www.journalworlds.com
AGRI JOURNAL WORLD
VOL. 6 ISSUE 2 APRIL-JUNE, 2026

CLIMATE RESILIENCE INDICES FOR AGRICULTURE

Sachin S. Chinchorkar*

Polytechnic in Agricultural Engineering, Anand Agricultural University, Muvaliya Farm, Dahod-389160, Gujarat, India

**Corresponding author email:* csachin.chinchorkar@gmail.com

ABSTRACT

Climate change increasingly threatens agriculture through droughts, floods, heatwaves, and other extreme events, making resilience assessment essential for sustainable food production. Climate resilience indices evaluate the capacity of agricultural systems to anticipate, withstand, adapt to, and recover from climate-related stresses. This review discusses the concepts, methodologies, and key dimensions of resilience, including exposure, vulnerability, adaptive capacity, and recovery. It also highlights the role of remote sensing, artificial intelligence, machine learning, and scenario planning in strengthening resilience assessment, supporting evidence-based adaptation, resource allocation, and sustainable agricultural development.

KEYWORDS: Adaptive capacity, artificial intelligence, climate adaptation, climate change, Climate resilience, remote sensing, resilience indices, vulnerability

INTRODUCTION

Climate change poses significant challenges to agricultural systems through increasing temperatures, erratic rainfall, droughts, floods, and other extreme events. These challenges affect crop production, livestock systems, natural resources, and rural livelihoods. Climate resilience indices have emerged as important tools for assessing the ability of agricultural systems to withstand, adapt to, and recover from climate-related shocks and stresses.

Resilience indices provide a quantitative framework for evaluating climate risks and adaptive responses across different agricultural systems and regions. They support decision-making by identifying vulnerable areas, assessing adaptation capacity, guiding investments, strengthening early-warning systems, and monitoring long-term resilience trends. By integrating climatic, environmental, and socio-economic indicators, resilience indices help policymakers and practitioners develop effective climate adaptation strategies.

CONCEPTUAL FRAMEWORK OF AGRICULTURAL RESILIENCE

Agricultural resilience refers to the capacity of a farming system to anticipate, prepare for, respond to, and recover from climate-related disturbances while maintaining essential functions and productivity. Four major dimensions form the foundation of resilience assessment:

EXPOSURE: Exposure represents the degree to which agricultural systems experience climate hazards such as droughts, floods, heatwaves, and storms. Areas frequently affected by extreme climatic events generally face higher exposure levels.

VULNERABILITY: Vulnerability reflects the susceptibility of agricultural systems to damage caused by climate hazards. Factors such as poor infrastructure, degraded soils, limited irrigation, and economic constraints increase vulnerability.

ADAPTIVE CAPACITY: Adaptive capacity refers to the ability of farmers and institutions to adjust to changing climatic conditions. Access to technology, financial resources, education, extension services, and climate information contributes significantly to adaptive capacity.

ADAPTIVE PERFORMANCE: Adaptive performance evaluates how effectively a system responds to climatic disturbances and how quickly it recovers after a shock. Recovery time and maintenance of productivity are common indicators of adaptive performance.

Together, these four dimensions provide a comprehensive understanding of agricultural resilience and climate risk.

COMPONENTS OF CLIMATE RESILIENCE INDICES

Climate resilience indices combine multiple indicators that represent environmental, social, economic, and institutional conditions. These indicators help assess resilience at plot, farm, regional, and national scales.

The primary components include:

- Climate exposure and hazard frequency.
- Vulnerability factors affecting agricultural production.
- Adaptive capacity indicators.
- Recovery and performance measures.
- Socio-economic and environmental conditions.

Assessment across multiple scales allows researchers to identify local vulnerabilities while also understanding broader regional patterns. Such analyses support targeted adaptation planning and resource allocation.

METHODOLOGICAL APPROACHES

The development of resilience indices generally follows a structured methodology involving data collection, indicator selection, weighting, modelling, and evaluation.

Data Collection: Reliable data are essential for resilience assessment. Common sources include meteorological records, agricultural statistics, remote sensing products, socio-economic surveys, and international databases such as those maintained by the World Bank, FAO, and UN agencies.

High-quality data should be accurate, representative, and available over sufficiently long periods to capture both normal and extreme climatic conditions.

INDICATOR SELECTION: Indicator selection is one of the most critical stages in index construction. Indicators should be scientifically valid, measurable, relevant to climate resilience, and suitable for the local context.

Examples include:

- Frequency of droughts and floods.
- Access to irrigation.
- Soil quality indicators.
- Crop diversity.
- Household income.
- Education levels.
- Availability of agricultural extension services.

The selected indicators should collectively capture the multidimensional nature of resilience.

WEIGHTING AND AGGREGATION: Indicators are commonly normalized and combined into composite indices using weighting schemes. Equal weighting, expert judgement, statistical methods, and multivariate techniques are often applied depending on data availability and study objectives.

UNCERTAINTY AND SENSITIVITY ANALYSIS: Because resilience indices depend on numerous indicators and assumptions, uncertainty analysis is essential. Sensitivity analysis evaluates how changes in specific indicators influence final resilience scores. These approaches improve transparency and reliability in decision-making.

SPATIAL AND TEMPORAL DIMENSIONS

Resilience assessment requires consideration of both spatial and temporal scales.

SPATIAL SCALE: Climate resilience can be evaluated at several levels:

- Plot level
- Farm level

- Community level
- Regional level
- National level

The choice of scale depends on study objectives and data availability. Farm-level assessments provide detailed insights into management practices, while regional analyses support policy development and resource allocation.

TEMPORAL SCALE: Resilience is dynamic and changes over time. Longitudinal assessments track variations in exposure, vulnerability, adaptive capacity, and performance across years or decades.

Trend analysis helps identify whether agricultural systems are becoming more resilient or more vulnerable under changing climatic conditions. Historical observations combined with future climate projections provide valuable information for long-term planning.

CLIMATE RISK DOMAINS AND INDICATOR CATEGORIES

Climate resilience indices typically organize indicators into climate risk domains that capture different dimensions of agricultural vulnerability and adaptation.

EXPOSURE AND HAZARD FREQUENCY: Climate hazards are the primary drivers of agricultural risk. Important indicators include:

- Drought frequency.
- Rainfall variability.
- Heatwave occurrence.
- Flood incidence.
- Storm intensity.

Historical observations and climate model projections are frequently used to estimate changing hazard patterns and return periods.

VULNERABILITY: Vulnerability indicators describe the susceptibility of farming systems to climate impacts. Common indicators include:

- Dependence on rainfed agriculture.
- Soil degradation.
- Water scarcity.
- Poverty levels.
- Limited market access.

Reducing vulnerability is a central objective of climate adaptation policies.

ADAPTIVE CAPACITY: Adaptive capacity indicators assess the resources available for managing climate risks. These may include:

- Irrigation infrastructure.
- Access to credit.
- Agricultural extension services.
- Climate information systems.
- Farmer education and training.
- Crop diversification.

Higher adaptive capacity generally improves resilience and reduces long-term climate risks.

ADAPTIVE PERFORMANCE AND RECOVERY: Performance indicators evaluate how effectively agricultural systems recover from climatic disturbances. Important measures include:

- Recovery time after droughts or floods.
- Yield stability.
- Income recovery.
- Resource regeneration.

Systems capable of rapid recovery are generally considered more resilient.

EMERGING TECHNOLOGIES AND FUTURE DIRECTIONS

Recent technological developments are transforming resilience assessment and monitoring.

REMOTE SENSING APPLICATIONS: Satellite observations provide continuous information on vegetation health, land use, soil moisture, crop conditions, and environmental changes. Remote sensing supports large-scale resilience assessments, especially in regions where ground observations are limited.

Modern satellite systems such as Sentinel and Landsat offer high-resolution data useful for monitoring agricultural conditions and climate impacts.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING: Artificial intelligence (AI) and machine learning techniques enhance the analysis of complex climate and agricultural datasets. These technologies can identify hidden patterns, improve prediction accuracy, and support early-warning systems.

Applications include:

- Drought prediction.
- Crop yield forecasting.
- Climate risk mapping.
- Land-use classification.

- Decision-support systems.

The integration of AI with remote sensing is creating new opportunities for near-real-time resilience monitoring.

SCENARIO PLANNING AND FLEXIBLE GOVERNANCE: Future climate conditions remain uncertain, making adaptive governance increasingly important. Scenario planning allows policymakers to evaluate multiple future pathways and test the effectiveness of adaptation strategies under different climate conditions.

Flexible governance systems can adjust policies as new information becomes available, reducing risks associated with uncertainty. Such approaches support long-term agricultural sustainability and climate resilience.

Climate resilience indices are becoming essential tools for evaluating agricultural vulnerability, adaptive capacity, and recovery potential under climate change. By integrating exposure, vulnerability, adaptive capacity, and performance indicators, these indices provide valuable insights for researchers, policymakers, and development practitioners. Advances in remote sensing, artificial intelligence, and climate modelling are further strengthening resilience assessment frameworks. As climate risks continue to intensify, resilience indices will play an increasingly important role in guiding adaptation investments, supporting sustainable agricultural development, and enhancing food security across diverse agricultural systems.

CONCLUSION

Climate resilience indices provide a valuable framework for assessing the capacity of agricultural systems to withstand, adapt to, and recover from climate-related shocks and stresses. By integrating key dimensions such as exposure, vulnerability, adaptive capacity, and adaptive performance, these indices enable a comprehensive understanding of climate risks and resilience levels across different agricultural contexts. Their application supports evidence-based decision-making, prioritization of adaptation investments, and development of effective climate-resilient agricultural policies. Advances in remote sensing, artificial intelligence, and climate modeling are further enhancing the accuracy and usefulness of resilience assessments. As climate change continues to affect global agriculture, resilience indices will play an increasingly important role in strengthening food security, promoting sustainable agricultural development, and improving the adaptive capacity of farming communities.

REFERENCES

Adhav, C., & Singh, H. (2025). Assessing climate change resilience in Central Indian agriculture: A regional indicators-based approach and agro-climatic zone mapping. *International Journal of*

Environment, Ecology and Climate Change, 15(2), 4709. https://doi.org/10.9734/ijecc/2025/v15i24709

Athare, P. G., Singh, D. R., Kumar, N. R., Jha, G. K., & Venkatesh, P. (2024). A spatial assessment of agricultural vulnerability to climate change using multidimensional data in Maharashtra State of India. *Indian Journal of Agricultural Sciences, 94*(11), 1–12. https://doi.org/10.56093/ijas.v94i11.152381

Druta, A., Rudi, T., Smerea, S., & Andronic, L. (2025). The climate vulnerability index applied to the agricultural sector in the Republic of Moldova. *Theoretical and Empirical Researches in Urban Management, 20*(3), 78–104. https://doi.org/10.52673/18570461.25.3-78.04

Gadafi, T., Toufic, S., Sagoe, A. A., Decui, L., & Anwar, H. (2025). Enhancing climate resilience through sustainable agricultural intensification: An attention-based neural network for climate-smart agriculture modeling in Ghana. *International Journal on Cybernetics & Informatics, 3*(3), 78–92. https://doi.org/10.1145/3767624.3767648

Giftson, S. P. J., Yogesh, B., Patil, D., Longkumer, T., Sharma, R., & Lokesh, O. (2026). Agrobiodiversity for climate resilience: A systematic review of yield stability, pest regulation, and nutrition outcomes. *International Journal of Environment, Ecology and Climate Change, 16*(4), 5359. https://doi.org/10.9734/ijecc/2026/v16i45359

Janani, H. K., Karunanayake, C., Gunathilake, M., & Rathnayake, U. (2024). Integrating indicators in agricultural vulnerability assessment to climate change. *Journal of Agricultural Science and Technology, 26*(1), 1–18. https://doi.org/10.1007/s40003-024-00727-5

Lamichhane, P., Miller, K., Hadjikakou, M., & Bryan, B. (2020). Resilience of smallholder cropping to climatic variability. *Science of the Total Environment, 716*, 137464. https://doi.org/10.1016/j.scitotenv.2020.137464

Meza, I., Siebert, S., Döll, P., Kusche, J., Herbert, C., Rezaei, E. E., et al. (2020). Global-scale drought risk assessment for agricultural systems. *Natural Hazards and Earth System Sciences, 20*(3), 695–712. https://doi.org/10.5194/nhess-20-695-2020

Niu, Z., Chen, J., & Feng, W. (2025). Digital agriculture and climate resilience in agri-food systems: Empirical evidence from China. *Food Security, 11*(1), 70178. https://doi.org/10.1002/fes3.70178

Parker, L., Bourgoin, C., Martinez-Valle, A., & Läderach, P. (2019). Vulnerability of the agricultural sector to climate change: The development of a pan-tropical climate risk vulnerability assessment to inform sub-national decision making. *PLOS ONE, 14*(3), e0213641. https://doi.org/10.1371/journal.pone.0213641

Rojas, O. (2021). Next generation agricultural stress index system (ASIS) for agricultural drought monitoring. *Remote Sensing*, *13*(5), 959. https://doi.org/10.3390/rs13050959

Shukla, R., Gleixner, S., Yalew, A. W., Schauberger, B., Sietz, D., & Gornott, C. (2021). Dynamic vulnerability of smallholder agricultural systems in the face of climate change for Ethiopia. *Environmental Research Letters*, *16*(1), 014058. https://doi.org/10.1088/1748-9326/abdb5c

Tessema, I., & Simane, B. (2019). Vulnerability analysis of smallholder farmers to climate variability and change: An agro-ecological system-based approach in the Fincha'a sub-basin of the Upper Blue Nile Basin of Ethiopia. *Ecology and Society*, *24*(1), 159. https://doi.org/10.1186/s13717-019-0159-7

Thimmegowda, M. N., Manjunatha, M. H., Huggi, L., Bal, S. K., Chandran, M. A. S., Soumya, D. V., & Jayaramaiah, R. (2025). Impact of rainfall variability on major crops using the deficient rainfall impact parameter (DRIP): A case study over Karnataka, India. *Meteorological Applications*, *32*(1), 70032. https://doi.org/10.1002/met.70032

Yessoufou, A. N. D., Kumar, S., Houessionon, P., Worou, O. N., Wane, A., & Whitbread, A. (2024). Vulnerability and resilience in the face of climate changes in Senegal's drylands: Measurement at the household level and determinant assessment. *Frontiers in Climate*, *6*, 1330025. https://doi.org/10.3389/fclim.2024.1330025

How to cite:

Chinchorkar, S. S. (2026). Climate resilience indices for agriculture. Leaves and Dew Publication, New Delhi 110059. *Agri Journal World* 6 (2): 75-82.

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