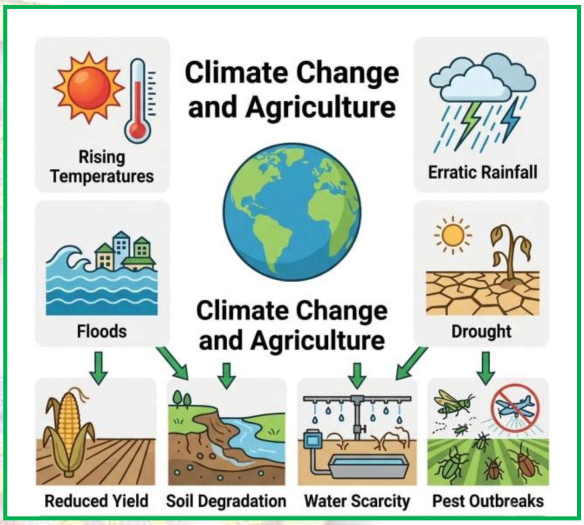
Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 04 (JULY-AUG, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

The Contribution of GIS and Remote Sensing to Climate-Resilient Agriculture

*Akansha Tyagi[1], Harshit Tomar[2], Soyal Kumar[3] and Lavi Dabas[3]
[1]Research Scholar, Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (250 110) U.P.
[2]Department of Vegetable Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (250 110) U.P.
[3]Research Scholar, Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (250 110) U.P.
*Corresponding Author's email: akanshatyagi743@gmail.com



Agriculture is highly dependent on climate. Seasonal variations in temperature, rainfall and weather pattern regulate crop growth, production and ultimately food security. However, climate change has drastically changed the natural cycles, creating unprecedented challenges for agricultural systems globally. Global warming, erratic precipitation, prolonged droughts, recurrent floods and extreme weather events are adversely affecting crop yields, soil fertility, water availability and rural livelihoods. According to the Food and Agriculture Organization (FAO), feeding a global population expected to approach 10 billion by 2050 will require agricultural systems that are not only more productive but also capable of adapting to increasing climatic uncertainty (FAO, 2021). Thus, improving agricultural resilience has become a primary objective in attaining sustainable development and global food security.

Climate-resilient agriculture (CRA) has emerged as an integrated approach which combines production, adaptation and environmental sustainability. Traditional farming methods frequently depend on broad management strategies whereas; climate-resilient agriculture prioritises timely, site-specific and resource-efficient decision-making. Emerging technologies, including geospatial tools (e.g., Geographic Information Systems (GISs) and remote sensing (RS) offer promising methods to support this transition from traditional farming to climate resilient agriculture.

Climate Change and the Need for Climate-Resilient Agriculture

Agriculture depends on stable weather, predictable rainfall and suitable temperatures, so even modest shift in climate can disrupt crop growth, pest dynamics, water availability and soil health. Over the past few years, greater climatic variability has intensified these risks, threatening both subsistence and commercial farming. The Intergovernmental Panel on Climate Change (IPCC) warns that rising temperatures, shifting precipitation patterns, glacier retreat, and more frequent extreme weather events will continue to reduce agricultural productivity especially in developing countries with limited adaptive capacity (IPCC, 2022). For example, India faces increasing heat waves, erratic monsoons and unseasonal rainfall, all of which harm crop yields and farmer livelihoods. These uncertainties threaten food security and undermine the livelihoods of millions of farming households that depend on agriculture as their primary source of income. These challenges highlight the limitations of conventional agricultural systems and form the foundation of Climate-Resilient Agriculture.

Climate-resilient agriculture is a holistic approach of agricultural development that aims to ensure food security while strengthening the ability of farming systems to adapt to climate variability and reducing environmental impacts. It aims to:

- Improve agricultural productivity
- Strengthen adaptive capacity
- Reduce greenhouse gas emissions

It requires solid environmental monitoring, careful risk assessment and timely, site-specific interventions. Conventional monitoring based on field surveys and manual observations is often time-consuming and labour-intensive. The growing complexity of climate threats calls for technological solutions that provide timely information across large areas. That's exactly where Geographic Information Systems and Remote Sensing have become central to climate-smart agriculture letting farmers and planners make informed decisions (Mulla, 2013).

GIS and Remote Sensing: Enabling Climate-Smart Agriculture

The growing need for accurate, timely, and location-specific information has positioned Geographic Information Systems (GIS) and Remote Sensing at the core of climate-resilient agriculture.

Geographic Information Systems (GIS) are advanced computer-based systems that store, analyze and visualize geographically referenced data. GIS helps users to understand patterns and relationships across a landscape by combining various type of spatial information such as maps, soil types and climate data etc.

Remote Sensing refers to the process of gathering information about the Earth's surface from a distance, using satellites, drones or aircraft. It capture images and data across large areas, enabling to monitor changes in land, crops and the environment without needing to be physically present in the field.

The true strength of these technologies lies in their complementary roles. Remote Sensing continuously observes agricultural landscapes and generates up-to-date spatial information, while GIS integrates these datasets with other environmental and socioeconomic information to transform raw observations into practical management recommendations. Together, they enable climate-resilient agriculture by helping farmers and decision-makers:

- Identify climate-related risks before they become severe.
- Monitor crop health and detect stress at an early stage.
- Evaluate land suitability and optimize crop selection.
- Improve irrigation and nutrient management according to local conditions.
- Assess droughts, floods, and other climatic hazards.
- Support precision agriculture and efficient resource use.
- Develop evidence-based agricultural policies and climate adaptation strategies.

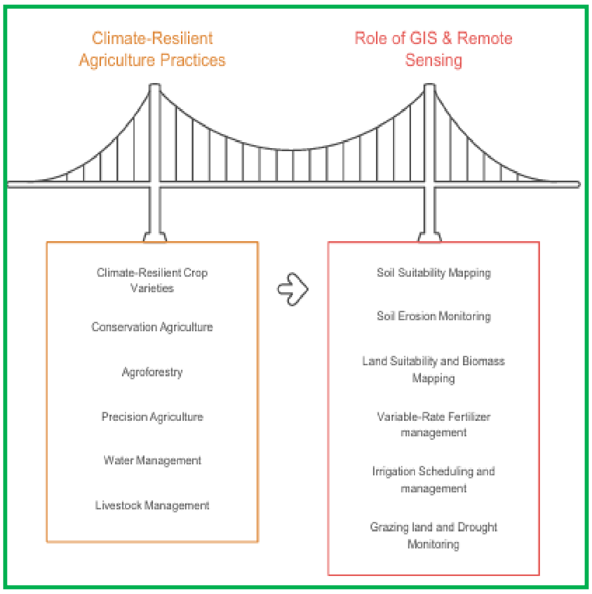
By replacing generalized management practices with data-driven, site-specific decision-making, GIS and Remote Sensing enable farming systems to anticipate climatic risks, respond proactively to changing environmental conditions, and recover more effectively following extreme weather events. Their integration therefore represents a cornerstone of modern climate-resilient agriculture, supporting productive, adaptive, and environmentally sustainable food systems.

Applications of GIS and Remote Sensing in Climate-Resilient Agriculture

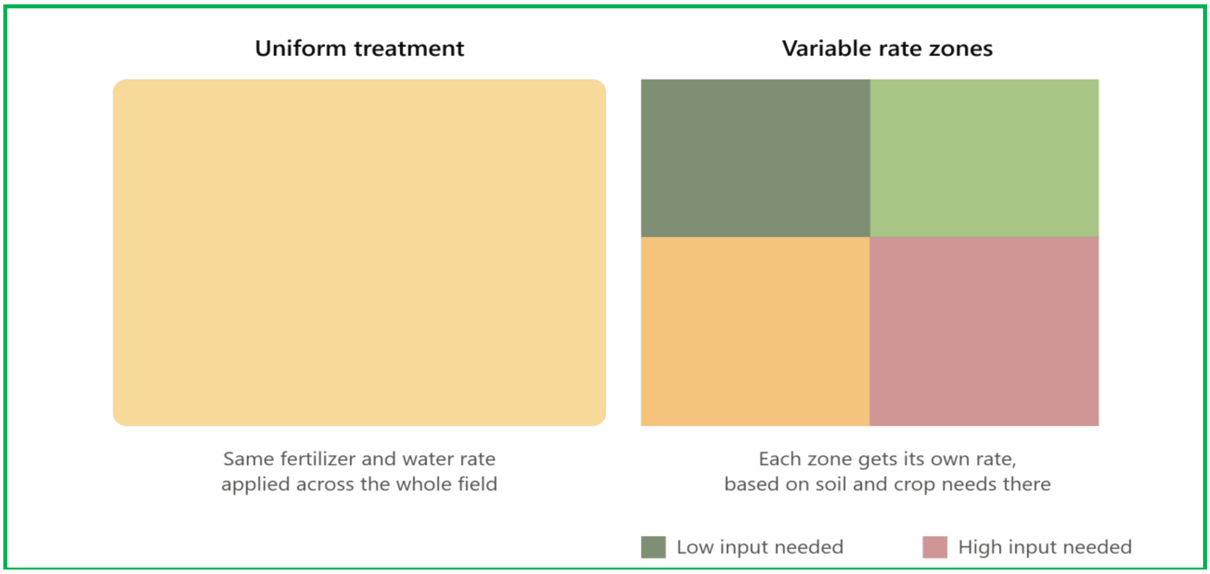
The success of climate-resilient agriculture increasingly depends on the availability of timely, accurate, and actionable information. Their ability to transform vast amounts of geospatial data into practical insights has significantly enhanced the resilience, efficiency, and sustainability of modern agricultural systems.

Crop Health Monitoring

Traditionally, crop assessment has relied on field surveys and visual inspections, which are labour-intensive, time-consuming, and often limited to small areas. Satellite-based observations overcome these limitations by providing continuous, large-scale monitoring of agricultural landscapes throughout the growing season.



Advanced vegetation indices such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil Adjusted Vegetation Index (SAVI) enable the assessment of plant vigour, chlorophyll content and photosynthetic activity. Variations in these indices can reveal water stress, nutrient deficiencies, pest infestations, and disease outbreaks long before visible symptoms appear in the field. Such early detection allows farmers to implement timely interventions, minimizing crop losses while reducing the excessive use of fertilizers and pesticides.



Soil and Water Resource Management

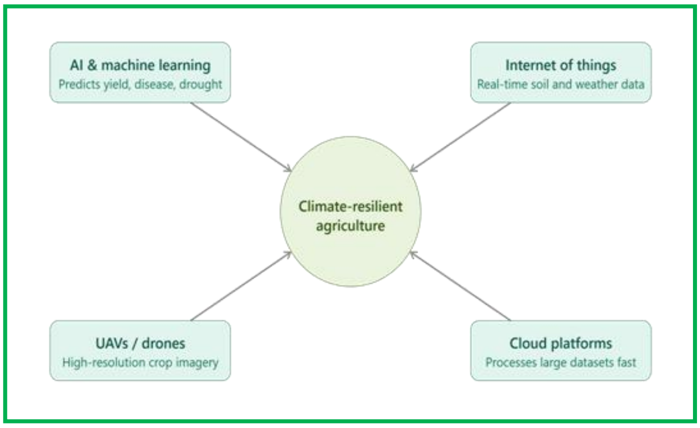
Soil characteristics such as texture, fertility, salinity, organic matter content and moisture, vary considerably within the same agricultural field. GIS integrates these spatially variable characteristics into detailed databases, enabling the development of detailed soil fertility and land suitability maps. These maps support informed decisions regarding crop selection, nutrient management, and sustainable land-use planning. Remote Sensing further strengthens resource management by providing reliable estimates of surface soil moisture and monitoring changes in water availability. Using microwave and thermal infrared sensors, it is possible to identify drought-prone areas at an early stage and assess the extent of moisture stress across large agricultural regions. Such information forms the basis of precision irrigation systems, which deliver water according to the actual requirements of crops rather than following fixed schedules. This targeted approach significantly improves water-use efficiency while conserving increasingly scarce freshwater resources.

Watershed and Water Management Planning

The contribution of geospatial technologies extends beyond field-level irrigation management to broader watershed planning. GIS-based spatial analysis helps identify suitable locations for rainwater harvesting structures, groundwater recharge zones, reservoirs, and drainage networks. By supporting integrated watershed management, these technologies improve water security, reduce the impacts of drought and erratic rainfall, and strengthen the resilience of farming communities to climate variability.

Site- specific management and Precision Agriculture

By integrating GIS, Remote Sensing, Global Positioning Systems (GPS) and field-based sensors, farmers can adopt site-specific management practices that optimize productivity while minimizing resource wastage. Variable Rate Technology (VRT) adjusts the application of fertilizers, pesticides, and irrigation according to the specific needs of different parts of a field. Similarly, GPS-guided agricultural machinery improves operational efficiency by reducing overlaps during fertilization and harvesting, which saves time, fuel and agricultural inputs. Yield monitors systems installed on modern harvesters generate spatial yield maps that reveal patterns of productivity across fields. When analysed through GIS, these maps help farmers identify consistently high- and low-performing areas, enabling long-term improvements in soil management, irrigation planning and crop rotation strategies (Gebbers and Adamchuk, 2010).



Agricultural Planning and Policy Support

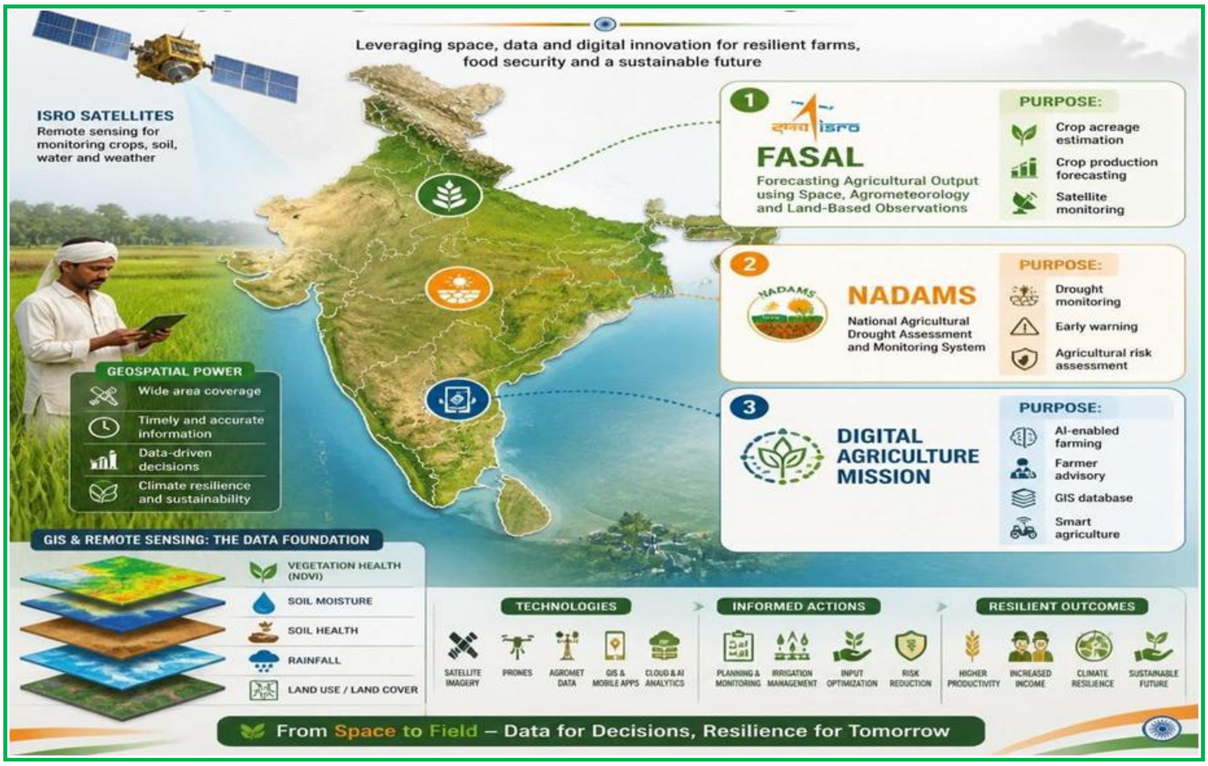
Remote Sensing contributes by tracking crop acreage, seasonal cropping patterns, and yields through satellite observations. These datasets lets governments forecast production, monitor cropping intensity and anticipate potential food shortages well before harvest. Consequently, policymakers can make informed decisions regarding food security planning, market regulation, procurement strategies and resource allocation.

Emerging Innovations and Real-World Applications

The integration of GIS and remote sensing with Artificial Intelligence, Machine Learning, IoT, UAV and cloud computing is transforming Climate resilient Agriculture by enabling predictive, data driven farm management (Gorelick *et al*., 2017).

Technology	Role in Climate-Resilient Agriculture
Artificial Intelligence (AI) & Machine Learning (ML)	Analyse geospatial and environmental data to predict crop yields, disease outbreaks, drought conditions and irrigation requirements.
Internet of Things (IoT)	Real-time monitoring of soil moisture, weather and crop conditions through interconnected sensors, enabling precision irrigation and nutrient management.
Unmanned Aerial Vehicles (UAVs/Drones)	Capture high-resolution multispectral and thermal imagery for crop health assessment, damage evaluation, and site-specific farm management.
Cloud-Based Geospatial Platforms	Process and analyse large satellite datasets in near real time, supporting rapid agricultural monitoring and evidence-based decision-making.

In India, the Indian Space Research Organisation (ISRO) has integrated satellite-based observations into agricultural planning through programmes such as Forecasting Agricultural Output using Space, Agrometeorology and Land-Based Observations (FASAL), which improves crop production forecasting by combining satellite imagery with meteorological and field data. Likewise, the National Agricultural Drought Assessment and Monitoring System (NADAMS) employ GIS and Remote Sensing to monitor drought conditions and provide early warning information for timely governmental interventions. The Digital Agriculture Mission further promotes technology-enabled farming by strengthening geospatial databases and digital advisory services for farmers. (ISRO, 2023)



Challenges

GIS and Remote Sensing are transforming climate-resilient agriculture yet certain challenges persist. Some of them are:

- High initial costs for infrastructure, data, and skilled personnel limit adoption, especially among smallholder farmers and resource-constrained organizations.
- Digital divide in rural areas hampers access due to limited internet connectivity, low digital literacy and insufficient training.
- Data standardization, interoperability and privacy concerns complicate the development of reliable, long-term geospatial information systems.
- Ongoing maintenance and technical support are needed to sustain and update spatial databases.

Conclusion

Climate change demands innovative approaches that can simultaneously enhance agricultural productivity and ensure environmental sustainability. GIS and Remote Sensing have emerged as transformative technologies, enabling data-driven, location-specific decision-making for effective crop monitoring, resource optimization and climate risk management. Their integration with emerging technologies such as Artificial Intelligence, IoT and UAVs is accelerating the transition towards intelligent and climate-responsive agriculture. However, realizing their full potential requires supportive policies, robust digital infrastructure, institutional capacity building and equitable access for smallholder farmers. Such integrated geospatial systems will strengthen climate adaptation and can contribute significantly to achieving the Sustainable Development Goals by ensuring global food security in an era of climate uncertainty.

References

1. Choudhury, I., Patel, N. R. and Parihar, J. S. (2016). *National Agricultural Drought Assessment and Monitoring System (NADAMS): A remote sensing approach*. Indian Space Research Organisation.
2. Food and Agriculture Organization. (2021). *The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses*. FAO.
3. Gebbers, R. and Adamchuk, V. I. (2010). Precision agriculture and food security. *Science, 327*(5967), 828–831.
4. Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D. and Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment, 202*, 18–27. Government of India. (2021). *Digital Agriculture Mission (2021–2025)*. Ministry of Agriculture & Farmers Welfare.
5. Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.
6. ISRO. (2023). *Forecasting Agricultural Output using Space, Agrometeorology and Land-Based Observations (FASAL)*. Indian Space Research Organisation.
7. Mulla, D. J. (2013). Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. *Biosystems Engineering, 114*(4), 358–371.