



A Monthly e Magazine  
ISSN:2583-2212

March, 2026 Vol.6(3), 640-646

Popular Article

## Climate-Resilient Soil Management: The Role of Farmers, Scientists and Stakeholders

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[DOI:10.5281/ScienceWorld.19188242](https://doi.org/10.5281/ScienceWorld.19188242)

### Introduction

Agriculture is increasingly challenged by climate change. Rising temperatures, erratic rainfall, droughts, floods and extreme weather events are affecting crop productivity and soil health worldwide. Soil, which forms the foundation of agricultural systems, is highly sensitive to climatic changes. When soils degrade due to erosion, nutrient depletion, or organic matter loss, their ability to support crops and store water declines. Healthy soils play a crucial role in sustaining crop productivity, regulating nutrient cycles, storing carbon, and maintaining biodiversity.

Climate-resilient soil management refers to the adoption of soil management practices that enhance soil health while enabling agricultural systems to adapt to climate variability and mitigate greenhouse gas emissions. These practices help improve soil organic carbon, water retention capacity, nutrient availability, and resilience to environmental stresses. Building climate resilience in agriculture is not solely the responsibility of farmers; it requires coordinated efforts from scientists, policymakers, extension agencies, and other stakeholders.



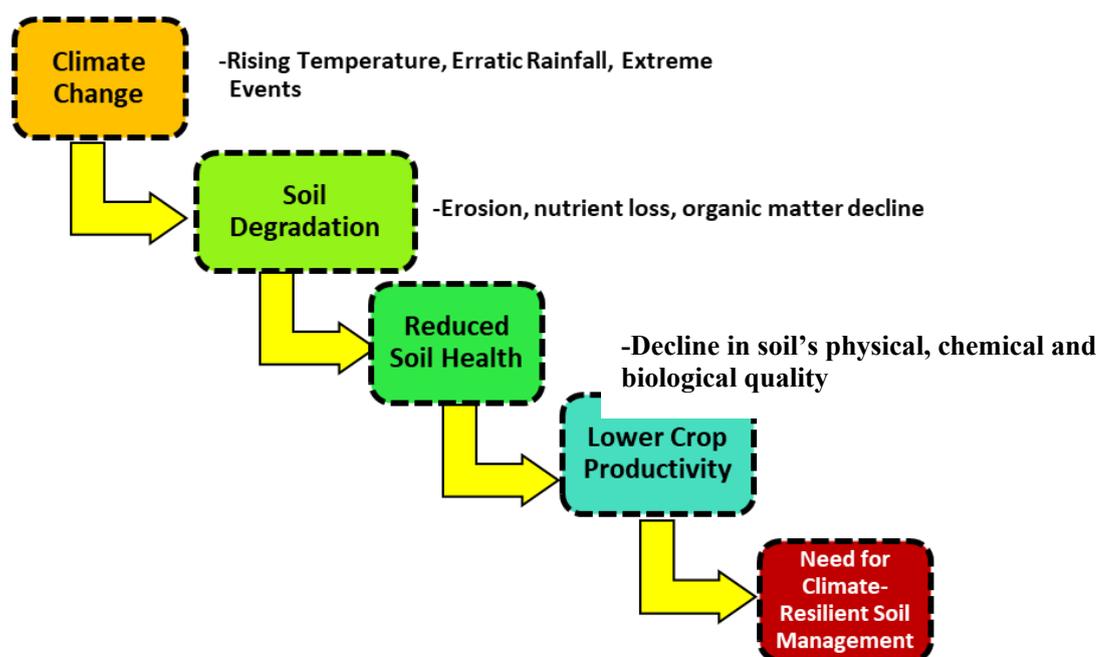
This article discusses the importance of climate-resilient soil management and highlights the key roles played by farmers, scientists, and stakeholders in promoting sustainable soil systems.

### **Climate Change and Soil Health**

Climate change significantly affects soil processes and agricultural productivity. Increasing temperatures and altered rainfall patterns can accelerate soil erosion, reduce soil organic matter, and disrupt nutrient cycling. As soil organic carbon decreases, soils lose their ability to retain moisture and support microbial activity, which ultimately affects crop growth and yield.

Unsustainable agricultural practices such as excessive tillage, overuse of chemical fertilizers, monocropping, and improper irrigation further worsen soil degradation. These practices reduce soil fertility and lead to compaction and poor water infiltration. In many regions, soil degradation has become a major threat to food security and environmental sustainability.

Climate-resilient soil management aims to address these challenges by improving soil structure, increasing carbon sequestration, and enhancing soil biodiversity. Practices such as conservation agriculture, cover cropping, agroforestry, organic amendments, and crop diversification contribute significantly to building resilient soils. By maintaining healthy soils, farmers can reduce the risks associated with climate variability and improve long-term agricultural productivity.



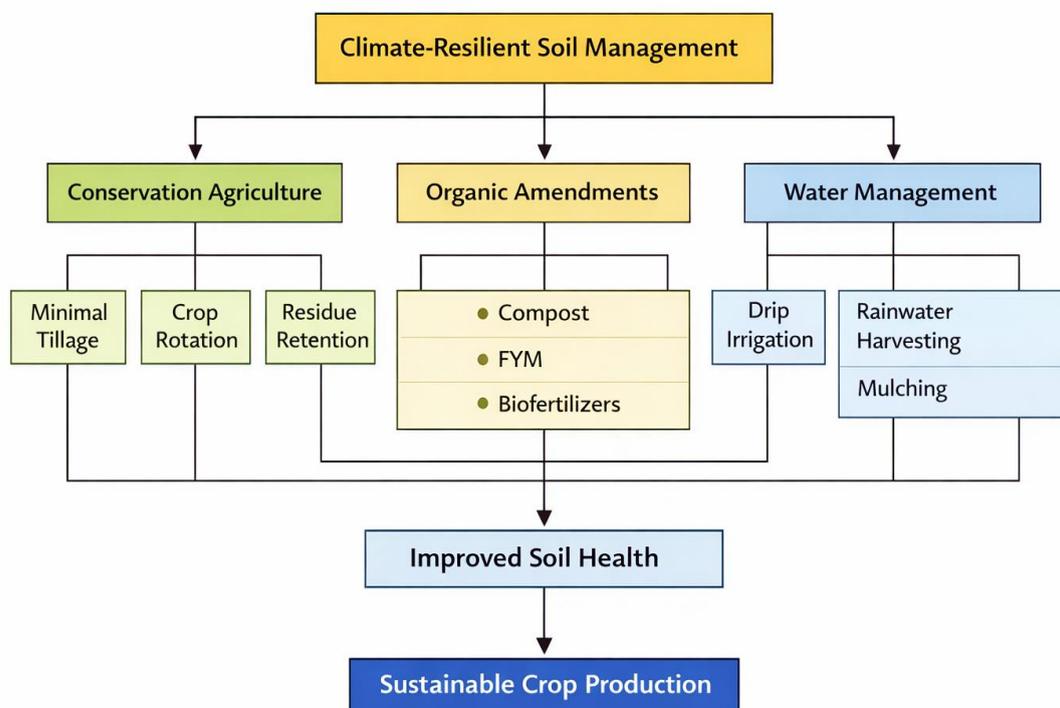
**Figure 1. Climate Change Impact on Soil and Agriculture**



## Key Principles of Climate-Resilient Soil Management

Several principles guide climate-resilient soil management strategies.

1. **Enhancing Soil Organic Matter:** Soil organic matter is vital for improving soil structure, nutrient availability, and water-holding capacity. The addition of crop residues, compost, and green manure increases soil carbon levels and enhances soil biological activity.
2. **Conservation Agriculture:** Conservation agriculture includes practices such as minimal soil disturbance, crop residue retention, and crop rotation. These practices reduce soil erosion, conserve soil moisture, and enhance soil fertility.
3. **Crop Diversification:** Diversified cropping systems reduce the risks associated with climate variability. Crop rotation and intercropping improve soil fertility and help control pests and diseases.
4. **Efficient Water Management:** Water conservation techniques such as drip irrigation, rainwater harvesting, and mulching help maintain soil moisture during dry periods.
5. **Soil and Water Conservation Practices:** Techniques such as contour farming, terracing, and watershed management reduce soil erosion and improve water infiltration. These practices enhance soil quality and support sustainable agricultural production.



**Figure 2. Components of Climate-Resilient Soil Management**



## **Role of Farmers in Climate-Resilient Soil Management**

Farmers are the primary managers of agricultural land and therefore play a central role in implementing climate-resilient soil management practices.

### **Adoption of Sustainable Practices**

Farmers can improve soil resilience by adopting conservation agriculture practices such as reduced tillage, crop rotation, and cover cropping. Cover crops protect soil from erosion and improve soil fertility by enhancing microbial activity and nutrient cycling.

### **Use of Organic Inputs**

Incorporating organic amendments such as farmyard manure, compost, and biofertilizers improves soil structure and increases soil organic carbon.

### **Efficient Resource Use**

Farmers can enhance soil resilience through efficient use of water and fertilizers. Precision irrigation and balanced nutrient management reduce resource wastage and prevent soil degradation.

### **Indigenous Knowledge and Local Innovations**

Traditional agricultural knowledge often includes practices that promote soil conservation and sustainable resource use. Integrating indigenous knowledge with modern scientific practices can strengthen climate resilience in farming systems.

## **Role of Scientists in Climate-Resilient Soil Management**

Scientists play a critical role in developing technologies and strategies that support climate-resilient agriculture.

### **Research and Innovation**

Agricultural scientists conduct research to develop improved soil management techniques, climate-resilient crop varieties, and sustainable farming practices. Advances in soil science, biotechnology, and agronomy contribute to improving soil health under changing climatic conditions.

### **Development of Decision-Support Tools**

Modern technologies such as remote sensing, geographic information systems (GIS), sensors, and artificial intelligence are increasingly used to monitor soil health and climate impacts. These technologies enable site-specific soil management and improve farm decision-making.



### Technology Transfer and Extension

Scientists also collaborate with extension agencies to transfer technologies and knowledge to farmers. Training programs, demonstration trials, and field schools help farmers adopt climate-resilient soil management practices.

### Climate Modelling and Forecasting

Scientists use climate models and crop simulation models to predict climate impacts on agriculture and develop strategies for adaptation. These tools help farmers make informed decisions regarding crop selection, planting time, and soil management.

### Role of Stakeholders and Policy Makers

Climate-resilient soil management requires strong support from governments, institutions, and other stakeholders.

### Policy Support and Incentives

Governments can promote climate-resilient practices through supportive policies, subsidies, and incentives. Programs such as India’s National Initiative on Climate Resilient Agriculture (NICRA) aim to develop and demonstrate technologies that improve soil health and agricultural resilience.

### Capacity Building and Training

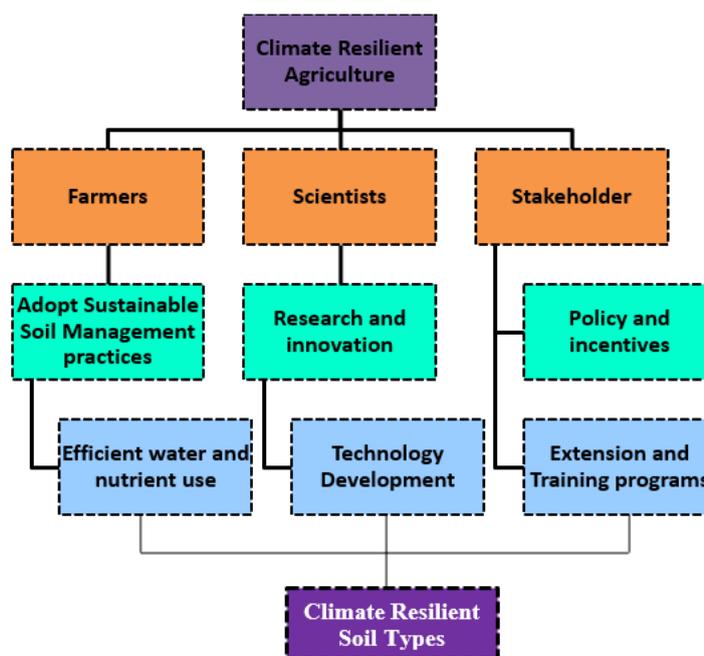
Extension agencies, NGOs, and agricultural institutions play an important role in educating farmers about climate-smart agricultural practices.

### Infrastructure and Financial Support

Access to credit, insurance, and agricultural infrastructure helps farmers adopt improved soil management practices.

### Collaborative Partnerships

Collaboration among researchers, farmers, private organizations, and policymakers is essential for developing sustainable solutions to climate challenges. Integrated approaches that



**Figure 3. Role of Farmers, Scientists and Stakeholders in Climate-Resilient Soil Systems**



combine scientific knowledge, policy support, and community participation are necessary to achieve long-term resilience.

### **Future Perspectives**

Climate change is expected to intensify in the coming decades, making climate-resilient soil management increasingly important. The integration of digital agriculture technologies, precision farming, and data-driven decision support systems will play a key role in enhancing soil resilience. Increasing awareness about soil health, strengthening extension services, and promoting sustainable agricultural practices will help ensure food security and environmental sustainability. Collaborative efforts among farmers, scientists, and stakeholders will be essential to build resilient agricultural systems.

### **Conclusion**

Climate-resilient soil management is essential for ensuring sustainable agriculture and food security in the face of climate change. Healthy soils enhance crop productivity, improve water retention, store carbon, and support biodiversity. Farmers play a crucial role in implementing sustainable soil management practices, while scientists contribute through research, innovation, and technology development. Stakeholders and policymakers provide the necessary support through policies, training, and financial assistance. A collaborative approach that integrates scientific knowledge, farmer participation, and supportive policies is vital for building climate-resilient agricultural systems. By protecting and restoring soil health, agriculture can adapt to climate change while sustaining productivity and environmental balance for future generations.

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