CLIMATE RESILIENT AGRICULTURE

SYLLABUS:

GS 3 > Economic Development >> Agriculture

REFERENCE NEWS:

Climate change poses serious risks to Indian agriculture through erratic weather, soil degradation, and pollution. With over **51% of India's net sown area rainfed** and contributing nearly **40% of food production**, agriculture is highly vulnerable to climate variability. Studies project significant yield losses in staples like rice by the end of the century if current practices continue.

CLIMATE RESILIENT AGRICULTURE:

Climate-resilient agriculture combines **biotechnology and complementary technologies** to sustain or improve farm productivity while reducing chemical dependence. Key tools include biofertilizers and biopesticides, soil microbiome analysis, genome-edited crops tolerant to drought, heat, salinity, and pests, AI-driven, data-based advisories for location-specific farming practices.

According to the **Food and Agriculture Organization (FAO)**, Climate-Resilient Agriculture refers to the ability of agricultural systems to anticipate, prepare for, adapt to, absorb, and recover from the impacts of climate variability and extreme weather, while ensuring food security and sustainable livelihoods.

In simple terms, **CRA is farming that can survive, adapt, and thrive under climate stress** such as heat waves, floods, droughts, salinity, and erratic rainfall, without degrading natural resources.

CRA seeks to achieve **four simultaneous objectives**:

- **Sustainably increase productivity**
- **Enhance adaptation and resilience**
- **Reduce greenhouse gas (GHG) emissions where possible**
- **Ensure long-term food and livelihood security**

CORE COMPONENTS OF CLIMATE-RESILIENT AGRICULTURE

- **Climate-Smart & Genome-Edited Crops:** Crops bred or edited to tolerate climate stress:
  - **Flood-tolerant rice (Sub1)** used in Bihar & Assam: Sub1 rice survives **14–17 days of submergence**, preventing total crop loss during floods.
  - **Drought-tolerant millets**
  - **Heat-tolerant wheat**

- **Salinity-tolerant coastal crops**

- **Agroforestry Systems:** Integration of **trees with crops and livestock** improves soil organic carbon, reduces erosion, enhances moisture retention and provides diversified income.
  - Tree-crop systems in semi-arid regions of Telangana reduce heat stress and crop failure.
- **Soil & Water Conservation Practices:** Zero tillage, contour bunding, farm ponds, check dams, mulching improves groundwater recharge and reduces drought vulnerability.
- **Sustainable & Diversified Farming:** Crop diversification (pulses, oilseeds, millets), integrated pest management (IPM), organic and natural farming
  - Shifting from water-intensive paddy to millets under PM-RKVY improves resilience and farmer income.
- **Precision & Digital Agriculture:** Use of **AI, remote sensing, and weather analytics** hyper-local weather advisories, pest outbreak prediction, precision irrigation scheduling.
  - **Meghdoot App** delivers district-level weather advisories to farmers.

Climate-Resilient Livestock & Fisheries: Heat-tolerant livestock breeds, stall feeding and mixed cropping and climate-resilient aquaculture systems.

Major Government Initiatives Promoting CRA:

- **National Innovations in Climate Resilient Agriculture (NICRA), 2011:** Launched by **Indian Council of Agricultural Research.** CRA technologies demonstrated in **448 villages. 1,800+ climate-resilient crop varieties** developed. **District Agriculture Contingency Plans** for 650 districts
- **National Mission for Sustainable Agriculture (NMSA):** Part of the **National Action Plan on Climate Change (NAPCC).** Focus areas Rainfed Area Development, Soil Health Management, On-Farm Water Management
- **Per Drop More Crop (PDMC):** Promotes **micro-irrigation.** Subsidy **55% for small & marginal farmers**
- **Crop Diversification Programmes:** Under **PM-RKVY, Krishi Unnati Yojana.** Encourages shift from paddy to pulses, oilseeds, millets, agroforestry.
- **Insurance & Financial Safety Nets: PM Fasal Bima Yojana (PMFBY),** weather-based crop insurance for faster compensation.
- **BioE3 Policy & Digital Agriculture Mission:** Promotes **biotechnology-led CRA,** strengthens AI-based advisories, AgriStack.

SIGNIFICANCE OF CLIMATE-RESILIENT AGRICULTURE (CRA) IN INDIA:

- **Safeguarding India's Food Security under Climate Stress:** India's food system is increasingly threatened by climate variability.
  - **51% of India's net sown area is rainfed**, contributing nearly **40% of total food production**.
  - Studies by **Indian Council of Agricultural Research (ICAR)** show that **without adaptation** rainfed rice yields may decline by **7–28%, w**heat yields by **3–5%,** maize yields by **9–10%**
  - **Flood-tolerant Sub1 rice** in Bihar and Assam survives **14–17 days of submergence**, protecting farmers from total crop loss during floods—directly enhancing food availability.
- **Protecting Rainfed and Small & Marginal Farmers:** Indian agriculture is dominated by smallholders who are most exposed to climate risks. Over **85% of Indian farmers** are small and marginal. Rainfed regions face high income volatility due to droughts, floods, and erratic monsoons.
  - Under **National Innovations in Climate Resilient Agriculture (NICRA)**, climate-resilient practices (crop diversification, moisture conservation, resilient varieties) were demonstrated

in **448 villages**, leading to reduced yield losses during drought years and improved farmer coping capacity during extreme events

- **Ensuring Long-Term Resource Sustainability:** Conventional agriculture has led to rapid **groundwater depletion** (especially in north-western India), declining **soil organic carbon,** rising input costs. CRA promotes sustainable use of natural resources through micro-irrigation, zero tillage, mulching, integrated nutrient management
    - **Zero-till wheat** in Punjab and Haryana reduces water use, improves soil structure, and lowers fuel costs while maintaining yields, demonstrating how CRA supports long-term land productivity.
- **Enhancing Farmer Income Stability and Reducing Poverty Traps:** Climate shocks often push farmers into debt due to total crop failure. Diversified farming systems (crops + livestock + trees) spread risk, stress-tolerant crops reduce income volatility and climate insurance complements CRA practices
    - **Agroforestry systems** in semi-arid Telangana and Karnataka provide farmers with timber, fodder, and fruit income even during crop failure years, enhancing economic resilience.
- **Supporting Climate Change Mitigation Goals:** While agriculture is a victim of climate change, it is also a contributor. Agriculture contributes around **14% of India's total GHG emissions.** Excessive nitrogen fertiliser use increases **nitrous oxide emissions**
    - **In-situ crop residue management** under NICRA reduces stubble burning, lowering air pollution and methane emissions in the Indo-Gangetic plains.
- **Strengthening Climate Adaptation at the Local Level:** Climate impacts vary widely across regions. CRA emphasises **location-specific solutions** rather than one-size-fits-all approaches.
    - **District Agriculture Contingency Plans (DACPs)** prepared by ICAR for **650 districts** provide crop and livestock advisories tailored to droughts, floods, frost, and heatwaves, improving preparedness and response.
- **Strategic and Economic Significance for India:** Reduces dependence on food imports under climate stress, strengthens India's **strategic autonomy in food systems and** aligns with global commitments under the Paris Agreement and SDGs
    - Integration of CRA into national missions like **National Mission for Sustainable Agriculture (NMSA)** under the **NAPCC** embeds climate adaptation into agricultural planning.

CHALLENGES TO CRA IN INDIA:

- **Low Adoption among Small and Marginal Farmers:** Over **85% of Indian farmers** are small and marginal, operating on less than 2 hectares. CRA practices like micro-irrigation, conservation agriculture, or precision tools involve **high upfront costs**.
    - Limited access to **formal credit**, insurance, and risk-bearing capacity discourages experimentation.
    - Adoption of drip irrigation under *Per Drop More Crop* remains uneven in rainfed regions due to capital constraints despite subsidies.
- **Quality and Trust Deficit in Bio-Inputs:** The bio-fertiliser and bio-pesticide market is flooded with **unregulated and sub-standard products**. Lack of uniform quality control undermines farmer confidence. Poor performance of spurious bio-inputs pushes farmers back to chemical fertilisers and pesticides. This weakens the ecological foundation of CRA.
    - **Indian Council of Agricultural Research (ICAR)** has flagged the need for stricter standards and monitoring of microbial inputs.

- **Slow "Lab-to-Land" Transfer of Climate-Resilient Seeds:** ICAR has developed **1,800+ climate-resilient crop varieties**, yet field-level adoption remains limited. Seed multiplication, certification, and last-mile distribution take **5–10 years**.
    - Flood-tolerant Sub1 rice is proven, but its spread remains uneven across flood-prone eastern India.
- **Digital Divide Limiting Precision Agriculture:** While mobile penetration is high, **digital literacy and rural connectivity** remain weak. AI-based advisories require reliable internet, data access, and user trust. CRA increasingly depends on **hyper-local weather forecasts, pest alerts, and irrigation advisories**. Exclusion of digitally marginal farmers widens inequality.
    - Apps like Meghdoot or Annavari have limited uptake in tribal and remote districts.
- **Fragmented Policy and Institutional Coordination:** CRA interventions are spread across multiple schemes NMSA, PMKSY, PM-RKVY. These often operate in **administrative silos**. Farmers struggle to access **holistic, integrated support**. Lack of convergence reduces efficiency and impact.
    - **National Innovations in Climate Resilient Agriculture (NICRA)** highlights the need for coordinated landscape-level planning.
- **Over-Reliance on Groundwater and Perverse Incentives:** Northern India accounts for one of the **highest rates of groundwater extraction globally**. Free or subsidised electricity incentivises water-intensive cropping. Climate-resilient practices like diversification and water conservation become unattractive.
    - Paddy-wheat monoculture in Punjab negates sustainability efforts.
- **Contribution of Agriculture to Greenhouse Gas Emissions:** Agriculture contributes around **14% of India's total GHG emissions**. Excessive nitrogen fertiliser use increases **nitrous oxide emissions**.
- **Weak Local Governance and Panchayat Involvement:** Climate action is inadequately mainstreamed into **Gram Panchayat Development Plans**. Limited awareness and capacity at the local government level. CRA requires **context-specific planning**, which is best handled locally. Absence of Panchayat ownership weakens implementation.
- **Climate Change Outpacing Adaptation Efforts:** Frequency of droughts, floods, heatwaves, and extreme rainfall events is increasing. Research-based solutions risk becoming **obsolete within a decade**. Static adaptation strategies cannot cope with dynamic climate risks.

WAY FORWARD:

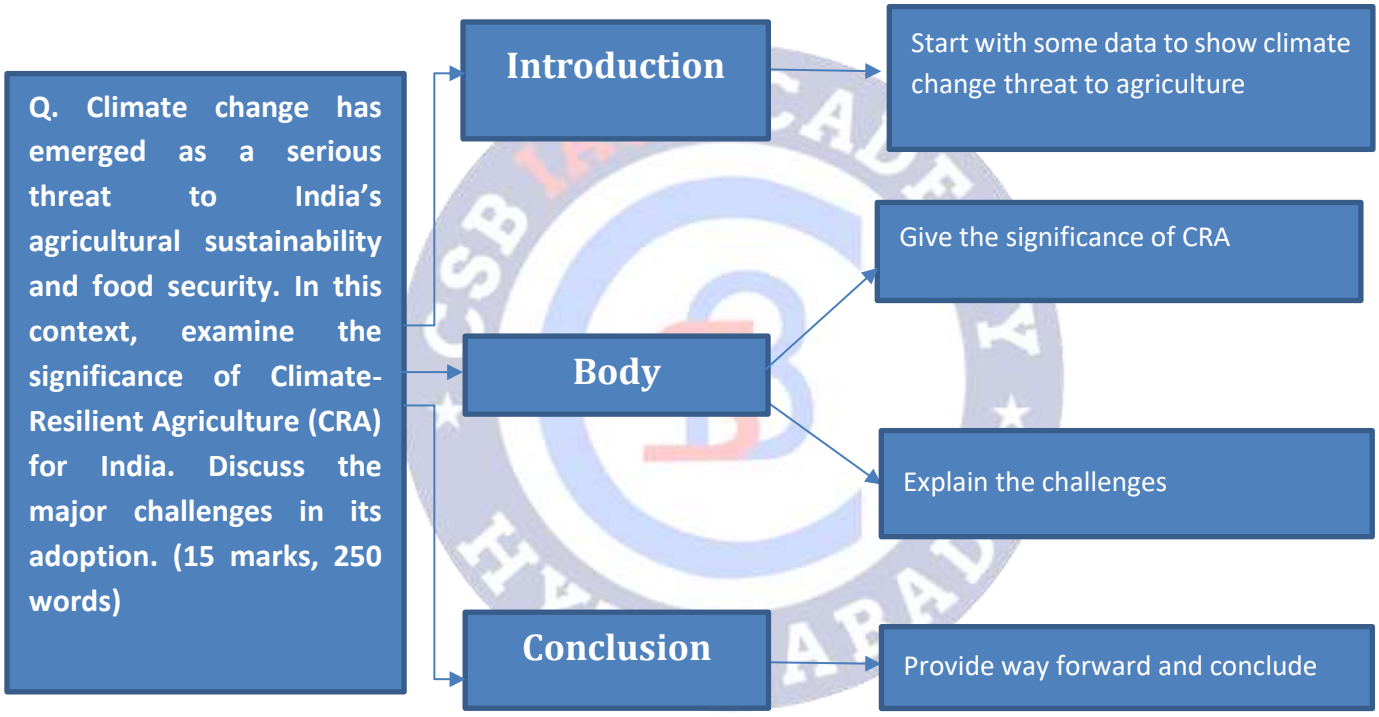
- **Fast-track Climate-Resilient and Genome-Edited Seeds (Lab-to-Land Push):** Fast-track seed multiplication, certification, and decentralised distribution through KVKs and FPOs.
- **Strengthen Quality Regulation of Bio-Inputs to Build Farmer Trust:** Enforce **uniform national quality standards**, periodic audits, and on-field performance testing. Establish **district-level bio-input testing labs**. QR-code–based traceability for bio-inputs (as piloted in organic clusters) can ensure purity and efficacy, restoring farmer confidence.
- **Bridge the Rural Digital Divide for Precision & AI-Based Agriculture:** Expand the **Digital Agriculture Mission** through vernacular advisories, offline functionality, community intermediaries like FPOs and Digital Sakhis. Using village-level resource persons to help farmers access **Meghdoot weather advisories** and pest alerts.
- **Reform Agricultural Incentives to Support Resource Sustainability:** Rationalise electricity subsidies for groundwater extraction. Align MSP and procurement with **crop diversification** (millets, pulses, oilseeds). Incentivise water-saving and low-emission practices. Promoting millets under public procurement to shift farmers away from water-intensive paddy.

- **Expand Climate-Linked Financial Safety Nets:** Shift from delayed compensation to **parametric (weather-based) insurance**. Integrate satellite data and remote sensing for faster payouts. Enhancing PMFBY with automated damage assessment for droughts and hailstorms in Maharashtra.
- **Create a Unified National CRA Roadmap with Local Ownership:** Develop a **coherent national CRA roadmap** under the **BioE3 Policy**, aligning biotechnology, climate adaptation, and agriculture. Mainstream CRA into **Gram Panchayat Development Plans**. Scaling the **ridge-to-valley watershed approach** under MGNREGA to enhance landscape-level resilience.

PRACTICE QUESTION:

Q. Climate change has emerged as a serious threat to India's agricultural sustainability and food security. In this context, examine the significance of Climate-Resilient Agriculture (CRA) for India. Discuss the major challenges in its adoption. (15 marks, 250 words)

APPROACH:



MODEL ANSWER:

With **over 51% of India's net sown area being rainfed and contributing nearly 40% of food production**, agriculture remains highly vulnerable to climate variability.

According to the **Food and Agriculture Organization (FAO)**, CRA refers to the ability of agricultural systems to *anticipate, adapt to, absorb, and recover from climate shocks while ensuring food security and sustainable livelihoods*.

Significance of Climate-Resilient Agriculture in India

- **Ensuring Food Security under Climate Stress:** Studies by **Indian Council of Agricultural Research (ICAR)** show potential yield declines of **7–28% in rainfed rice, 3–5% in wheat, 9–10% in maize.** Flood-tolerant **Sub1 rice**, capable of surviving **14–17 days of submergence**, has protected farmers in flood-prone districts of Bihar and Assam from complete crop failure.

- **Protecting Small and Marginal Farmers:** Over **85% of Indian farmers** are small and marginal. Rainfed agriculture exposes them to high income volatility and climate shocks. CRA acts as a livelihood safety net by reducing crop failure risk and improving adaptive capacity.
    - Under **NICRA**, climate-resilient technologies were demonstrated in **448 villages**, reducing yield losses during drought years and enhancing farmers' coping capacity.
- **Promoting Long-Term Resource Sustainability:** Conventional farming has led to groundwater depletion, declining soil organic carbon, and rising input costs. Practices like zero tillage, mulching, micro-irrigation, and integrated nutrient management conserve resources while maintaining productivity.
    - **Zero-till wheat** in Punjab and Haryana has reduced water use and fuel costs while improving soil health.
- **Enhancing Farmer Income Stability:** Diversified farming systems (crops–livestock–trees) spread risk and provide alternative income sources. Agroforestry systems in semi-arid Telangana and Karnataka provide timber, fodder, and fruit income even during crop failure years.
- **Supporting Climate Change Mitigation:** CRA practices convert farms into carbon sinks by reducing emissions and enhancing carbon sequestration. In-situ crop residue management under NICRA has reduced stubble burning and associated air pollution in the Indo-Gangetic Plains.

Challenges in Adoption of CRA

- **Structural Constraints of Small and Marginal Farmers:** Farmers prioritise **short-term survival over long-term resilience**. Risk aversion prevents adoption of new practices even when they are climate-appropriate. Despite subsidies under *Per Drop More Crop*, micro-irrigation adoption remains **uneven in rainfed regions**, where capital availability is lowest.
- **Quality and Trust Deficit in Bio-Inputs:** The bio-fertiliser and bio-pesticide market suffers from weak regulation, lack of standardisation, spurious or low-efficacy products. **Indian Council of Agricultural Research (ICAR)** has repeatedly highlighted the need for stricter monitoring of microbial inputs.
- **Slow "Lab-to-Land" Transfer of Climate-Resilient Seeds:** Although **1,800+ climate-resilient varieties** have been developed seed multiplication, certification, distribution take **5–10 years**. Climate change progresses **faster than seed diffusion cycles**. **Flood-tolerant Sub1 rice** has proven effectiveness, yet adoption remains patchy across eastern India.
- **Digital Divide Limiting Precision and AI-based CRA:** CRA increasingly depends on hyper-local weather forecast, pest outbreak alerts, irrigation scheduling. Advisory platforms like *Meghdoot* or *Annavari* have limited penetration in **tribal and remote districts**.
- **Weak Local Governance and Panchayat Capacity:** Climate action is poorly integrated into Gram Panchayat Development Plans. Limited awareness and technical capacity at local levels.
- **Climate Change Outpacing Adaptation Efforts:** Frequency of heatwaves, floods, extreme rainfall is rising faster than research cycles.

Way Forward

- **Fast-track climate-resilient and genome-edited seeds** through decentralised multiplication via KVKs and FPOs
- **Strengthen quality regulation of bio-inputs** with standardisation, testing labs, and traceability
- **Bridge the rural digital divide** using vernacular advisories and community intermediaries
- **Reform incentives and MSP policies** to promote crop diversification and water-efficient practices

- **Expand climate-linked financial safety nets**, including parametric insurance and satellite-based assessment
- **Create a unified national CRA roadmap** under the BioE3 framework with Panchayat-level ownership

Climate-Resilient Agriculture is no longer optional but **indispensable** for India's food security, farmer welfare, and ecological sustainability. While India has strong scientific capacity and multiple initiatives, **scaling, coherence, and inclusiveness** remain the key gaps. A well-coordinated national CRA strategy can transform Indian agriculture into a **productive, adaptive, and climate-secure system**, capable of withstanding future climate uncertainties