low soil moisture, floods, and extreme temperatures. Effective natural resource management and improved crop production technologies are crucial to addressing these issues.

Climate resilient technologies: Adaptation and mitigation of climate change

The impact of climate stresses can be reduced with help of technologies like selection of site-specific efficient smart cropping systems, varieties, crop diversification, water harvesting for conserving water resources, contingency planning etc. Integration of forecasting tools, agro-advisories, integrated farming system, carbon sequestration and resource management at community levels are few measures which are effective in developing climate resilient agriculture (Table 1).

Table 1. Climate resilient technologies for different climate vulnerabilities

Climate extremes	Climate resilient technologies
Flood	• Crop diversification with flood tolerant crops/ farming systems cultivation • Flood tolerant rice varieties like Swarna Sub-1, Ranjith Sub-1, Swarna Shreya • Transplanting of rice seedlings after recession of flood • Relay cropping of blackgram and toria in rice • Altering planting dates to avoid flood • Integrated farming systems (Rice-duck system) • Integrated farming systems (Rice–fish farming, scientific fish cultivation) • Shelter management in animals (mechang type and floating type shelter)
Water-logged	• Vegetable cultivation in floating beds • Cultivation of aquatic vegetables • Fish cultivation • Drainage and trench cum bunding • Raised bed and broad bed method of cultivation
Salinity	• Cultivation of salinity-tolerant rice varieties, salinity-resistant jute, peanut, sugarcane, kohlrabi, sweet potato, sesame, millet varieties • Practising rice-fish-vegetables cultivation in the same land • Crop through ditch and dyke, and raised bed, floating beds to avoid saline water flooding • Sulphur application @ 20 kg/ha • Green manuring and residue management
Heat stress	• Heat tolerant varieties • Protected cultivation • Shelter management for animals • Altering the sowing dates of *kharif* crops • Frequent irrigation through sprinklers • KNO_3 spray @ 2% • Livestock breed upgradation (Sirohi goat, Kadaknath poultry breed)
Drought	• Cultivation of drought tolerant/ low water-requiring crops like millets • Water harvesting and use of the farm pond water for supplemental irrigation • Construction of *Jalkunds* for supplemental irrigation to crops • *In situ* moisture conservation through conservation furrows / Raised bed planting and mulching • Improving the feed and fodder for the animals
Cold stress	• Cold tolerant crops • Protected cultivation • Improved shelter management for livestock • Low tunnel vegetable nursery

Natural resource management practices

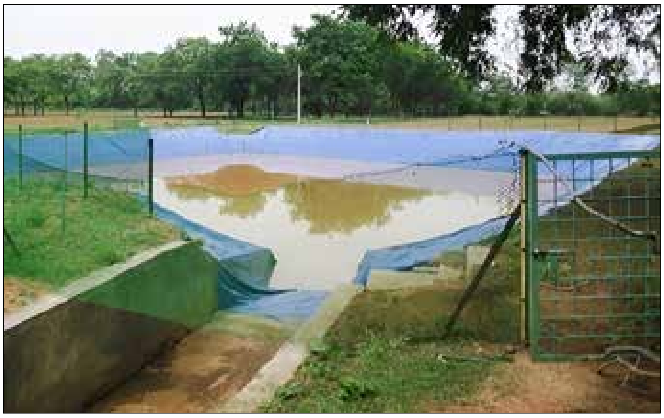
Climate change influences the intensity and distribution of rainfall during the monsoon season. Some regions may experience more intense and erratic rainfall, while others may have reduced precipitation. Higher rainfall intensity, often results in increased runoff. Furthermore, delay in the onset and early withdrawal of monsoon, is also observed. This affects the time of sowing and agricultural activities which in turn reduces the crop productivity. Rise in temperature increases evapotranspiration, which lead to more rapid depletion of soil moisture leading to higher water requirement. Projections suggest that 1°C rise in temperature could increase the crop water demand by 2% and overall water demand by 10%. Hence, efficient use of natural resources such as water and soil are highly critical for adaptation to climate change.

Soil moisture conservation

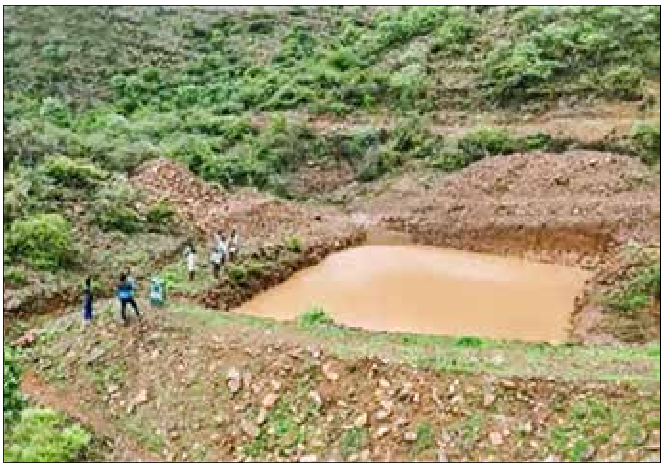
Resilient technologies for soil and rainwater conservation, water harvesting of surplus water and use of the harvested water for life saving irrigation can play a crucial role in sustainable water management. Improvement of irrigation accessibility and water-use efficiency is crucial for crop production. Furthermore, the importance of rainwater harvesting has grown in recent years due to the increase in rainfall variability and depletion of groundwater levels.

Ex-situ water conservation

Rainwater harvesting through farm ponds and *Jalkund*, restoration of old rainwater harvesting structures by desilting, use of percolation ponds to recharge open wells, and injection wells for recharging groundwater replenishment can significantly enhance the farm level water storage. Desilting has increased the storage capacity of village tanks further helping recharge of bore wells, and increase in groundwater table, besides providing supplemental irrigation. This also help to meet the drinking water availability of livestock during the summer. At the farm level, harvested water can be used for supplemental irrigation during critical periods of growth stage or for providing pre-sowing irrigation to winter crop. This approach has enabled supplemental irrigation for crops like groundnut, sorghum, and onion improving the crop yields by 20–30% in different crops



Farm pond



Farm pond

across different locations. Besides this, the ex-situ harvested water helps in groundwater recharge

In-situ moisture conservation

In-situ moisture conservation is achieved by increasing water infiltration and reducing runoff through land configuration methods like ridge and furrow, raised beds, broad bed and furrow (BBF), compartmental bunding, and conservation tillage. The raised bed, and ridge and furrow methods help store moisture, and drain excess water during heavy rainfall, reducing the effects of both drought and intense storms during the cropping season.

Hence, these are adaptation strategies for both deficit rainfall as well as higher intense rainfall. The *in-situ* moisture conservation methods enable higher water infiltration, soil hydraulic conductivity which consequently increase soil moisture storage and improve the moisture availability which promote crop growth and increase the crop productivity by 20-40% as compared to farmers practice across different locations. Ridge and furrow method of sowing increased the crop yields by 22, 28, 39 and 27% in pigeon pea, black gram, green gram and soybean respectively. Similarly, *in-situ* moisture conservation measures like ploughing across the slope, trench cum bunding and contour bunding increased the crop yields by 12–22% over no bunding.

Apart from land configuration, vegetative hedges and crop residues mulch, cover crops could be employed for better rainwater conservation and increase rainwater use efficiency.

Desilting farm ponds or tanks and applying the nutrient-rich silt to light-textured soils enhances water holding capacity and boosts crop yields by 16–22% compared to not using tank silt. Conservation agriculture, which includes zero tillage, crop residue recycling, and crop diversification, is a climate-resilient practice that enhances crop productivity, reduces residue burning, saves time on land preparation, and allows for early sowing.

Climate smart crops/cropping system diversification and variety selection

The climatic vulnerabilities like heat/cold wave, flood, cyclone, frost, hail storm, reduce the potential yield of a crop or a variety. Hence, a climate-smart efficient location specific cropping system or a variety can be cultivated. Crop diversification with climate-resilient crops, such as millets, is an effective strategy for enhancing resilience to climate change. Millets are hardy, tolerant of water and heat stress, carbon-smart, and highly nutritious, making them suitable for rainfed regions. Thus, integrating millets into cropping systems is recommended for these areas.

Monocropping in rainfed areas is a risky practice for farmers, as relying on a single crop increases the likelihood of failure and contributes to food, income, and environmental insecurity due to climatic stresses. Mixed cropping, intercropping with short duration and long duration crops, deep rooted and shallow crops relay cropping reduce the impact of different climatic vulnerabilities in general and drought in particular. In the extreme climatic stresses, if one crop fails, farmers can get income from another crop. Inclusion of a legume in cropping system add sustainability to this system through soil cover, and addition of biological nitrogen. An efficient cropping system always meet the climatic requirement based on the particular region and increases the crop productivity. For example, there is an urgent need for diversification of the conventional puddled transplanted rice, and intensively tilled wheat to other cropping systems such as maize-wheat, pulse-wheat, maize-pulse, oilseed-wheat and direct seeded rice-wheat. The latter system are less water and nutrient demanding (with legume) and use resources more efficiently thereby increasing farmers' income and

Conservation furrow

Raised bed planting

Pigeon pea on raised bed planting

exhorting less pressure on the natural resource base.

Farmers traditionally grow low-yielding, long-duration local crop varieties that are not adapted to climatic stresses such as drought, floods, and heat, leading to reduced productivity. The improved high yielding varieties are short duration and resistant to different climatic stresses (drought, heat, flood as well as salinity) which helps to get higher crop productivity. The studies conducted on improved crop varieties in technology demonstration component of NICRA in different villages through KVKs has shown yield improvement over the traditional farmers practice (Table 2).

Table 2. Climate resilient varieties for different vulnerabilities

Improved crop varieties	% yield increase over local	Source
Drought tolerant rice (Sahbhagi Dhan) and ragi (ML-365)	18-20	KVK, Godda and Tumakur
Flood tolerant paddy (MTU 1061 and RGL-2537)	35	KVK, Srikakulam
Heat tolerant wheat (PBW-803, DBW-187 and DBW-222)	97	KVK, Bathinda
Short duration chickpea (NBeG-49)	12	KVK, Kurnool
Drought tolerant groundnut (Kadiri Lepakshi)	20	KVK, Anantapur
Short duration sunflower (KBSH-78)	30	KVK, Chickkaballapura

Source: NICRA-TDC-Research highlights, 2019-2023.

Cotton + redgram intercropping system (*Courtesy*: KVK Adilabad)

Finger millet + pigeon pea intercropping system (*Courtesy*: KVK Tumukur)

Livestock and fodder-based interventions

Livestock rearing is an adaptation strategy which make significant contribution for livelihood security of farmers particularly in rainfed regions. Successful livestock rearing can be achieved through increased fodder availability, improved shelter management for resilience against different climate vulnerabilities. Introduction of improved breeds of small ruminants, improving the health of animals as better health makes animals more tolerant to climatic stresses. The fodder availability can be increased by cultivation of high biomass fodder crops (fodder bajra, oats, Napier grass, multicut sorghum), improved fodder varieties. Feed supplements, micronutrient use to overcome mineral deficiency to enhance adaptation to heat stress are some key interventions. This improved fodder can increase milk production by 10–15% and a reduction in the calving period by 45–60 days in addition to the birth of healthy offspring.

Supplemental feeding can meet off-season fodder needs, but its high cost is often unaffordable for smallholders. Establishing fodder banks on available community land in villages offers a more viable solution. In the fodder bank, high-quality and higher biomass fodder species which grows in short time and bridge the forage scarcity during the annual dry seasons are preferred. Community fodder banks were established in different villages, particularly, in villages which face acute scarcity of fodder during dry/summer seasons.

Improved pig shelter (*Courtesy*: KVK Namsai)

Backyard poultry (*Courtesy*: KVK Dhenkanal)

Introducing improved poultry breeds like Vanaraja, Gramapriya, Rajashree, Kalinga Brown, Chabro, and Kadaknath is a key intervention for various agro-climatic conditions, along with better shelters for temperature control and protection. In the northeast, pig productivity can be enhanced by introducing improved breeds like Hampshire Cross, Ghungroo, Duric, and White Yorkshire, where pigs are a vital part of farming systems

Mitigation potential

Climate resilient practices for achieving Sustainable Development Goals (SDGs)

The climate resilient agricultural practices like zero tillage, crop diversification and moisture conservation practices align with achieving the Sustainable Development Goals (SDGs) through three core principles viz. increase agricultural productivity to enhance incomes, ensure food security, and promote overall development; enhance adaptive capacity across multiple levels, from individual farms to national systems; and reduce greenhouse gas emissions and promote the establishment of carbon sinks to mitigate climate change effects.

SUMMARY

Climate change poses significant challenges to agriculture in India, impacting crop yields, planting and harvesting cycles, and overall productivity. Rainfed regions, covering 52% of India's net sown area and contributing 40% of food production, are vital to food security but highly vulnerable to climate risks. Small and marginal farmers, who make up 86% of the farming population, face declining crop productivity, water scarcity, and livestock losses due to these risks. Climate-resilient strategies, such as efficient water and soil management, crop diversification, and improved crop varieties, are critical for adaptation. Technologies like rainwater harvesting and *in-situ* moisture conservation can mitigate water shortages, while improved varieties of drought-tolerant crops ensure better yields in adverse conditions. Agroforestry, livestock interventions, and enhanced fodder production also offer opportunities to enhance resilience. Additionally, capacity-building programs are essential to empower farmers with knowledge of climate-smart agriculture and sustainable practices, enabling them to adapt to changing climatic conditions and secure food and income stability.

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