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ASRB-NET

AGRONOMY

Agricultural Scientists Recruitment Board (ASRB)

VOLUME – 3

SIERRA INNOVATIONS

ASRB - NET (Agronomy)

VIII UNIT

Sustainable Land Use Systems

Concept Of Sustainability And Sustainability Parameters

Introduction

Sustainability in agriculture is a cornerstone of modern agronomic practices, ensuring long-term productivity, environmental health, and socio-economic viability. In India, where agriculture supports ~60% of the population, sustainable land use systems are critical for addressing challenges like soil degradation, water scarcity, and climate change. Sustainability parameters and indicators, such as soil organic carbon (SOC), water use efficiency, and biodiversity, provide measurable benchmarks to assess agricultural systems. This part explores the concept of sustainability, its pillars (economic, social, environmental), principles, parameters, and indicators, with applications in Indian agriculture.

Concept of Sustainability

Definition and Pillars

- **Definition**: Sustainability in agriculture is the ability to maintain or enhance productivity, environmental health, and socio-economic benefits over time, meeting current needs without compromising future generations' ability to meet theirs (FAO, 1995).
- **Pillars**:
  - **Economic Sustainability**: Ensures profitability, cost-effectiveness, and market stability for farmers.
    - Example: High-yielding varieties (HD-2967 wheat) increase income in Punjab.
  - **Social Sustainability**: Promotes equitable access to resources, farmer welfare, and rural development.
    - Example: Farmer cooperatives in Gujarat enhance community resilience.
  - **Environmental Sustainability**: Protects soil, water, biodiversity, and reduces GHG emissions.
    - Example: Conservation agriculture (CA) in Haryana improves soil health.
- **Principles**:
  - Resource conservation (soil, water, nutrients).
  - Biodiversity preservation (crop, genetic diversity).
  - Resilience to climate change and economic shocks.
  - Integration of traditional and modern practices.
  - **Example**: Rice-wheat system in Punjab adopts CA to balance economic returns, social equity, and environmental health.

Importance in Indian Agriculture

- **Food Security**: Sustains production for India's 1.4 billion population.
- **Soil Health**: Mitigates degradation affecting ~30% of arable land (ICAR, 2023).
- **Climate Resilience**: Addresses erratic rainfall, temperature rise in semi-arid zones.
- **Example**: Organic farming in Sikkim enhances sustainability, supporting 100% organic certification.

Applications

- **Crop Systems**: Rice-wheat rotation with residue retention in Punjab.
- **Organic Farming**: Zero chemical use in Sikkim's cardamom farms.
- **Agroforestry**: Poplar + wheat in Uttar Pradesh for income and carbon sequestration.
- **Example**: CA in Haryana's wheat fields reduces soil erosion by 20%, enhancing sustainability.

Sustainability Parameters and Indicators

Parameters

1. **Soil Health**:
   - o Indicators: SOC (%), soil pH, nutrient availability (N, P, K), microbial activity.
   - o Importance: Soil health supports 90% of crop productivity in India.
   - o Example: SOC in Punjab's rice-wheat system = 0.5–1%, critical for fertility.
2. **Water Use Efficiency (WUE)**:
   - o Indicators: Crop yield per unit water (kg/m³), irrigation efficiency (%).
   - o Importance: Addresses water scarcity in 60% of India's rainfed areas.
   - o Example: Drip irrigation in Maharashtra's sugarcane achieves WUE = 5 kg/m³.
3. **Biodiversity**:
   - o Indicators: Crop diversity index, pollinator abundance, soil fauna.
   - o Importance: Enhances ecosystem resilience, pest control.
   - o Example: Intercropping maize + pigeonpea in Karnataka supports pollinator diversity.
4. **Carbon Sequestration**:
   - o Indicators: Soil carbon stock (t/ha), biomass carbon (t/ha).
   - o Importance: Mitigates climate change, sequesters 5–10 t/ha CO_2 in agroforestry.
   - o Example: Teak plantations in Uttar Pradesh sequester 8 t/ha carbon annually.
5. **Yield Stability**:
   - o Indicators: Coefficient of variation (CV) of yields, resilience to drought.
   - o Importance: Ensures consistent production in variable climates.
   - o Example: CV of Swarna rice in Odisha = 10%, indicating stable yields.

Indicators and Metrics

Parameter	Indicator	Metric	Example Application
Soil Health	SOC (%)	0.5–2%	Punjab rice-wheat system
Water Use Efficiency	Yield per unit water (kg/m³)	3–5 kg/m³	Maharashtra sugarcane drip irrigation
Biodiversity	Crop diversity index	0–1 (Shannon index)	Karnataka maize + pigeonpea
Carbon Sequestration	Soil carbon stock (t/ha)	5–10 t/ha	Uttar Pradesh agroforestry
Yield Stability	CV of yield (%)	5–15%	Odisha rice trials

Measurement and Monitoring

- **Soil Health**: SOC measured via Walkley-Black method, nutrient analysis via spectrometry.
- **WUE**: Calculated as yield (kg) / water applied (m³), monitored via soil moisture sensors.
- **Biodiversity**: Shannon index for crop diversity, field surveys for fauna.
- **Carbon Sequestration**: Measured via soil sampling, biomass estimation.
- **Yield Stability**: CV calculated from multi-year yield data ($\sigma / \bar{x} \times 100$).
- **Example**: SOC monitoring in Haryana's CA fields shows a 0.2% increase over 5 years.

Applications

1. **Crop Systems**:
   - o Rice-wheat system in Punjab: SOC = 0.8%, WUE = 4 kg/m³.
   - o Example: CA increases SOC by 10% in 3 years.
2. **Organic Farming**:
   - o Sikkim's organic farms: High biodiversity, low CV (8%).
   - o Example: Cardamom farms maintain yield stability.
3. **Agroforestry**:
   - o Poplar + wheat in Uttar Pradesh: Sequesters 6 t/ha carbon.
   - o Example: Enhances soil health and income.

4. **Rainfed Agriculture**:
   - Maize in Karnataka: WUE = 3.5 kg/m³, CV = 12%.
   - Example: Intercropping improves resilience.

Innovations

1. **Remote Sensing**:
   - Use: Satellite imagery for SOC, biodiversity monitoring.
   - Example: ISRO's RISAT monitors soil health in Punjab.
2. **Precision Agriculture**:
   - Use: Sensors for WUE, nutrient management.
   - Example: Soil moisture sensors in Maharashtra's sugarcane fields.
3. **Carbon Credit Systems**:
   - Use: Monetizes sequestration (₹5,000–10,000/ha).
   - Example: Agroforestry farmers in Uttar Pradesh earn credits.
4. **Data Analytics**:
   - Use: R, Python for sustainability indicator analysis.
   - Example: R analyzes CV in Odisha rice trials.

PYQ Analysis

1. "What is a pillar of sustainability?"
   (A) Economic (B) Chemical
   (C) Mechanical (D) Genetic

Answer: (A) Economic.
Explanation: Economic sustainability ensures profitability.

2. "Which indicator measures soil health?"
   (A) SOC (B) CV
   (C) LER (D) R^2

Answer: (A) SOC.
Explanation: SOC reflects soil fertility.

3. "What does a low CV indicate?"
   (A) High variability
   (B) Stable yields
   (C) Skewed data
   (D) No significance

Answer: (B) Stable yields.
Explanation: Low CV shows consistent production.

4. "What measures WUE?"
   (A) Yield per unit water
   (B) SOC
   (C) Biodiversity index
   (D) Carbon stock

Answer: (A) Yield per unit water.
Explanation: WUE is yield (kg) / water (m³).

5. "Which parameter supports climate change mitigation?"
   (A) Yield
   (B) Carbon sequestration
   (C) Fertilizer use
   (D) Tillage

Answer: (B) Carbon sequestration.
Explanation: Sequestration reduces GHG emissions.

- **Trend**: PYQs focus on sustainability definitions, indicators, and applications, with recent emphasis on carbon sequestration and WUE.

Case Study: Sustainability in Rice-Wheat System

In Punjab (Ludhiana):

- **Context**: Rice-wheat system, loamy soils, pH 7.5, irrigated, CA adoption.
- **Parameters**:
  - SOC: 0.8%, increased by 0.2% with residue retention.
  - WUE: 4 kg/m³ with drip irrigation.
  - Biodiversity: Shannon index = 0.6 with intercropping.
  - Carbon Sequestration: 5 t/ha/year with CA.
  - Yield Stability: CV = 10% over 5 years.
- **Analysis**:
  - CA practices (zero tillage, residue cover) enhance SOC, WUE.
  - Intercropping boosts biodiversity, yield stability.
- **Impact**: Increases profitability by ₹20,000/ha, reduces GHG emissions by 15%. This case study illustrates the application of sustainability parameters in agronomy, a key exam concept.

Conclusion

This part explored the concept of sustainability and its parameters, vital for the ASRB NET JRF exam. Sustainability, with its economic, social, and environmental pillars, ensures long-term agricultural productivity, while parameters like SOC, WUE, biodiversity, carbon sequestration, and yield stability provide measurable benchmarks. Applications in rice-wheat, organic farming, and agroforestry demonstrate practical utility. Innovations like remote sensing and data analytics enhance monitoring efficiency.

Conservation Agriculture: Principles And Practices

Introduction

Conservation agriculture (CA) is a sustainable farming approach that enhances soil health, water efficiency, and crop resilience while reducing environmental degradation, making it a cornerstone of sustainable land use systems in India. With ~60% of India's agriculture dependent on rainfed systems and facing challenges like soil erosion, water scarcity, and climate change, CA's principles—minimum tillage, permanent soil cover, and crop rotation—offer transformative solutions. This part explores CA's principles, practices (zero tillage, residue retention, diversified cropping), benefits, challenges, and applications in Indian agriculture.

Conservation Agriculture: Principles

Definition and Core Principles

- **Definition**: Conservation agriculture is a farming system that promotes sustainable crop production through minimal soil disturbance, permanent organic soil cover, and diversified cropping to enhance soil health, biodiversity, and resource efficiency (FAO, 2007).
- **Core Principles**:
  - **Minimum Tillage**:
    - Reduces soil disturbance to maintain soil structure, organic matter, and microbial activity.
    - Example: Zero tillage in wheat (Haryana) reduces soil erosion by 20%.
  - **Permanent Soil Cover**:
    - Maintains crop residues or cover crops on soil to protect against erosion, retain moisture, and suppress weeds.
    - Example: Rice straw retention in Punjab improves soil moisture by 15%.
  - **Crop Rotation/Diversification**:
    - Rotates or intermixes crops to enhance soil fertility, break pest cycles, and improve resilience.
    - Example: Maize-wheat-mungbean rotation in Karnataka increases yield stability.
- **Importance**:
  - Enhances soil organic carbon (SOC) by 0.1–0.3% annually.
  - Reduces water use by 20–30% and GHG emissions by 10–15%.
  - Improves yield stability (CV reduced by 5–10%).
- **Example**: CA in Haryana's rice-wheat system increases SOC to 0.8%, saves 25% irrigation water.

Theoretical Foundations

- **Soil Health**: Minimum tillage and residue cover preserve soil aggregates, increase SOC (0.5–1%), and boost microbial diversity.
- **Water Conservation**: Soil cover reduces evaporation, improves infiltration (10–20% higher), and enhances WUE (3–5 kg/m³).
- **Pest and Disease Management**: Crop rotation disrupts pest life cycles, reducing incidence by 15–25%.
- **Example**: Zero tillage in Punjab's wheat fields maintains soil aggregates, reducing compaction by 10%.

Applications

- **Rainfed Agriculture**: CA in Maharashtra's sorghum systems improves WUE by 20%.
- **Irrigated Systems**: CA in Punjab's rice-wheat system reduces tillage costs by ₹5,000/ha.
- **Dryland Farming**: CA in Rajasthan's pearl millet fields enhances SOC by 0.2%.
- **Example**: Maize-wheat rotation in Karnataka under CA increases yields by 10% over conventional tillage.

Conservation Agriculture: Practices

Zero Tillage (ZT)

- **Definition**: Planting crops without plowing, using specialized seeders (e.g., happy seeder) to sow directly into residue-covered soil.
- **Benefits**:
  - Reduces soil erosion by 20–30%.
  - Saves 20–25% irrigation water.
  - Lowers fuel costs by ₹2,000–3,000/ha.
- **Challenges**:
  - Initial investment in ZT machinery (₹1–2 lakh).
  - Weed pressure in early years (10–15% higher).
- **Example**: ZT in Haryana's wheat fields increases yield by 5% (4.8 t/ha vs. 4.5 t/ha conventional).

Residue Retention

- **Definition**: Leaving crop residues (e.g., rice straw, wheat stubble) on fields as mulch to cover soil.
- **Benefits**:
  - Improves soil moisture retention by 10–15%.
  - Enhances SOC by 0.1–0.2% annually.
  - Suppresses weeds by 20–30%.
- **Challenges**:
  - Residue management (e.g., chopping, spreading) requires labor or machinery.
  - Potential pest/disease carryover if not managed.
- **Example**: Rice straw retention in Punjab's wheat fields reduces irrigation by 20%.

Diversified Cropping

- **Definition**: Rotating or intercropping crops to enhance soil fertility, reduce pest pressure, and improve resilience.
- **Types**:
  - Rotation: Maize-wheat-mungbean, rice-wheat-pulses.
  - Intercropping: Maize + pigeonpea, sorghum + cowpea.
- **Benefits**:
  - Increases yield stability (CV reduced by 5–10%).
  - Improves N fixation (20–40 kg/ha in legume rotations).
  - Reduces pest incidence by 15–20%.
- **Challenges**:
  - Crop selection requires knowledge of compatibility.
  - Market demand for secondary crops (e.g., pulses) varies.
- **Example**: Maize-wheat-mungbean rotation in Karnataka adds 30 kg/ha N, boosts yields by 10%.

Supporting Practices

Integrated Nutrient Management (INM):

- Combines organic (FYM, compost) and inorganic fertilizers to sustain soil fertility.
- Example: INM in Haryana's CA wheat fields applies 50% N via urea, 50% via FYM.

Water Management:

- Drip irrigation, alternate wetting and drying (AWD) enhance WUE.
- Example: AWD in Odisha's CA rice fields saves 25% water.

Weed Management:

- Pre-emergence herbicides (e.g., pendimethalin) and mulch control weeds.
- Example: Pendimethalin in Punjab's ZT wheat reduces weed biomass by 30%.

Pest Management:

- IPM (e.g., pheromone traps, biocontrol) minimizes pesticide use.
- Example: Trichogramma in Karnataka's CA maize controls stem borers.

CA Practices and Benefits

Practice	Key Features	Benefits	Example Application
Zero Tillage	No plowing, direct seeding	Reduces erosion, saves water	Haryana wheat fields
Residue Retention	Crop residues as mulch	Improves SOC, suppresses weeds	Punjab rice-wheat system
Diversified Cropping	Rotation, intercropping	Enhances fertility, yield stability	Karnataka maize-wheat-mungbean
INM	Organic + inorganic fertilizers	Sustains soil health	Uttar Pradesh CA sugarcane

Applications in Indian Agriculture

- **Rice-Wheat System**:
  - Region: Punjab, Haryana, Uttar Pradesh (~10 Mha).
  - Practices: ZT wheat, rice straw retention, wheat-mungbean rotation.
  - Benefits: Increases SOC by 0.2%, saves 20% water, boosts profit by ₹10,000/ha.
  - Example: ZT wheat in Haryana yields 4.8 t/ha, 5% higher than conventional.
- **Maize-Based Systems**:
  - Region: Karnataka, Madhya Pradesh (~3 Mha).
  - Practices: ZT maize, maize-wheat-mungbean rotation, residue mulch.
  - Benefits: Reduces erosion by 25%, improves WUE by 20%.
  - Example: Maize + pigeonpea intercropping in Karnataka achieves LER = 1.3.
- **Rainfed Systems**:
  - Region: Rajasthan, Maharashtra (~30 Mha).
  - Practices: ZT pearl millet, sorghum + cowpea intercropping, residue cover.
  - Benefits: Enhances SOC by 0.1%, stabilizes yields (CV = 12%).
  - Example: ZT sorghum in Maharashtra increases yield by 10%.
- **Sugarcane Systems**:
  - Region: Uttar Pradesh, Tamil Nadu (~5 Mha).
  - Practices: ZT in ratoon crops, residue retention, INM rotations.
  - Benefits: Saves 15% water, reduces costs by ₹5,000/ha.
  - Example: CA sugarcane in Uttar Pradesh yields 90 t/ha, stable over years.

Challenges and Solutions

High Initial Costs:

- Challenge: ZT machinery costs ₹1–2 lakh.
- Solution: Subsidies (50–80% under PMKSY), custom hiring centers.
- Example: Haryana's custom hiring centers provide ZT seeders at ₹500/ha.

Weed Pressure:

- Challenge: Initial weed increase (10–15%) in ZT.
- Solution: Integrated weed management (herbicides, mulch).
- Example: Pendimethalin in Punjab's ZT wheat controls weeds by 30%.

Farmer Awareness:

- Challenge: Limited knowledge of CA benefits (~40% adoption in Punjab).
- Solution: Extension services, farmer field schools.
- Example: ICAR's CA training in Karnataka boosts adoption by 20%.

Residue Management:

- Challenge: Labor-intensive residue handling.
- Solution: Mechanized choppers, balers (₹50,000–1 lakh).
- Example: Happy seeder in Punjab manages rice straw efficiently.

Innovations

1. **Precision Machinery**:
   - Use: Happy seeder, turbo seeder for ZT planting.
   - Example: Happy seeder in Haryana reduces fuel use by 50%.

2. **Remote Sensing**:
   - Use: Monitors residue cover, soil health via satellite imagery.
   - Example: ISRO's RISAT tracks CA adoption in Punjab.
3. **Digital Tools**:
   - Use: Apps for CA practice guidance (e.g., Kisan Suvidha).
   - Example: Kisan Suvidha app in Uttar Pradesh advises on ZT timing.
4. **Biochar Integration**:
   - Use: Converts residues into biochar, enhancing SOC.
   - Example: Biochar in Karnataka's CA maize fields increases SOC by 0.3%.

PYQ Analysis

1. "What is a principle of CA?"
   (A) Deep tillage
   (B) Minimum tillage
   (C) Chemical weeding
   (D) Monocropping

Answer: (B) Minimum tillage.
Explanation: Reduces soil disturbance.

2. "What is a benefit of residue retention?"
   (A) Weed increase
   (B) SOC improvement
   (C) Pest proliferation
   (D) Water loss

Answer: (B) SOC improvement.
Explanation: Enhances soil fertility.

3. "Which practice saves water in CA?"
   (A) Deep plowing
   (B) ZT
   (C) Flood irrigation
   (D) No rotation

Answer: (B) ZT.
Explanation: Saves 20–25% water.

4. "What enhances yield stability in CA?"
   (A) Monocropping
   (B) Crop rotation
   (C) Heavy tillage
   (D) No mulch

Answer: (B) Crop rotation.
Explanation: Reduces CV by 5–10%.

5. "What is a challenge of CA adoption?"
   (A) Low cost (B) High initial cost
   (C) No weeds (D) High yields

Answer: (B) High initial cost.
Explanation: ZT machinery is expensive.

- **Trend**: PYQs focus on CA principles, benefits, and challenges, with recent emphasis on residue management and adoption constraints.

Case Study: CA in Rice-Wheat System

In Haryana (Karnal):

- **Context**: Rice-wheat system, loamy soils, pH 7.5, irrigated, CA adoption since 2015.
- **Practices**:
  - ZT wheat using happy seeder.
  - Rice straw retention (3–5 t/ha).
  - Wheat-mungbean rotation.
- **Impacts**:
  - Yield: Wheat = 4.8 t/ha (+5%), mungbean = 0.8 t/ha.
  - SOC: Increased from 0.6% to 0.8% in 5 years.
  - WUE: 4 kg/m³, 20% water savings.
  - Profit: ₹15,000/ha higher than conventional.
- **Analysis**:
  - ZT reduces costs by ₹3,000/ha, erosion by 25%.
  - Residue mulch suppresses weeds by 30%.
- **Impact**: Recommends CA for sustainable rice-wheat systems. This case study illustrates the application of CA in agronomy, a key exam concept.

Conclusion

This part explored conservation agriculture principles (minimum tillage, soil cover, crop rotation) and practices (zero tillage, residue retention, diversified cropping), vital for the ASRB NET JRF exam. CA enhances soil health, water efficiency, and yield stability, addressing India's agricultural challenges. Applications in rice-wheat, maize, and rainfed systems demonstrate practical utility. Innovations like precision machinery and remote sensing boost CA adoption.

Climate Change Mitigation In Agriculture

Introduction

Climate change poses significant challenges to Indian agriculture, with rising temperatures, erratic rainfall, and increased greenhouse gas (GHG) emissions threatening food security for a population of ~1.4 billion. Agriculture contributes ~16% to India's GHG emissions (MoEFCC, 2023), necessitating robust mitigation strategies to reduce emissions while sustaining productivity. Mitigation approaches, such as carbon sequestration, reduced tillage, agroforestry, and methane capture, align with sustainable land use systems, enhancing resilience and environmental health. This part explores climate change impacts on agriculture and mitigation strategies, covering concepts, mechanisms, applications, challenges, and practical examples in Indian agriculture.

Climate Change Impacts on Agriculture

Overview of Climate Change

- **Definition**: Climate change refers to long-term shifts in weather patterns driven by anthropogenic GHG emissions (CO_2, CH_4, N_2O), leading to global warming, altered precipitation, and extreme weather events.
- **Key Metrics**:
  - Global temperature rise: ~1.1°C above pre-industrial levels (IPCC, 2021).
  - India's temperature increase: ~0.7°C since 1900 (IMD, 2023).
  - GHG emissions: India's agriculture emits ~500 Mt CO_2e annually (2023).
- **Example**: India's monsoon variability has increased by 10% since 2000, affecting kharif crop yields.

Impacts on Indian Agriculture

Temperature Rise:

- Effect: Reduces crop yields by 1–2% per °C increase for wheat, rice.
- Example: Wheat yields in Punjab decline by 5% during heatwaves (>35°C).

Erratic Rainfall:

- Effect: Delays sowing, reduces water availability in 60% rainfed areas.
- Example: Delayed monsoon in Maharashtra reduces sorghum yields by 10–15%.

Extreme Weather:

- Effect: Floods, droughts, cyclones damage crops (~20% annual losses).
- Example: Cyclone Amphan (2020) destroyed 30% of Odisha's rice crop.

Soil Degradation:

- Effect: Increased erosion, reduced SOC (0.5–1% in semi-arid zones).
- Example: Rajasthan soils lose 0.1% SOC annually due to heat stress.

Pest and Disease:

- Effect: Warmer climates increase pest incidence by 15–20%.
- Example: Fall armyworm in Karnataka's maize fields rose by 25% since 2018.

Agricultural Contribution to Emissions

- **Sources**:
  - Methane (CH_4): 50% from rice paddies, livestock (~250 Mt CO_2e).
  - Nitrous oxide (N_2O): 30% from fertilizer use (~150 Mt CO_2e).
  - CO_2: 20% from tillage, residue burning (~100 Mt CO_2e).
- **Example**: Rice paddies in Punjab emit ~5 t/ha CH_4 annually due to flooding.

Climate Change Mitigation Strategies

Carbon Sequestration

- **Definition**: The process of capturing and storing atmospheric CO_2 in soil, biomass, or long-lived products to reduce GHG concentrations.
- **Mechanisms**:
  - **Soil Carbon Storage**: SOC increases via organic inputs (residue, manure).
  - **Biomass Carbon**: Trees, crops store CO_2 in plant tissues.
  - **Biochar**: Stable carbon form enhances soil carbon (20–50 t/ha).

- **Practices**:
  - Conservation agriculture (CA): Zero tillage, residue retention.
  - Agroforestry: Tree integration (e.g., poplar, teak).
  - Organic farming: Compost, FYM applications.
- **Benefits**:
  - Sequesters 5–10 t/ha CO_2 annually in CA, 8–15 t/ha in agroforestry.
  - Improves SOC by 0.1–0.3% per year.
  - Enhances soil fertility, yield stability (CV reduced by 5%).
- **Challenges**:
  - Slow sequestration rates (5–10 years for measurable SOC increase).
  - High initial costs (e.g., biochar: ₹10,000/ha).
- **Example**: CA in Haryana's rice-wheat system sequesters 6 t/ha CO_2, increases SOC to 0.8%.

Reduced Tillage

- **Definition**: Minimizing soil disturbance (e.g., zero tillage, strip tillage) to reduce CO_2 emissions and enhance soil carbon storage.
- **Mechanisms**:
  - Preserves soil aggregates, reducing CO_2 release from SOC decomposition.
  - Lowers fuel use (10–15 L/ha savings), reducing emissions by 20–30 kg CO_2/ha.
- **Practices**:
  - Zero tillage (ZT) with happy seeder in wheat.
  - Strip tillage in maize, soybean.
- **Benefits**:
  - Reduces emissions by 15–20% (50–100 kg CO_2/ha).
  - Saves ₹2,000–3,000/ha in fuel costs.
  - Increases SOC by 0.1–0.2% annually.
- **Challenges**:
  - Weed pressure in early years (10–15% increase).
  - Machinery costs (₹1–2 lakh for ZT seeders).
- **Example**: ZT wheat in Punjab reduces emissions by 80 kg CO_2/ha, saves 20% water.

Agroforestry

- **Definition**: Integrating trees with crops or livestock to sequester carbon, enhance biodiversity, and diversify income.
- **Mechanisms**:
  - Trees store CO_2 in biomass (8–15 t/ha/year).
  - Root systems enhance soil carbon (5–10 t/ha).
  - Reduces emissions from land clearing.
- **Systems**:
  - Agri-silviculture: Poplar + wheat (Punjab).
  - Silvi-pastoral: Subabul + guinea grass (Rajasthan).
  - Agri-horti: Coconut + banana (Kerala).
- **Benefits**:
  - Sequesters 10–20 t/ha CO_2 annually.
  - Increases income by ₹20,000–50,000/ha.
  - Improves soil health, biodiversity (Shannon index = 0.6–0.8).
- **Challenges**:
  - Long gestation period (5–10 years for trees).
  - Land tenure issues limit adoption (~25% of farmers).
- **Example**: Poplar + wheat in Uttar Pradesh sequesters 12 t/ha CO_2, yields ₹50,000/ha timber.

Methane Capture

- **Definition**: Reducing or capturing methane (CH_4) emissions from rice paddies and livestock through management practices or technology.
- **Mechanisms**:
  - **Alternate Wetting and Drying (AWD)**: Reduces anaerobic conditions in rice fields, cutting CH_4 by 30–50%.
  - **Biogas Plants**: Convert livestock manure into energy, capturing CH_4.
  - **Dietary Adjustments**: Feed additives (e.g., seaweed) reduce enteric CH_4 by 10–20%.

- **Practices**:
  - AWD in rice paddies (Odisha).
  - Biogas units in dairy farms (Gujarat).
  - Feed additives in cattle (Tamil Nadu).
- **Benefits**:
  - Reduces CH_4 emissions by 2–5 t/ha in rice, 0.5–1 t CO_2e/cow.
  - Saves ₹5,000–10,000/ha in energy costs via biogas.
  - Improves air quality, farmer income.
- **Challenges**:
  - Biogas plant cost (₹50,000–1 lakh).
  - AWD requires precise water management.
- **Example**: AWD in Odisha's rice fields cuts CH_4 emissions by 40%, saves 25% water.

Other Mitigation Strategies

1. **Integrated Nutrient Management (INM)**:
   - Reduces N_2O emissions by 20–30% via precise fertilizer use.
   - Example: INM in Punjab wheat reduces N_2O by 50 kg/ha.
2. **Cover Crops**:
   - Enhances carbon sequestration, reduces soil exposure.
   - Example: Mungbean cover in Karnataka sequesters 2 t/ha CO_2.
3. **Renewable Energy**:
   - Solar pumps, biomass energy replace diesel, cutting CO_2 emissions.
   - Example: Solar pumps in Rajasthan save 100 kg CO_2/ha/year.
4. **Precision Agriculture**:
   - Optimizes inputs, reducing emissions (10–15%).
   - Example: Drone-based fertilizer in Maharashtra cuts N_2O by 20%.

Mitigation Strategies and Impacts

Strategy	Mechanism	Impact	Example Application
Carbon Sequestration	Soil and biomass storage	5–15 t/ha CO_2 reduction	Haryana CA rice-wheat
Reduced Tillage	Minimizes soil disturbance	15–20% emissions cut	Punjab ZT wheat
Agroforestry	Tree biomass sequestration	10–20 t/ha CO_2/year	Uttar Pradesh poplar + wheat
Methane Capture	AWD, biogas, feed additives	30–50% CH_4 reduction	Odisha rice AWD

Applications in Indian Agriculture

Rice-Wheat System:

- Region: Punjab, Haryana, Uttar Pradesh (~10 Mha).
- Strategies: CA (ZT, residue retention), AWD, INM.
- Impacts: Reduces CO_2 by 6 t/ha, CH_4 by 2 t/ha, saves ₹10,000/ha.
- Example: ZT wheat + AWD rice in Haryana cuts emissions by 20%.

Maize-Based Systems:

- Region: Karnataka, Madhya Pradesh (~3 Mha).
- Strategies: CA, cover crops, agroforestry.
- Impacts: Sequesters 5 t/ha CO_2, improves SOC by 0.2%.
- Example: Maize + pigeonpea in Karnataka with CA reduces emissions by 15%.

Rainfed Systems:

- Region: Rajasthan, Maharashtra (~30 Mha).
- Strategies: Agroforestry, reduced tillage, INM.
- Impacts: Sequesters 8 t/ha CO_2, stabilizes yields (CV = 12%).
- Example: Subabul + pearl millet in Rajasthan sequesters 10 t/ha CO_2.

Livestock Systems:

- Region: Gujarat, Tamil Nadu (~50 million cattle).
- Strategies: Biogas, feed additives, manure management.
- Impacts: Reduces CH_4 by 0.5 t/cow, saves ₹5,000/farm.
- Example: Biogas units in Gujarat cut CH_4 by 30%.

Challenges and Solutions

- **High Costs**:
  - Challenge: ZT machinery, biogas plants cost ₹50,000–2 lakh.
  - Solution: Subsidies (50–80% under NMSA), cooperative models.
  - Example: Punjab's ZT seeder subsidies increase adoption by 25%.
- **Farmer Awareness**:
  - Challenge: Only 30% of farmers aware of mitigation benefits.
  - Solution: Extension services, farmer field schools.
  - Example: ICAR's CA training in Karnataka boosts awareness by 20%.
- **Technical Complexity**:
  - Challenge: AWD, precision agriculture require expertise.
  - Solution: Digital apps, training programs.
  - Example: Kisan Suvidha app in Odisha guides AWD implementation.
- **Policy Gaps**:
  - Challenge: Limited incentives for carbon sequestration.
  - Solution: Carbon credit schemes (₹5,000–10,000/ha).
  - Example: Uttar Pradesh agroforestry farmers earn credits.

Innovations

Remote Sensing:

- Use: Monitors SOC, emissions via satellite imagery.
- Example: ISRO's RISAT tracks CA emissions in Punjab.

AI and IoT:

- Use: Predicts emissions, optimizes inputs.
- Example: AI-based yield models in Karnataka reduce N_2O by 15%.

Biochar Technology:

- Use: Converts residues into stable carbon, sequesters 20–50 t/ha.
- Example: Biochar in Maharashtra's CA fields boosts SOC by 0.3%.

Carbon Markets:

- Use: Monetizes sequestration, incentivizes farmers.
- Example: Carbon credits in Uttar Pradesh agroforestry yield ₹8,000/ha.

PYQ Analysis

1. "What is a mitigation strategy in agriculture?"
   (A) Deep tillage
   (B) Carbon sequestration
   (C) Flood irrigation
   (D) Monocropping

Answer: (B) Carbon sequestration.
Explanation: Reduces atmospheric CO_2.

2. "What reduces CH_4 emissions in rice?"
   (A) Continuous flooding (B) AWD
   (C) Heavy tillage (D) No rotation

Answer: (B) AWD.
Explanation: Cuts CH_4 by 30–50%.

3. "Which practice reduces CO_2 emissions?"
   (A) ZT
   (B) Burning residues
   (C) Deep plowing
   (D) Chemical weeding

Answer: (A) ZT.
Explanation: Saves 50–100 kg CO_2/ha.

4. "What sequesters carbon in agroforestry?"
   (A) Soil erosion (B) Biomass storage
   (C) Pest increase (D) Water loss

Answer: (B) Biomass storage.
Explanation: Trees store 8–15 t/ha CO_2.

5. "What is a challenge of mitigation adoption?"
   (A) Low cost (B) High cost
   (C) No emissions (D) High yields

Answer: (B) High cost.
Explanation: Machinery, biogas plants are expensive.

- **Trend**: PYQs focus on mitigation strategies, emission sources, and challenges, with recent emphasis on AWD and carbon credits.

Case Study: Mitigation in Rice-Wheat System In Punjab (Ludhiana):

- **Context**: Rice-wheat system, loamy soils, pH 7.5, irrigated, CA since 2015.
- **Strategies**:
  - ZT wheat with happy seeder.
  - AWD in rice paddies.
  - Poplar agroforestry in field boundaries.
  - INM with 50% organic N.

- **Impacts**:
  - CO_2 reduction: 6 t/ha/year via CA, agroforestry.
  - CH_4 reduction: 2 t/ha via AWD.
  - SOC: Increased from 0.6% to 0.8% in 5 years.
  - Profit: ₹15,000/ha higher than conventional.
- **Analysis**:
  - ZT saves 80 kg CO_2/ha, AWD cuts CH_4 by 40%.
  - Agroforestry sequesters 10 t/ha CO_2.
- **Impact**: Recommends CA, AWD, agroforestry for climate-resilient farming. This case study illustrates the application of mitigation strategies in agronomy, a key exam concept.

Conclusion

This part has explored climate change mitigation in agriculture, vital for the ASRB NET JRF exam. Mitigation strategies like carbon sequestration, reduced tillage, agroforestry, and methane capture reduce GHG emissions while sustaining productivity. Applications in rice-wheat, maize, and livestock systems demonstrate practical utility. Innovations like AI, remote sensing, and carbon markets enhance mitigation efficiency.

Alternate Land Use Systems

Introduction

Alternate land use systems, such as agroforestry, silvi-pastoral, agri-horti, and ley farming, offer sustainable alternatives to conventional monocropping, enhancing land productivity, environmental resilience, and farmer livelihoods in India. With ~55 million hectares (Mha) of degraded and marginal lands (ICAR, 2023), these systems are critical for diversifying income, conserving resources, and mitigating climate change in a country where agriculture supports ~60% of the population. This part explores alternate land use systems, covering types (agroforestry, silvi-pastoral, agri-horti, ley farming), features, applications, benefits, challenges, and practical examples in Indian agriculture.

Alternate Land Use Systems: Overview

Definition and Importance

- **Definition**: Alternate land use systems integrate crops, trees, and/or livestock on the same land unit, either simultaneously or sequentially, to optimize productivity, diversify income, and enhance environmental sustainability compared to traditional monocropping.
- **Importance**:
  - Reclaims ~55 Mha of wastelands (degraded, saline, eroded lands) in India.
  - Increases income by 20–50% through diversified products (e.g., timber, fruits, fodder).
  - Enhances soil health (SOC by 0.1–0.3%), water retention (10–20%), and carbon sequestration (5–15 t/ha/year).
  - Supports climate resilience in 60% rainfed areas facing erratic rainfall.
- **Example**: Agroforestry (poplar + wheat) in Punjab generates ₹50,000/ha from timber, stabilizes yields, and sequesters 10 t/ha CO_2 annually.

Objectives

- **Productivity**: Maximize output per unit area (e.g., crops + timber).
- **Sustainability**: Conserve soil, water, biodiversity.
- **Resilience**: Mitigate climate risks (e.g., drought, floods).
- **Diversification**: Reduce dependence on single crops, enhancing economic stability.
- **Example**: Silvi-pastoral systems in Rajasthan provide fodder, fuelwood, and income during droughts.

Types of Alternate Land Use Systems

1. **Agroforestry**: Integrates trees with crops and/or livestock.
2. **Silvi-Pastoral**: Combines trees with pasture or livestock.
3. **Agri-Horti**: Integrates crops with horticultural plants (e.g., fruit trees).

4. **Ley Farming**: Alternates crops with temporary grasslands (leys) for soil fertility.

- **Example**: Agri-horti (coconut + banana) in Kerala yields 10,000 nuts/ha and 20 t/ha bananas, diversifying income.

Agroforestry

Definition and Features

- **Definition**: Agroforestry is a land use system integrating trees or shrubs with crops and/or livestock to optimize ecological and economic benefits.
- **Features**:
  - Multi-layered structure (trees, crops, grasses).
  - Long-term investment (5–20 years for tree maturity).
  - High biodiversity (Shannon index = 0.6–0.8).
  - Carbon sequestration (8–15 t/ha/year).
- **Example**: Poplar + wheat in Uttar Pradesh combines fast-growing trees with annual crops.

Sub-Types

- **Agri-Silviculture**: Trees + crops (e.g., teak + rice).
- **Silvi-Pastoral**: Trees + pasture/livestock (e.g., subabul + guinea grass).
- **Agri-Horti-Silviculture**: Trees + crops + fruits (e.g., mango + wheat + vegetables).
- **Homegardens**: Mixed trees, crops, livestock (e.g., coconut + spices in Kerala).

Benefits

- **Economic**: Timber, fruits, fodder increase income by ₹20,000–50,000/ha.
- **Environmental**: Sequesters 10–20 t/ha CO_2, reduces erosion by 20–30%.
- **Social**: Provides fuelwood, employment, supports ~25% of rural households.
- **Example**: Teak + rice in Tamil Nadu yields ₹1 lakh/ha timber after 20 years, improves SOC by 0.2%.

Challenges

- **Long Gestation**: Trees require 5–20 years for returns.
- **Land Tenure**: Limits adoption on leased lands (~30% of farmers).
- **Management Complexity**: Requires knowledge of tree-crop interactions.
- **Example**: Poplar + wheat in Punjab faces shading issues, reducing wheat yield by 10% if unpruned.

Applications

- **Northern India**: Poplar + wheat in Punjab, Haryana (~1 Mha).
- **Southern India**: Coconut + spices in Kerala, Tamil Nadu (~0.5 Mha).
- **Northeast India**: Bamboo + rice in Assam (~0.2 Mha).
- **Example**: Poplar + wheat in Uttar Pradesh sequesters 12 t/ha CO_2, yields ₹50,000/ha timber.

Silvi-Pastoral Systems

Definition and Features

- **Definition**: Silvi-pastoral systems combine trees with pasture or livestock to produce fodder, timber, and animal products while conserving soil and water.
- **Features**:
  - Trees provide shade, fodder (e.g., subabul leaves: 15% protein).
  - Pastures support grazing (e.g., guinea grass: 20 t/ha fodder).
  - Low input requirements, suitable for marginal lands.
- **Example**: Subabul + guinea grass in Rajasthan supports cattle, yields 5 t/ha timber.

Benefits

- **Economic**: Fodder, milk, timber increase income by ₹15,000–30,000/ha.
- **Environmental**: Reduces erosion by 25%, sequesters 5–10 t/ha CO_2.
- **Social**: Supports pastoral communities, enhances livestock health.
- **Example**: Babul + stylosanthes in Gujarat provides 15 t/ha fodder, stabilizes soil.

Challenges

- **Overgrazing**: Degrades pastures, reduces tree regeneration.
- **Tree-Livestock Conflict**: Grazing damages young trees.
- **Market Access**: Limited demand for fodder species.
- **Example**: Overgrazing in Rajasthan's silvi-pastoral systems reduces grass yield by 20%.

Applications

- **Arid Regions**: Babul + cenchrus in Rajasthan (~2 Mha).
- **Semi-Arid Regions**: Subabul + stylosanthes in Gujarat, Maharashtra.
- **Hilly Areas**: Pine + grasses in Himachal Pradesh.
- **Example**: Subabul + guinea grass in Rajasthan supports 5 cows/ha, sequesters 8 t/ha CO_2.

Agri-Horti Systems

Definition and Features

- **Definition**: Agri-horti systems integrate annual crops with perennial horticultural plants (e.g., fruit trees) to diversify production and enhance resilience.
- **Features**:
  - Combines food crops (e.g., wheat) with fruits (e.g., mango).
  - High-value products (fruits, vegetables).
  - Intensive management (irrigation, pruning).
- **Example**: Coconut + banana in Kerala yields nuts and fruits, diversifying income.

Benefits

- **Economic**: Fruits fetch ₹30,000–60,000/ha, crops add ₹20,000/ha.
- **Environmental**: Improves soil cover, sequesters 5–10 t/ha CO_2.
- **Social**: Enhances nutrition, supports smallholder farmers (~40% of India's farmers).
- **Example**: Mango + wheat in Uttar Pradesh yields 10 t/ha fruits, 4 t/ha wheat.

Challenges

- **High Inputs**: Irrigation, fertilizers cost ₹10,000–20,000/ha.
- **Market Volatility**: Fruit prices fluctuate by 20–30%.
- **Pest Pressure**: Fruit trees attract pests (e.g., mango fly).
- **Example**: Banana wilt in Kerala's agri-horti systems reduces yields by 15%.

Applications

- **Southern India**: Coconut + banana, mango + vegetables in Kerala (~1 Mha).
- **Northern India**: Mango + wheat in Uttar Pradesh, Haryana.
- **Western India**: Guava + pulses in Gujarat.
- **Example**: Coconut + banana in Tamil Nadu generates ₹80,000/ha annually.

Ley Farming

Definition and Features

- **Definition**: Ley farming alternates arable crops with temporary grasslands (leys) for 2–5 years to restore soil fertility, control weeds, and support livestock.
- **Features**:
  - Leys (e.g., berseem, lucerne) fix N (20–40 kg/ha).
  - Short-term pastures improve soil structure.
  - Rotational system (crops-ley-crops).
- **Example**: Berseem ley + wheat in Punjab restores 30 kg/ha N, enhances wheat yield.

Benefits

- **Economic**: Reduces fertilizer costs by ₹5,000/ha, provides fodder.
- **Environmental**: Increases SOC by 0.1–0.2%, controls weeds by 20%.
- **Social**: Supports dairy farming, improves farmer income.
- **Example**: Lucerne ley + maize in Haryana adds 25 kg/ha N, yields 15 t/ha fodder.

Challenges

- **Land Availability**: Leys reduce cropping area temporarily.
- **Management**: Requires grazing or fodder harvesting skills.
- **Adoption**: Limited to ~10% of farmers due to awareness gaps.
- **Example**: Ley farming in Rajasthan faces water scarcity, limiting grass growth.

Applications

- **Northern India**: Berseem + wheat in Punjab, Haryana.
- **Western India**: Lucerne + sorghum in Gujarat.
- **Central India**: Stylosanthes + maize in Madhya Pradesh.
- **Example**: Berseem ley + wheat in Punjab increases wheat yield by 5% (4.8 t/ha).

Alternate Land Use Systems: Comparative Analysis

System	Components	Benefits	Challenges	Example Application
Agroforestry	Trees + crops/livestock	Sequesters 10–20 t/ha CO_2	Long gestation period	Punjab poplar + wheat
Silvi-Pastoral	Trees + pasture/livestock	Reduces erosion by 25%	Overgrazing	Rajasthan subabul + guinea grass
Agri-Horti	Crops + fruit trees	₹50,000–80,000/ha income	High inputs	Kerala coconut + banana
Ley Farming	Crops + temporary grasslands	Adds 20–40 kg/ha N	Land availability	Haryana berseem + wheat

Applications in Indian Agriculture

- **Degraded Lands**:
  - Region: Rajasthan, Gujarat (~20 Mha wastelands).
  - Systems: Silvi-pastoral, agroforestry.
  - Impacts: Reclaims 10–15% of wastelands, sequesters 8 t/ha CO_2.
  - Example: Babul + cenchrus in Rajasthan restores 5% of degraded land.
- **Rainfed Areas**:
  - Region: Maharashtra, Madhya Pradesh (~30 Mha).
  - Systems: Agroforestry, ley farming.
  - Impacts: Stabilizes yields (CV = 12%), adds 20 kg/ha N.
  - Example: Subabul + sorghum in Maharashtra yields 2 t/ha fodder.
- **Irrigated Areas**:
  - Region: Punjab, Uttar Pradesh (~15 Mha).
  - Systems: Agri-horti, agroforestry.
  - Impacts: Increases income by ₹30,000/ha, improves SOC by 0.2%.
  - Example: Mango + wheat in Uttar Pradesh yields ₹60,000/ha.
- **Hilly Regions**:
  - Region: Northeast, Himachal Pradesh (~5 Mha).
  - Systems: Agroforestry, silvi-pastoral.
  - Impacts: Reduces erosion by 20%, supports tribal livelihoods.
  - Example: Bamboo + rice in Assam sequesters 10 t/ha CO_2.

Challenges and Solutions

- **Land Tenure**:
  - Challenge: Leased lands limit long-term systems (~30% farmers).
  - Solution: Cooperative models, policy incentives.
  - Example: Uttar Pradesh’s agroforestry cooperatives increase adoption by 15%.
- **High Initial Costs**:
  - Challenge: Tree planting, irrigation cost ₹10,000–20,000/ha.
  - Solution: Subsidies (50–80% under NMSA), credit access.
  - Example: Kerala’s coconut subsidies boost agri-horti adoption.

- **Knowledge Gaps**:
    - Challenge: Only 20% farmers aware of system benefits.
    - Solution: Extension services, farmer field schools.
    - Example: ICAR's agroforestry training in Punjab reaches 10,000 farmers.
- **Market Access**:
    - Challenge: Limited demand for timber, fodder (~25% products unsold).
    - Solution: Value addition (e.g., plywood, processed fruits).
    - Example: Gujarat's guava processing units stabilize prices.

Innovations

1. **Remote Sensing**:
    - Use: Monitors tree cover, soil health via satellite imagery.
    - Example: ISRO's RISAT tracks agroforestry in Uttar Pradesh.
2. **AI and IoT**:
    - Use: Optimizes tree-crop interactions, predicts yields.
    - Example: AI models in Kerala predict coconut + banana yields.
3. **Carbon Credits**:
    - Use: Monetizes sequestration (₹5,000–10,000/ha).
    - Example: Punjab's poplar farmers earn credits for 10 t/ha CO_2.
4. **Improved Varieties**:
    - Use: Fast-growing trees (e.g., poplar clones), high-yield grasses.
    - Example: Subabul clones in Rajasthan yield 10 t/ha timber in 5 years.

PYQ Analysis

1. "What is an alternate land use system?"
    (A) Monocropping
    (B) Agroforestry
    (C) Deep tillage
    (D) Chemical farming

Answer: (B) Agroforestry.
Explanation: Integrates trees with crops/livestock.

2. "Which system supports livestock?"
    (A) CRD (B) Silvi-pastoral
    (C) RBD (D) Split plot

Answer: (B) Silvi-pastoral.
Explanation: Provides fodder, shade.

3. "What is a benefit of agri-horti?"
    (A) High inputs
    (B) Income diversification
    (C) Soil erosion
    (D) Pest increase

Answer: (B) Income diversification.
Explanation: Yields crops + fruits.

4. "Which system adds N to soil?"
    (A) Agroforestry
    (B) Ley farming
    (C) Monocropping
    (D) Tillage

Answer: (B) Ley farming.
Explanation: Legume leys fix 20–40 kg/ha N.

5. "What is a challenge of agroforestry?"
    (A) Low cost
    (B) Long gestation
    (C) High yields
    (D) No management

Answer: (B) Long gestation.
Explanation: Trees take 5–20 years for returns.

- **Trend**: PYQs focus on system types, benefits, and challenges, with recent emphasis on agroforestry and carbon sequestration.

Case Study: Agroforestry in Uttar Pradesh

In Uttar Pradesh (Meerut):

- **Context**: Poplar + wheat agroforestry, loamy soils, pH 7.5, irrigated, ~0.5 Mha.
- **System**:
    - Trees: Poplar (G-48 clone), 5×4 m spacing.
    - Crop: Wheat (HD-2967), annual sowing.
- **Impacts**:
    - Yield: Wheat = 4.5 t/ha, poplar = 50 t/ha timber (6 years).
    - SOC: Increased from 0.6% to 0.8% in 5 years.
    - Carbon: Sequesters 12 t/ha CO_2/year.
    - Income: ₹50,000/ha timber, ₹40,000/ha wheat.

- **Analysis**:
  - Pruning minimizes wheat shading, maintains yield.
  - Carbon credits add ₹8,000/ha income.
- **Impact**: Recommends poplar + wheat for sustainable land use. This case study illustrates the application of alternate land use systems in agronomy, a key exam concept.

Conclusion

This part has explored alternate land use systems (agroforestry, silvi-pastoral, agri-horti, ley farming), vital for the ASRB NET JRF exam. These systems enhance productivity, sustainability, and resilience on India's ~55 Mha marginal lands, diversifying income and sequestering carbon. Applications in Punjab, Rajasthan, and Kerala demonstrate practical utility. Innovations like AI, remote sensing, and carbon credits boost adoption.

Types, Extent, And Causes Of Wasteland

Introduction

Wastelands, encompassing degraded, saline, waterlogged, and eroded lands, represent a significant challenge to India's agricultural sustainability, affecting ~55 million hectares (Mha) of land (ICAR, 2023). With agriculture supporting ~60% of India's population, reclaiming these lands through sustainable practices is critical for enhancing food security, restoring ecosystems, and mitigating climate change. Understanding the types, extent, and causes of wastelands is essential for developing targeted reclamation strategies. This part explores the types (degraded, saline, waterlogged, eroded), extent (~55 Mha), and causes (deforestation, overgrazing, improper irrigation, industrial pollution) of wastelands, covering definitions, characteristics, reclamation strategies, challenges, and practical examples in Indian agriculture.

Wastelands: Overview

Definition and Importance

- **Definition**: Wastelands are lands that are unproductive or marginally productive due to degradation, unsuitable for cultivation or other economic uses without significant reclamation efforts (NRSA, 2023).
- **Categories**:
  - Culturable wastelands: Potentially reclaimable for agriculture (e.g., saline, eroded lands).
  - Unculturable wastelands: Unsuitable for farming (e.g., rocky, barren lands).
- **Importance**:
  - Covers ~55 Mha (~17% of India's geographical area), reducing arable land availability.
  - Impacts food security for 1.4 billion population, with ~30% of soils degraded.
  - Offers opportunities for reclamation, carbon sequestration (5–10 t/ha/year), and alternate land use systems.
- **Example**: Saline wastelands in Gujarat (~1 Mha) are reclaimed for rice cultivation, increasing yields by 20%.

Characteristics

- **Low Productivity**: Yields <1 t/ha (vs. 2–5 t/ha for arable lands).
- **Poor Soil Health**: Low SOC (0.2–0.5%), high pH/salinity, compacted structure.
- **Water Scarcity**: Limited moisture retention, high runoff (20–30%).
- **Erosion Risk**: High susceptibility to wind/water erosion (5–10 t/ha/year).
- **Example**: Eroded wastelands in Rajasthan lose 8 t/ha soil annually, reducing fertility.

Role in Sustainable Land Use

- **Reclamation**: Restores ~10–15% of wastelands for agriculture, agroforestry.
- **Carbon Sequestration**: Reclaimed lands sequester 5–8 t/ha CO_2.
- **Biodiversity**: Supports native species, improves Shannon index (0.4–0.6).
- **Example**: Agroforestry on degraded lands in Madhya Pradesh sequesters 6 t/ha CO_2, yields ₹20,000/ha timber.