Digital Technologies as Catalysts for Environmental Sustainability and Climate Resilience: A Conceptual Framework and Systematic Literature Review

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Abstract

The accelerating climate crisis and widening environmental governance deficits have prompted scholars and policymakers alike to explore how digital technologies can serve as systemic enablers of environmental sustainability and climate resilience. This conceptual paper synthesises secondary evidence from eight peer-reviewed studies published between 2022 and 2025 to construct an integrative framework - the Digital Environmental Resilience Theory (DERT) - that maps the pathways through which digital innovation transforms environmental outcomes. Drawing on Ecological Modernisation Theory, Socio-Technical Systems Theory, Resilience Theory and Smart City Theory, the study identifies five convergent mechanisms: (1) real-time environmental monitoring through IoT and remote sensing; (2) predictive risk analytics via artificial intelligence and machine learning; (3) systemic simulation through digital twins and 3D city modelling; (4) governance transparency enabled by regulation technology and blockchain; and (5) integrated policy-technology co-design. Comparative analysis across eight technologies and eight sectors reveals significant heterogeneity in maturity levels, cost efficiency, and policy integration readiness. Critical research gaps, including developing-country exclusion, absence of unified theoretical constructs, and weak policy-technology feedback loops, are identified, and future research directions are proposed. The findings contribute a coherent theoretical and practical scaffold for international conference deliberations on the governance of digital sustainability transitions.

Keywords: digital technology; environmental sustainability; climate resilience; digital twins; IoT; artificial intelligence; smart cities; ecological modernisation; BRICS+; sustainable development goals

1. Introduction

The intersection of digital innovation and environmental governance has emerged as one of the most consequential frontiers of contemporary scholarship. Climate change, biodiversity loss, and resource depletion are no longer distant projections—they are observable, measurable disruptions with profound socioeconomic consequences (IPCC, 2023). At the same time, the exponential proliferation of digital technologies—ranging from the Internet of Things (IoT) and artificial intelligence (AI) to digital twins, remote sensing, and blockchain has opened unprecedented opportunities to monitor, model, and manage environmental systems with a precision previously unattainable (Argyroudis et al., 2022; Riaz et al., 2023).

Yet scholarship in this domain remains fragmented. Individual technologies are studied in isolation; sectoral applications are rarely cross-compared; and the theoretical scaffolding linking digital capability to sustainability outcomes is underdeveloped (Aprizal et al., 2025). This fragmentation constrains both the design of effective policy interventions and the scalability of promising technological solutions—particularly in developing and emerging economies where environmental vulnerabilities are greatest (Liu et al., 2025).

This paper addresses these limitations by offering a conceptual synthesis grounded in a systematic review of eight recent empirical and review studies (2022–2025).

The central research questions are:

RQ1: Through what mechanisms do digital technologies contribute to environmental sustainability and climate resilience?
RQ2: How do different technologies and sectors compare in terms of effectiveness, scalability, and policy integration?
RQ3: What theoretical frameworks best explain the relationship between digital innovation and environmental outcomes, and what gaps remain?

The paper proceeds as follows: Section 2 presents the methodological approach; Section 3 develops the theoretical background; Section 4 provides a systematic review of literature; Section 5 presents comparative analysis tables; Section 6 proposes the Digital Environmental Resilience Theory (DERT) conceptual framework; Section 7 discusses implications and limitations; and Section 8 concludes with recommendations for future research.

2. Methodology

This paper adopts a conceptual research design grounded in systematic secondary analysis, consistent with the methodological traditions of theoretical framework development (Jaakkola, 2020). Conceptual research is appropriate where the primary objective is theory construction or integration rather than primary data collection (Gilson & Goldberg, 2015). The study does not involve human subjects or primary empirical data collection.

2.1 Literature Selection Protocol

The source corpus was identified through database searches on Scopus, Web of Science, and Google Scholar. Searches were restricted to English-language, peer-reviewed publications from 2022 to 2025. Eight studies were selected based on their theoretical richness, methodological diversity, and thematic relevance to the research questions (see Table 1). The selected corpus spans quantitative econometric work (Liu et al., 2025; Cao et al., 2025), systematic literature reviews (Aprizal et al., 2025; Reddy et al., 2025), conceptual framework papers (Argyroudis et al., 2022; Nagargoje, 2025), mixed-method reviews (Riaz et al., 2023), and qualitative case analysis (Mohamad & Z.M., 2025).

2.2 Analytical Approach

Content analysis was applied to identify recurring themes, mechanisms, and gaps across the literature. Thematic synthesis (Thomas & Harden, 2008) guided the transition from descriptive codes. Cross-study comparison was operationalised through structured tables evaluating technologies, sectors, theoretical lenses, and research gaps. The resulting DERT framework integrates these findings into a coherent conceptual architecture.

3. Theoretical Background

Multiple theoretical traditions inform the relationship between digital technologies and environmental outcomes. Table 5 (presented in Section 5) provides a detailed comparative analysis. Below we describe the key frameworks that anchor the DERT proposal.

3.1 Ecological Modernisation Theory

Ecological Modernisation Theory (EMT) argues that advanced industrial societies can resolve environmental problems through technological and institutional innovation, thereby 'greening' capitalism rather than abandoning it (Mol & Spaargaren, 2000). Liu et al. (2025) explicitly invoke this logic in their analysis of BRICS+ nations, demonstrating that digital economic transformation—when coupled with green finance—generates measurable environmental resilience dividends. EMT is particularly relevant to this paper's focus because it frames digital technology not merely as an economic tool but as an ecological governance mechanism.

3.2 Socio-Technical Systems Theory

Socio-Technical Systems (STS) Theory recognises that technologies do not operate in a social vacuum; their adoption and impact are co-determined by institutional arrangements, user practices, and policy environments (Geels, 2004). Argyroudis et al. (2022) demonstrate this principle in the context of critical infrastructure resilience, showing that digital tools such as BIM and sensors generate climate-adaptive outcomes only when embedded in multi-level governance frameworks. Mohamad and Z.M. (2025) similarly find that technology-policy alignment is the decisive variable in construction-sector sustainability transitions.

3.3 Resilience Theory

Resilience Theory conceptualises systems' capacity to absorb disturbance, adapt to change, and transform when necessary (Folke et al., 2010). In the environmental context, climate resilience denotes the ability of communities, ecosystems, and infrastructure to withstand and recover from climate-related shocks. Riaz et al. (2023) and Aprizal et al. (2025) operationalise this theory by mapping how digital twins, early warning systems, and remote sensing technologies enhance each phase of the resilience cycle—anticipate, absorb, recover, and adapt.

3.4 Smart City Theory

Smart City Theory posits that the integration of data-driven digital systems into urban governance can radically improve resource efficiency, environmental quality, and citizen wellbeing (Caragliu et al., 2011). Nagargoje (2025) applies this framework to propose an integrated smart environmental management system for Indian cities, demonstrating potential carbon footprint reductions of approximately 25%. Riaz et al. (2023) extend the logic to 3D city modelling and real-time flood risk simulation, connecting smart city infrastructure to disaster risk reduction policy.

4. Review of Literature

4.1 Digital Technologies and National-Level Environmental Resilience

Liu et al. (2025) conduct a cross-national quantitative analysis of BRICS+ economies—Brazil, Russia, India, China, South Africa, and the expanded cohort—to assess how the digital-green paradigm shapes environmental resilience. They develop a composite index incorporating digital economy depth, green finance flows, and environmental performance indicators across a 20-year panel. Their central finding is that digitalisation functions as a catalyst rather than a direct driver: the environmental benefits of digital expansion are largest when complementary green financial systems are in place. This interaction effect is particularly pronounced in economies with high institutional quality, suggesting that governance capacity moderates the digital-environmental nexus. The study advances EMT by providing rare panel-data evidence that decoupling economic growth from resource depletion is achievable when digital and green transitions are coordinated.

Cao et al. (2025) complement this macro-level analysis by examining the legal and governance dimensions of digital technology deployment for environmental risk management. Using econometric modelling across 65 countries, they demonstrate that digital governance regulation—encompassing data protection laws, e-governance standards, and environmental information disclosure mandates—significantly reduces firms' environmental risk exposure. Critically, digital governance regulation and technology deployment exhibit positive complementarity: neither alone achieves optimal outcomes. This finding has profound implications for international environmental law and for multilateral negotiations on digital governance standards.

4.2 Smart Technologies in Sectoral Sustainability

Reddy et al. (2025) provide a multi-sectoral analysis of smart technology applications in agriculture, urban development, and energy management within the Indian context. Their systematic review encompasses over 90 peer-reviewed studies and synthesises evidence on IoT-based precision agriculture, AI-driven energy management, and smart urban planning tools. In agriculture, precision irrigation and remote sensing technologies reduce water consumption by 20–35% and cut synthetic fertiliser use by up to 28%, with commensurate reductions in nitrous oxide emissions. In the energy sector, AI-powered smart grid optimisation improves renewable energy integration efficiency by 15–22%, while smart building management systems reduce commercial energy consumption by 10–18%. The study highlights persistent barriers including high upfront capital costs, inadequate rural connectivity infrastructure, and skill deficits among smallholder farmers—barriers that disproportionately burden lower-income communities.

Nagargoje (2025) extends the urban dimension by proposing a Resilient Urban Environmental Management (RUEM) framework that integrates smart sensor networks, AI-based analytics, and participatory governance mechanisms. The framework is tested conceptually across three Indian metropolitan areas and suggests potential reductions in urban carbon footprint of approximately 25% over a decade-long implementation horizon. A notable contribution is the inclusion of community-level resilience metrics, recognising that smart city frameworks have historically privileged infrastructure efficiency over social equity—a critique echoed by Aprizal et al. (2025) in their global systematic review.

4.3 Digital Twins and Early Warning Systems for Climate Resilience

Riaz et al. (2023) offer the most technologically granular contribution in the reviewed corpus, providing a detailed analysis of digital twin (DT) technology, 3D city modelling, and early warning systems (EWS) in the context of climate resilience management. Digital twins—virtual replicas of physical systems that update in real time via sensor data—represent a qualitative leap in urban risk management. The authors demonstrate that cities employing integrated DT-EWS architectures can reduce emergency response times by up to 40% and improve pre-event evacuation planning accuracy significantly. However, the substantial infrastructure investment required—estimated at €15–50 million for mid-sized cities—limits adoption primarily to high-income urban settings. The study proposes a modular, staged implementation model that could democratise access, though empirical validation of this model in low-income contexts remains outstanding.

Argyroudis et al. (2022) broaden the infrastructure lens to encompass transportation networks, energy grids, water systems, and communication infrastructure. They argue persuasively that digital technologies—when embedded at the design stage rather than retrofitted—generate multi-hazard resilience benefits that outperform traditional engineering solutions. Specifically, sensor-embedded infrastructure enables condition monitoring, predictive maintenance, and adaptive response across earthquake, flood, and extreme heat hazard profiles. Their framework anticipates the Life-Cycle Resilience concept, linking digital investment decisions to long-term infrastructure sustainability.

4.4 Environmental Sustainability in Construction

Mohamad and Z.M. (2025) address one of the most carbon-intensive sectors: construction, which accounts for approximately 37% of global CO_2 emissions. Through qualitative case study analysis of Malaysian and international construction projects, they identify Green Building Information Modelling (Green BIM) and IoT-enabled site monitoring as the most impactful digital sustainability tools. However, their central thesis is that technology alone is insufficient—meaningful sustainability outcomes require synchronised policy instruments including green building codes, procurement standards, and professional certification requirements. The study identifies a critical 'implementation valley': organisations invest in green digital tools but fail to realise their potential due to misaligned incentives between developers, contractors, and regulatory authorities.

4.5 Developing-Country Perspectives and the Technology Divide

Aprizal et al. (2025) provide perhaps the most important corrective to the overwhelmingly high-income-country perspective that characterises much of the digital sustainability literature. Their systematic literature review and bibliometric mapping of 150 studies reveals a striking geographic skew: over 72% of empirical studies on technology-resilience linkages are conducted in high-income OECD countries, while small island developing states (SIDS) and least developed countries (LDCs)—which face the most severe climate exposures—are systematically underrepresented. The authors identify four structural barriers to technology-climate resilience adoption in developing countries: (1) inadequate digital infrastructure; (2) absence of localised technology standards; (3) limited institutional capacity; and (4) financing gaps in technology transfer. These findings underscore the risk that digital sustainability transitions may exacerbate rather than reduce global climate inequality if access and affordability constraints are not addressed through targeted multilateral action.

5. Comparative Analysis: Tables and Cross-Study Synthesis

Table 1

Summary of Reviewed Literature on Digital Technologies and Environmental Sustainability (2022–2025)

Author(s) & Year	Study Focus	Key Technology	Geographic Scope	Key Finding	Methodology
Liu et al. (2025)	Digital-green paradigm for BRICS+ nations	Digital innovation + green finance	BRICS+ countries	Digital economies boost environmental resilience via resource-efficiency transitions	Quantitative / panel data
Reddy et al. (2025)	Smart technologies for environmental sustainability	IoT, AI, precision agriculture	India (multi-sector)	Smart tech reduces agricultural emissions by up to 30% and improves energy efficiency	Systematic review
Argyroudis et al. (2022)	Digital tech for climate resilience of infrastructure	BIM, digital twins, sensors	Europe / global	Multi-hazard resilience improved when digital monitoring is embedded in design stage	Conceptual framework
Aprizal et al. (2025)	Technology role in climate resilience	AI, IoT, remote sensing	Global (SLR)	Technology integration gaps remain, especially in developing nations	Systematic literature review
Cao et al. (2025)	Digital governance and	Digital platforms, regulation tech	Global	Digital governance moderates environmental	Empirical / econometric

	environmental risk			risks; regulation synergises with tech	
Riaz et al. (2023)	Digital twins & EWS for climate resilience	Digital twin, 3D city models, EWS	Ireland + global	Digital twins enable real-time risk assessment & proactive disaster management	Mixed-methods review
Mohamad & Z.M. (2025)	Sustainability in construction via tech & policy	Green BIM, IoT, policy tools	Malaysia / global	Policy-technology alignment is essential for meaningful sustainability outcomes	Qualitative case study
Nagargoje (2025)	Smart environmental management frameworks	Smart sensors, AI analytics	Urban India	Integrated smart frameworks reduce urban carbon footprint by ~25%	Conceptual/framework

Note. SLR = Systematic Literature Review; EWS = Early Warning System; BRICS+ = Brazil, Russia, India, China, South Africa, and expanded economies. Adapted from reviewed sources.

Table 2

Comparative Assessment of Key Digital Technologies Across Environmental Sustainability Dimensions

Technology	Real-Time Monitoring	Predictive Analytics	Scalability	Cost Efficiency	Policy Integration	Maturity Level
IoT Sensors	Very High	Moderate	High	Moderate	Low–Moderate	High
Artificial Intelligence / ML	Moderate	Very High	Very High	High (long-run)	Moderate	High
Digital Twins	High	High	Moderate	Low–Moderate	High	Moderate
Remote Sensing / GIS	High	High	Very High	High	Moderate	High
Blockchain (for env. governance)	Low	Low	High	Low	High	Low–Moderate
3D City Modelling	Moderate	High	Moderate	Low	Very High	Moderate
Early Warning Systems (EWS)	Very High	High	High	High	High	High
Green BIM	Moderate	Moderate	Moderate	Moderate	Very High	Moderate

Note. Ratings are derived from synthesis of reviewed literature. 'Maturity Level' refers to technology readiness level (TRL) as indicated in reviewed sources. High = well-established; Moderate = emerging; Low = nascent.

Table 3

Sectoral Applications of Digital Technologies: Environmental Benefits, Barriers, and SDG Alignment

Sector	Primary Technology	Environmental Benefit	Supporting Study	Implementation Barrier	Policy Mechanism	SDG Linkage
Agriculture	IoT, Precision Tech, AI	Reduced emissions, water saving	Reddy et al. (2025)	Infrastructure cost	Agri-tech subsidies	SDG 2, 13
Urban Infrastructure	Digital twins, 3D models, EWS	Flood / heat risk reduction	Riaz et al. (2023); Nagargoje (2025)	Data standardisation	Smart city mandates	SDG 11, 13
Energy	AI, smart grids, IoT	Efficiency gains, RE integration	Reddy et al. (2025)	Grid interoperability	Carbon pricing	SDG 7, 13
Construction	Green BIM, IoT monitoring	Lower embodied carbon	Mohamad & Z.M. (2025)	Skill gap	Green building codes	SDG 9, 11
Critical Infrastructure	Digital twins, sensors, BIM	Multi-hazard resilience	Argyroudis et al. (2022)	High CapEx	Resilience frameworks	SDG 9, 11, 13
Governance / Policy	Blockchain, reg-tech	Transparency, compliance	Cao et al. (2025)	Institutional inertia	Digital governance law	SDG 16, 17
Cross-sector / National	Digital economy platforms	Systemic decarbonisation	Liu et al. (2025)	Geopolitical coordination	Green finance policy	SDG 13, 17
Disaster Management	EWS, AI, remote sensing	Early warning, reduced loss	Aprizal et al. (2025)	Connectivity in LDCs	DRR national plans	SDG 1, 11, 13

Note. SDG = Sustainable Development Goal. LDCs = Least Developed Countries. DRR = Disaster Risk Reduction. All SDG linkages are author-derived based on reviewed evidence.

Table 4

Research Gaps Identified Across the Reviewed Literature and Proposed Future Research Directions

Identified Gap	Source Study	Implication	Proposed Research Direction
Lack of integrated digital-green frameworks in BRICS+ nations	Liu et al. (2025)	Policy incoherence reduces resilience dividend	Develop composite Digital-Green Resilience Index
Limited empirical evaluation of smart tech outcomes in agriculture	Reddy et al. (2025)	Interventions lack longitudinal validation	Longitudinal multi-country impact studies
Digital twin adoption limited by cost & data standards	Riaz et al. (2023); Argyroudis et al. (2022)	Resilience benefits not fully realised	Open-data standards & public-private DT consortia
Developing-country exclusion from tech-resilience research	Aprizal et al. (2025)	Solutions biased toward high-income contexts	Context-adapted frameworks for LDCs
Weak policy-technology feedback loops in construction	Mohamad & Z.M. (2025)	Green BIM adoption stalled	Policy co-design with practitioners
Insufficient governance frameworks for environmental digital regulation	Cao et al. (2025)	Legal vacuums undermine tech deployment	Comparative law & governance research
Smart city frameworks lack community-level resilience metrics	Nagargoje (2025)	Urban equity concerns unaddressed	Participatory resilience assessment tools
Absence of unified theory linking digital innovation to env. resilience	Across all reviewed studies	Conceptual fragmentation limits policy relevance	Develop integrative Digital Environmental Resilience Theory (DERT)

Note. Gaps are synthesised from explicit limitations sections and implicit theoretical voids identified by the authors through content analysis of reviewed studies.

Table 5

Theoretical Lenses Applied in Reviewed Studies: Propositions, Relevance, and Limitations

Theoretical Lens	Core Proposition	Relevance to Digital Sustainability	Representative Study	Limitation
Socio-Technical Systems (STS) Theory	Technology and society co-evolve; neither is determinist	Explains why digital tech adoption depends on institutional readiness	Argyroudis et al. (2022)	Under-specifies economic constraints
Ecological Modernisation Theory (EMT)	Capitalism can green itself through innovation	Supports digital-green paradigm; frames tech as solution	Liu et al. (2025)	Critiqued for neglecting equity
Resilience Theory	Systems absorb, adapt, and transform under disturbance	Core logic for climate-resilience tech (EWS, DT)	Riaz et al. (2023); Aprizal et al. (2025)	Difficult to operationalise

Resource-Based View (RBV)	Competitive advantage from unique, inimitable resources	Digital capabilities = strategic environmental resource	Liu et al. (2025); Cao et al. (2025)	Static; ignores dynamic change
Institutional Theory	Organisations adopt practices via coercive, mimetic & normative isomorphism	Explains policy-tech alignment in construction & governance	Mohamad & Z.M. (2025)	May over-emphasise conformity
Smart City Theory	Urban intelligence through data & connectivity	Framework for integrated urban environmental management	Nagargoje (2025); Riaz et al. (2023)	Infrastructure-centric; excludes rural
Green Growth Theory	Decoupling economic growth from environmental degradation	Links digital economy policy with emission reduction	Liu et al. (2025); Cao et al. (2025)	Empirical decoupling still debated

Note. Theoretical lens assignments reflect primary analytical framework of each study. Studies may employ multiple lenses; only the dominant lens is recorded here.

6. Proposed Conceptual Framework: Digital Environmental Resilience Theory

Drawing on the literature synthesised above and the theoretical traditions reviewed in Section 3, this paper proposes the Digital Environmental Resilience Theory (DERT) as an integrative conceptual framework. DERT addresses the theoretical fragmentation identified across the reviewed corpus by providing a unified explanatory architecture that maps input conditions, transformation mechanisms, and sustainability outcomes.

6.1 Framework Architecture

DERT is structured around four interacting layers:

Layer 1 — Digital Capability Input: This layer comprises the technological resources that enable environmental sensing, simulation, and governance—specifically IoT infrastructure, AI/ML analytical systems, digital twin platforms, remote sensing and GIS tools, and regulation technology. The reviewed literature consistently demonstrates that these capabilities are necessary but not sufficient conditions for sustainability outcomes (Argyroudis et al., 2022; Riaz et al., 2023).

Layer 2 — Institutional and Governance Mediators: Drawing on STS Theory and Institutional Theory, DERT recognises that digital capabilities are transformed into sustainability outcomes through governance mediators including regulatory frameworks (Cao et al., 2025), policy-technology co-design processes (Mohamad & Z.M., 2025), and institutional capacity. This layer operationalises the critical finding that technology alone is insufficient—governance quality is the decisive moderating variable.

Layer 3 — Resilience and Sustainability Mechanisms: This layer identifies five specific mechanisms through which the interaction of digital capability and governance generates environmental outcomes: (a) real-time environmental monitoring for early detection; (b) predictive risk analytics for proactive adaptation; (c) systemic simulation for planning and design; (d) transparency and accountability mechanisms for governance legitimacy; and (e) cross-sectoral integration for systemic decarbonisation.

Layer 4 — Sustainability Outcomes: The terminal layer captures multi-dimensional sustainability outcomes across environmental, economic, and social dimensions: reduced greenhouse gas emissions; enhanced climate resilience; resource use efficiency; ecosystem protection; and climate equity—particularly the reduction of technology-mediated climate inequality between developed and developing nations (Aprizal et al., 2025).

6.2 DERT Propositions

Based on the literature synthesis, DERT generates five falsifiable theoretical propositions:

P1 (Digital-Governance Complementarity): Digital technology investments generate greater environmental sustainability outcomes when accompanied by coherent governance frameworks. The relationship between digitalization and environmental performance is moderated positively by institutional quality (Liu et al., 2025; Cao et al., 2025).

P2 (Technology Specificity): Different digital technologies activate different resilience mechanisms; there is no universal 'best' technology for environmental sustainability. Technology selection must be calibrated to sectoral characteristics, hazard profiles, and economic contexts (Reddy et al., 2025; Riaz et al., 2023).

P3 (Design-Stage Integration): Digital sustainability technologies generate greater life-cycle resilience benefits when integrated at the design stage of infrastructure and urban systems than when retrofitted (Argyroudis et al., 2022; Nagargoje, 2025).

P4 (Equity-Resilience Tension): Without deliberate policy intervention, digital sustainability transitions disproportionately benefit high-income actors and geographies, potentially widening climate vulnerability gaps (Aprizal et al., 2025; Liu et al., 2025).

P5 (Policy-Technology Feedback Loops): Sustainable digital transitions require iterative feedback between technology performance data and policy redesign. Linear, one-directional technology transfer approaches are systematically less effective than co-evolutionary policy-technology systems (Mohamad & Z.M., 2025; Cao et al., 2025).

7. Discussion

7.1 Synthesis of Key Insights

The systematic literature review and comparative analysis presented in this paper yield several insights of both theoretical and practical significance. First, the evidence base strongly supports the proposition that digital technologies are not merely efficiency tools but potential agents of systemic environmental transformation. The scale of environmental benefits documented—25% urban carbon reductions (Nagargoje, 2025), 20–35% agricultural water savings (Reddy et al., 2025), and significantly improved infrastructure resilience (Argyroudis et al., 2022)—suggests that well-governed digital sustainability transitions could make substantial contributions to national climate commitments under the Paris Agreement.

Second, the comparative analysis in Table 2 reveals a crucial maturity asymmetry: while IoT sensors and remote sensing technologies are well-established and widely deployable, newer approaches such as digital twins and blockchain-based governance tools remain costly and technically complex, restricting their adoption to well-resourced institutional contexts. This asymmetry has important implications for technology transfer policy: policymakers in developing countries should be cautious about skipping established technologies in favour of frontier solutions that lack contextual validation.

Third, the cross-cutting theme of governance emerges as the dominant explanatory variable across virtually every study in the corpus. From the macro-level finding of Cao et al. (2025) that legal-technological complementarity drives environmental risk reduction, to the micro-level insight of Mohamad and Z.M. (2025) that implementation valleys emerge when policy incentives are misaligned with technology adoption, the evidence consistently positions governance—not technology—as the binding constraint on digital sustainability transitions.

7.2 Limitations of the Study

This paper carries several limitations that should be acknowledged. First, the scope of the reviewed corpus, while purposively selected, is limited to eight studies, which may not fully represent the diversity of scholarly opinion in this rapidly evolving field. Second, the conceptual nature of the research means that the proposed DERT framework has not been empirically validated; its five propositions require testing through primary research across diverse geographic and sectoral contexts. Third, the focus on English-language publications may introduce a selection bias that underrepresents non-Anglophone scholarship, particularly from East Asian and Latin American contexts where significant digital sustainability innovation is occurring. Fourth, secondary analysis is inherently constrained by the quality and reporting standards of primary sources; the study cannot verify the internal validity of the empirical findings it synthesises.

7.3 Implications for Policy and Practice

For policymakers, the findings suggest three priority action areas. First, governance co-design: technology-specific digital sustainability roadmaps should be developed collaboratively between technology developers, industry practitioners, civil society, and regulatory authorities to prevent implementation valleys. Second, equity-centred technology transfer: international climate finance mechanisms - including the Green Climate Fund and the Technology Mechanism of the UNFCCC-should explicitly prioritise funding for digital resilience infrastructure in LDCs and SIDS, where technology access gaps are most acute. Third, standards harmonisation: as Riaz et al. (2023) and Argyroudis et al. (2022) demonstrate, interoperability is a fundamental prerequisite for systemic digital sustainability; international standards bodies should accelerate the development of open, interoperable data standards for environmental digital infrastructure.

For researchers, the identified gaps in Table 4 define a clear agenda: longitudinal impact studies across diverse country contexts, empirical testing of the DERT propositions, and methodological innovation to measure the equity dimensions of digital sustainability transitions are among the most pressing needs.

8. Conclusion

This paper has presented a systematic conceptual synthesis of eight peer-reviewed studies on the relationship between digital technologies, environmental sustainability, and climate resilience, published between 2022 and 2025. The synthesised evidence demonstrates that digital technologies spanning IoT, AI, digital twins, remote sensing, and regulation technology—

constitute a powerful and increasingly empirically validated toolkit for environmental governance. However, their transformative potential is contingent on institutional quality, governance design, and equitable access.

The proposed Digital Environmental Resilience Theory (DERT) advances scholarship in three ways. First, it provides the first integrated theoretical framework that maps the pathways from digital capability inputs through governance mediators to sustainability outcomes, resolving the conceptual fragmentation that currently characterises the field. Second, it generates five falsifiable propositions that can anchor a future programme of empirical research. Third, it explicitly centres the equity dimension of digital sustainability transitions- the risk that technology-driven environmental governance may entrench rather than reduce global climate inequality—as a core theoretical and policy concern.

As the international community intensifies its ambitions under the Paris Agreement, the Global Biodiversity Framework, and the 2030 Agenda for Sustainable Development, the governance of digital sustainability transitions will become an increasingly critical arena. The DERT framework and the comparative evidence presented in this paper provide a conceptual foundation for scholars, practitioners, and policymakers shaping this governance architecture.

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