

Building Resilient River Basins: A New Paradigm with the Catchment Risk and Resilience (CRI) Index in India

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CGIAR Climate Action Program

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Front cover photo: A farmer implements Alternate Wetting and Drying (AWD) irrigation on his field in Ranga Reddy district, Telangana, India (*photo:* Tanmoy Bhaduri/IWMI India)

Back cover photo: A rice field in Ranga Reddy district, Telangana, India (*photo:* Tanmoy Bhaduri/IWMI India)

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Background

The Catchment Risk and Resilience Index (CRI) represents a pioneering approach to addressing the intertwined challenges of water resource management, climate change, and land degradation. By combining risk and resilience metrics into a unified framework, the CRI offers decision-makers critical insights into vulnerabilities and opportunities within river catchments. Its application, as demonstrated in the Godavari Basin, underscores its potential to guide transformative watershed management practices, enabling evidence-based, targeted interventions to enhance ecological integrity, support livelihoods, and foster sustainable economic development. Scaling the CRI framework to additional basins aligns seamlessly with the International Water Management Institute (IWMI) strategy by emphasizing the importance of integrated water resource management for climate adaptation and resilience. As part of broader initiatives, supported by Indian Council of Agricultural Research (ICAR) to IWMI through Increasing agricultural resilience through Agricultural Disaster Risk Management Strategy in India (INTEGRATE) and CGIAR's Nexus Gains, the CRI framework to enhancing agricultural resilience and supporting sustainable basin-wide development. The CRI's focus on minimizing erosion, pollution, and water-related risks while maximizing biodiversity and carbon sequestration complements IWMI's vision for optimizing resource use and advancing food, water, and ecosystem security. Moreover, the CRI fosters dialogue among policymakers, scientists, and community stakeholders, bridging knowledge gaps and promoting socially embedded solutions for flood and drought management. By integrating spatial planning, ecosystem services, and socio-economic factors, the CRI supports IWMI's goal of transforming water management into a driver of resilient development, ensuring feedback loops between population growth, land use changes, and climate impacts are well-addressed. Ultimately, the CRI emerges as a cornerstone for building adaptive, inclusive, and sustainable catchment management strategies globally.

Objectives

The CRI aims to establish a robust and scalable framework that:

1. Identifies vulnerabilities and risks: Highlights areas prone to hazards like droughts, floods, and ecosystem degradation.
2. Quantifies resilience: Measures the capacity of ecosystems, infrastructure, and communities to recover from disturbances.
3. Guides decision-making: Provides a data-driven basis for watershed management, planning, and investment.

CRI Framework Overview

The CRI is a comprehensive tool designed to integrate various indicators of risk and resilience (Figure 1) to evaluate the overall vulnerability of river catchments. It provides a structured approach to assess the interplay between natural hazards, human activities, and adaptive capacities within a watershed. By combining these elements into a singular, quantitative measure, the CRI offers a clear snapshot of catchment health and vulnerability, which is critical for guiding sustainable management and development strategies.

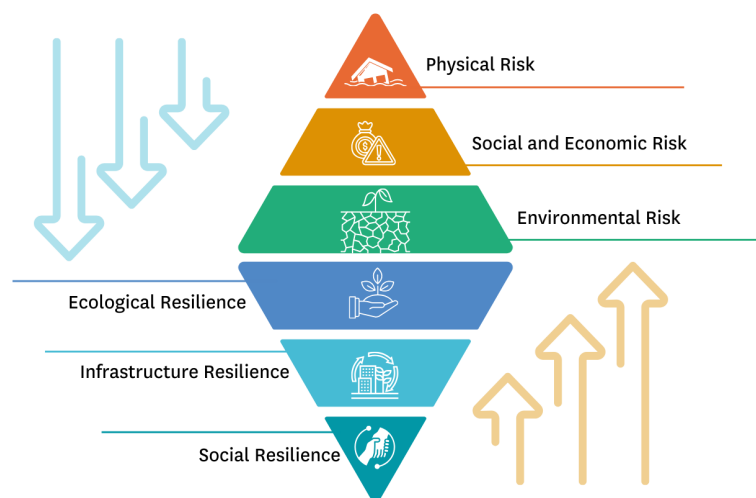


Figure 1. Indicators of Catchment Risk and Resilience Index.

Key Components of the CRI

1. Risk Indicators

Risk indicators evaluate the susceptibility of a catchment to vulnerable, focusing on factors that amplify the impact of natural hazards such as floods, droughts, cyclone and water scarcity. These indicators span multiple dimensions, including environmental, social, and economic factors, to provide a holistic understanding of the vulnerabilities within a watershed. For example:

- **Environmental Risks:** Changes in land use, such as deforestation or urbanization, can increase runoff and reduce natural water retention, heightening flood risks. Similarly, degraded ecosystems often lack the capacity to buffer against extreme weather events.
- **Social Risks:** High population density in vulnerable areas can exacerbate the consequences of hazards, straining resources and complicating emergency responses.
- **Economic Risks:** Reliance on water-intensive industries, such as agriculture or hydropower, can amplify the socioeconomic impact of water-related hazards. A high-risk score reflects the convergence of these factors, signaling the need for targeted interventions to reduce exposure and vulnerability.

2. Resilience Indicators

Resilience indicators measure the ability of a catchment to withstand disturbances and recover effectively. They assess the adaptive capacity across three domains: ecological, infrastructural, and social. For instance:

- **Ecological Resilience:** Biodiversity, the extent of riparian vegetation, and the health of aquatic ecosystems are crucial for maintaining natural processes that mitigate risks. Healthy ecosystems provide services such as water filtration, flood attenuation, and habitat stability.
- **Infrastructural Resilience:** This dimension examines the design, quality, and capacity of critical infrastructure, such as dams, levees, and drainage systems. Well-maintained and adaptive infrastructure enhances the ability to manage hazards effectively.
- **Social Resilience:** Community awareness, resource-sharing networks, and institutional adaptability are vital for ensuring preparedness and effective responses to emergencies. For example, areas with strong governance systems and disaster response plans are better equipped to handle crises.

The CRI synthesizes risk and resilience indicators into a unified, quantitative index that encapsulates catchment vulnerability. This integration offers a dual perspective: areas with high risk and low resilience are flagged for immediate attention, while regions with robust resilience mechanisms may require less intervention. The CRI synthesizes these components into a single index that provides a snapshot of catchment vulnerability, guiding the prioritization of interventions. Ultimately, the CRI framework serves as a decision-support tool that bridges data analysis with practical action, ensuring resources are directed toward building sustainable and resilient catchments.

Case Study: Godavari River Basin

The Godavari River Basin, India's second largest, is a vital resource supporting agriculture, drinking water, and energy production. However, it faces significant challenges driven by rainfall variability, with stark regional differences causing frequent droughts and floods. Rapid urbanization and agricultural expansion have led to extensive land use changes, including deforestation and increased runoff, which compromise groundwater recharge and ecosystem health. Additionally, rising population demands strain water resources and infrastructure, amplifying the basin's vulnerabilities to both natural and human-induced pressures.

CRI Applications

Basin Development and Planning

The CRI serves as a critical tool for guiding sustainable development and planning efforts within river catchments. By pinpointing areas with heightened vulnerabilities, the CRI directs attention to zones most at risk from hazards such as flooding, droughts, and ecosystem degradation (Figure 2). For instance, flood-prone areas can prioritize interventions like establishing riparian buffer zones to reduce runoff and enhance natural absorption, or

implementing advanced stormwater management systems to mitigate urban flooding risks. Additionally, the CRI supports sustainable land-use practices by identifying high-risk zones where construction should be avoided. Protecting natural floodplains and promoting the use of green infrastructure, such as nature-based solutions, further enhances resilience while minimizing the environmental footprint of development.

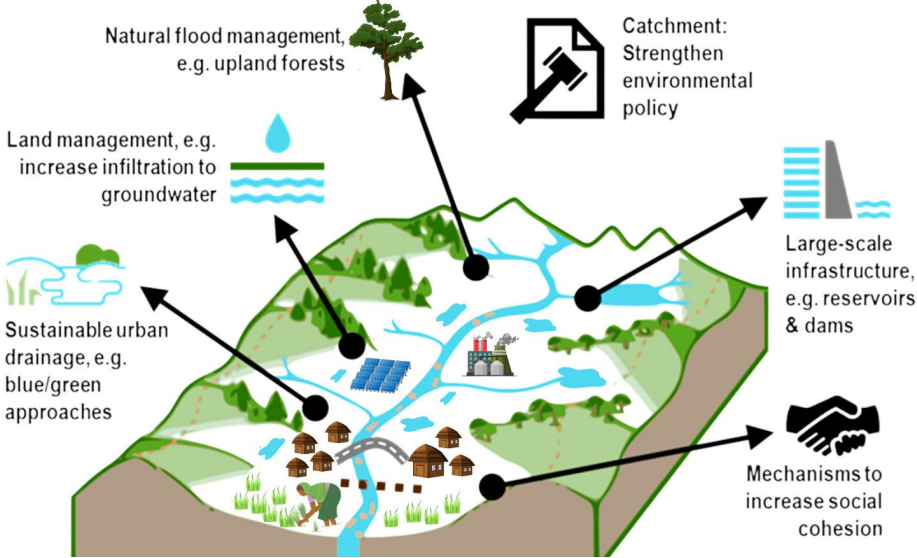


Figure 2. Examples of possible resilience-enhancing measures in a river catchment.

Basin Prioritization

The CRI facilitates the prioritization of watershed management initiatives by enabling decision-makers to rank projects based on their potential to reduce risk, enhance resilience, and deliver long-term benefits. This ensures that limited resources are allocated to the most impactful interventions. For example, sub-basins with high flood risk may be prioritized for the construction of modern flood barriers or the implementation of early warning systems. Moreover, the CRI identifies critical infrastructure, such as irrigation networks and water storage facilities, that require urgent maintenance or upgrades. By addressing such priorities, the CRI helps preserve the functionality of essential systems and ensures the continuity of ecosystem services that support livelihoods and local economies.

Basin Investment

The The CRI provides a robust framework for justifying current and future investments in resilient watershed management by quantifying the return on investment in resilience measures. It offers evidence-based insights into the cost-effectiveness and long-term benefits of specific projects, helping to attract funding from government agencies, international organizations, and private investors. For instance, initiatives such as reforestation, built natural infrastructure, dam rehabilitation, and the construction of water storage systems can be showcased as pivotal interventions that not only mitigate hazards but also promote sustainable resource use. Additionally, the CRI supports ongoing monitoring and evaluation of funded projects, ensuring that resources are utilized efficiently and contribute meaningfully to enhancing resilience and reducing vulnerabilities within catchments.

Conclusion

The Catchment Risk and Resilience Index (CRI) is a vital tool for evaluating and addressing the intricate relationship between risks and resilience in river catchments. Its successful application to the Godavari River Basin demonstrates the CRI's potential to guide transformative watershed management practices by enabling precise, targeted interventions and optimizing resource allocation. By fostering sustainable and resilient ecosystems, the CRI equips communities and ecosystems to better withstand future challenges posed by climate change and resource pressures.

Scaling the CRI to additional river basins is imperative for tackling global water management challenges and advancing climate adaptation strategies. The framework's flexibility allows it to be adapted across diverse geographical and ecological contexts, uncovering region-specific vulnerabilities and resilience needs. This scalability not only facilitates tailored interventions but also promotes knowledge-sharing, where insights gained from one basin inform strategies in others, enabling a cohesive and unified approach to watershed management.

By integrating CRI methodologies into national and global strategies, policymakers and stakeholders can better prioritize sustainable development, optimize investments, and mitigate risks in river systems worldwide. This approach reinforces the CRI's relevance as a cornerstone for addressing the growing complexity of water resource management in a changing climate.



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