



Implementing Environmental Flows in Transboundary Rivers under Climate Change



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Introduction

- Freshwater systems are increasingly stressed by dams, rising demand, pollution, and climate change
- Impacts are amplified in transboundary river basins due to fragmented governance
- Climate stress on shared water resources can amplify social tensions and political conflict when coupled with socio-economic pressures
- Environmental flows (E-Flows), particularly for shared basins plays a critical role in sustaining river ecosystems and water security
- Most transboundary agreements focus on water allocation, not ecological flow regimes
- Existing treaties lack enforceable and adaptive e-flow provisions
- Governance approaches remain fragmented (legal, economic, monitoring treated separately)
- This leads to a persistent implementation gap where E- Flows are recognized but not operationalized
- Climate uncertainty further challenges static and rigid water-sharing agreements
- Need for integrated, enforceable, and adaptive governance frameworks

Methodology

- Comparative analysis of 13 transboundary agreements (1922–2012)
- Evaluated using 5 components: E-flow recognition, Legal, Economic, Monitoring Reporting & Verification (MRV) systems and climate adaptivity.
- Agreements shortlisted through systematic literature review (Scopus, Google Scholar) using keywords: “transboundary rivers”, “environmental flows”, “water treaties”, “ecological flows”, “environmental water”.

Objectives of Study

- Analyze transboundary agreements to assess E-Flow implementation challenges
- Identify key gaps in legal, data sharing, institutional, and climate adaptivity aspects
- Evaluate best practices from basin-scale frameworks
- Develop a governance approach for adaptive and enforceable e-flow implementation

Results & Discussion

Heatmap: Transboundary E-Flow Governance Gaps

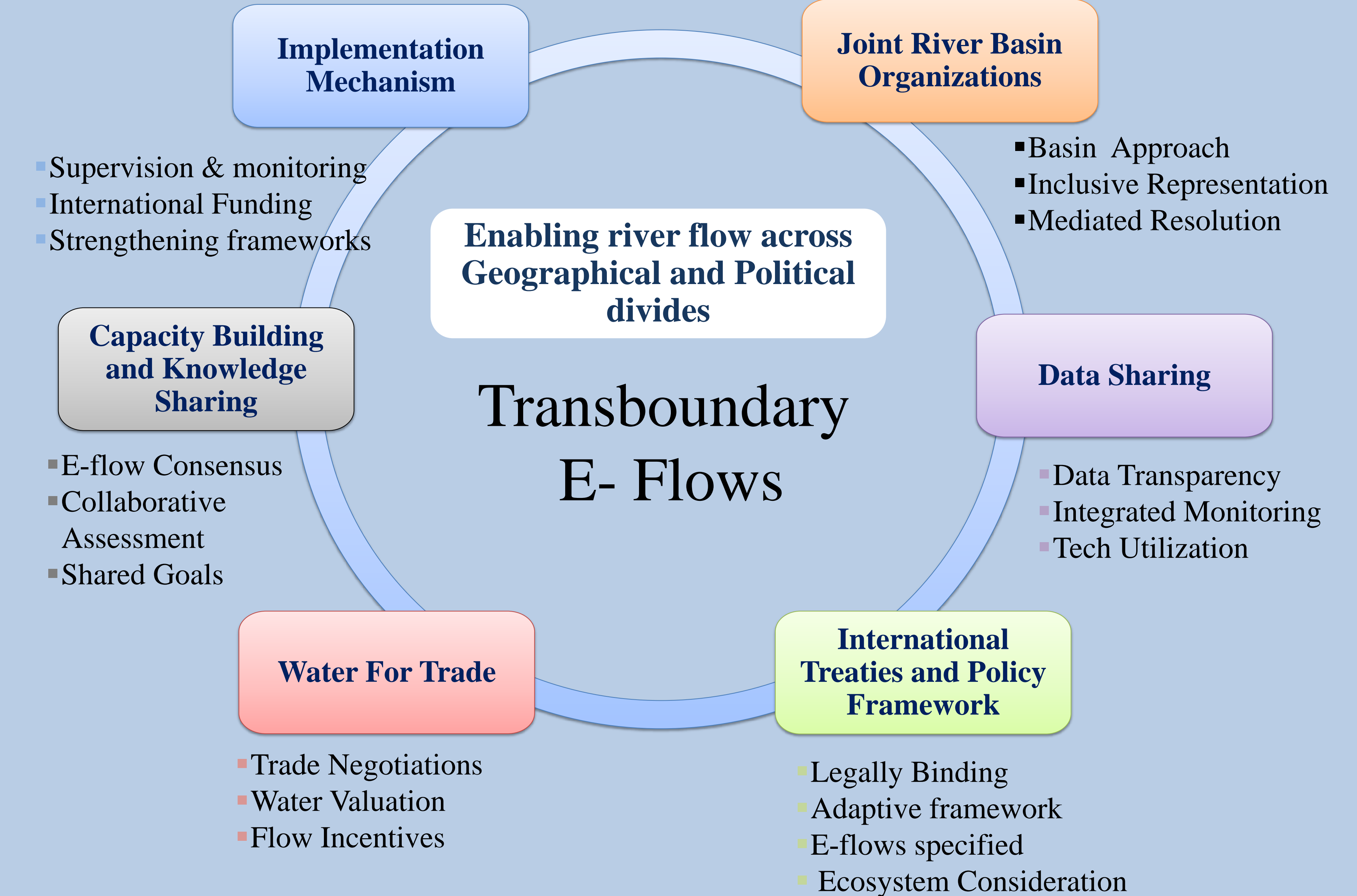
□ = Strong | ◇ = Moderate | ○ = Weak / Absent

Agreement / Framework	E-flow Recognition	Legal Enforceability	Economic Mechanisms	MRV Systems	Climate Adaptivity
❖ Colorado River Compact (1922)	○	□	◇	□	○
❖ Indus Waters Treaty (1960)	○	□	○	◇	○
❖ Columbia River Treaty (1964)	◇	□	□	□	◇
❖ Helsinki Rules (1966)	◇	○	○	○	○
❖ UNECE Water Convention (1992)	◇	◇	◇	□	◇
❖ Mekong River Commission Agreement (1995)	□	◇	◇	□	◇
❖ Ganga Water Sharing Treaty (1996)	○	◇	○	○	○
❖ UN Watercourses Convention (1997)	◇	○	○	◇	○
❖ Nile Basin Initiative (1999)	◇	○	◇	◇	◇
❖ ORASECOM Agreement (2000)	◇	◇	◇	◇	◇
❖ EU Water Framework Directive (2000)	□	□	◇	□	□
❖ Berlin Rules (2004)	◇	○	○	◇	○
❖ Murray–Darling Basin Plan (2012)	□	□	□	□	□

- Temporal analysis reveals a shift from allocation-focused treaties toward more integrated and adaptive governance, though implementation gaps persist
- Despite progress, economic instruments and climate adaptivity remain consistently weak across decades, indicating a persistent governance gap
- Governance is fragmented across legal, economic, and MRV systems, leading to poor implementation
- Data-sharing gaps and institutional constraints significantly hinder transboundary coordination
- Agreements largely ignore water quality and ecosystem requirements, focusing only on quantity
- Climate adaptivity is missing, with rigid treaties unable to respond to hydrological variability
- Economic instruments (e.g., water markets) are absent despite strong potential for improving allocation
- Monitoring systems exist but lack enforcement linkage, reducing their effectiveness
- Integrated basin frameworks (e.g., Mekong, Murray–Darling) demonstrate better outcomes through coordinated governance

Findings highlight that effective implementation is linked to integrated basin governance, adaptive management, and the use of economic and technological tools that are currently missing in most transboundary agreements

Conclusions & way forward



Looking ahead, climate change and technological advancements will reshape transboundary river governance, requiring flexible and adaptive e-flow provisions. Investing in real-time data systems, equitable water allocation mechanisms, and basin-level coordination will be critical. The key elements shown in Fig. should guide future frameworks to ensure sustainable and cooperative river management.

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