EDITORIAL: Sustainable Development Through Technological Innovations and Data Analytics

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Abstract

The integration of technological innovations and data analytics into sustainable development presents an opportunity to address pressing global challenges such as climate change, resource scarcity, and social inequities. This editorial introduces the Sustainable Development Impact Through Technological Innovations and Data Analytics (SDITIDA) framework, offering a conceptual foundation for aligning technology with the United Nations Sustainable Development Goals (SDGs). Through a rigorous review process, eight articles were selected for this special issue, showcasing interdisciplinary approaches and diverse applications of technology in sustainability. These contributions examine areas such as smart home technologies, AI maturity frameworks, blockchain-enabled agricultural practices, and big data analytics for organizational performance. Collectively, the issue highlights actionable strategies for researchers, practitioners, and policymakers, advancing the discourse on the socio-technical dimensions of sustainability and promoting equitable, sustainable outcomes.

Keywords: *Data Analytics; Technological Innovations; Socio-Technical Systems; Sustainable Development Goals (SDGs); Artificial Intelligence and Sustainability.*

1. Introduction

Sustainable development is anchored in the principle of meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations). However, achieving sustainable development is not a straightforward task; it requires addressing global grand challenges that are inherently complex, multifaceted, and socially embedded (Henriksen et al., 2021). The Sustainable Development Goals (SDGs) exemplify these challenges, but their implementation often encounters tensions and "design-reality gaps" that arise when theoretical frameworks fail to align with practical realities (Corbett et al., 2023; Dennehy et al., 2014; Ncube et al., 2023). While optimism remains high about the potential of technology and analytics to support sustainable global development (Dennehy et al., 2024), uncertainties persist regarding their genuine contribution to bridging sustainability challenges and achieving the SDGs, as these domains remain nascent and underexplored in current research (Del Río Castro et al., 2021).

There is an increasing expectation that the academic community should play an active role in achieving sustainable development through contributions that integrate economic well-being, social inclusion, and environmental protection (Baghdadi et al., 2020; Tarhini et al., 2023). Despite advances in research that explore how technological innovations and analytics can

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encourage sustainable development and energy conservation (e.g., Albizri, 2020), a concerted effort involving interdisciplinary collaboration between academia, policymakers, practitioners, and civil society is essential for building a sustainable and resilient future for people (Harfouche et al., 2023a) and the planet (Harfouche et al., 2023b).
Organizations play a pivotal role in this ecosystem. While some focus on driving business value and staying competitive, others strive to generate both business and social value, particularly by investing in responsible technological innovations such as responsible Artificial Intelligence (Dennehy et al., 2023; Johnson et al., 2023; Merhi, 2023; Tutun et al., 2023) and privacy-preserving blockchain (Rossi et al., 2019; Akanfe et al., 2024).
These innovations aim to foster an ethical and inclusive digitized society (Dennehy et al. 2021a). Yet, challenges remain in bridging the gap between potential and practice, necessitating the development of frameworks that facilitate alignment between technology and sustainability goals (Dennehy et al., 2021b).

To structure this editorial, we will first introduce the Sustainable Development Impact Through Technological Innovations and Data Analytics (SDITIDA) framework, which offers a conceptual lens for aligning technology and sustainability goals. Next, we provide an overview of the selected articles included in this special issue, highlighting their theoretical and practical contributions to sustainable development. Finally, we conclude with a discussion of future research directions and implications for practice and policy.

2. Sustainable Development Impact through Technological Innovations and Data Analytics (SDITIDA)

We propose an integrated framework that synthesizes multiple complementary theoretical perspectives and incorporates a multilayered, dynamic approach of the Adaptive Ecosystem of sustainable development goals (SDGs). We call it the Framework of ***Sustainable Development Impact through Technological Innovations and Data Analytics*** (SDITIDA). The SDITIDA Framework models sustainable development as a complex Multi-layered Adaptive Ecosystem that interplays Stakeholders & Context with Operational Aspects, Actions, and Goals & Outcome. Each layer is interconnected, providing a structured yet flexible approach to align technological innovation with sustainable practices.

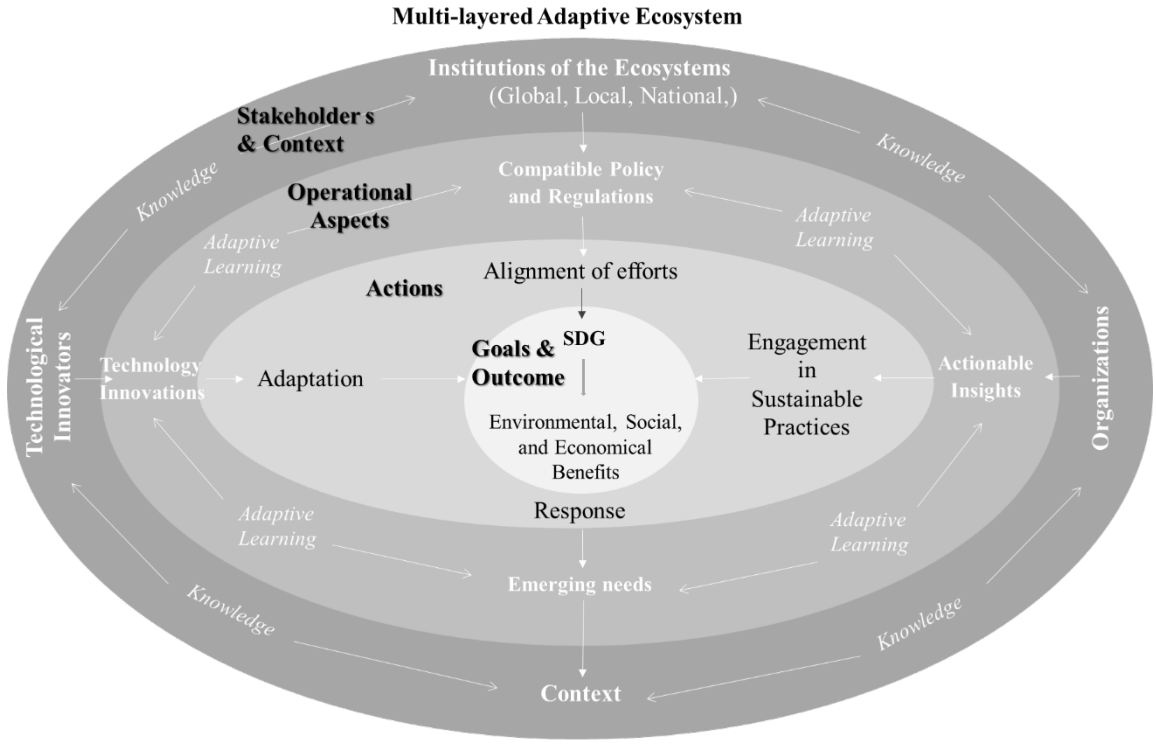
The layer **Stakeholders & Context** identifies key actors - governments, NGOs, communities, businesses & organizations, Technology innovators, and the social, economic, and environmental contexts that shape sustainable initiatives. It emphasizes the importance of aligning technological innovations with local needs and diverse perspectives within the ecosystem. For example, Gasmi et al., (2024) show that digital literacy and stakeholder inclusion play pivotal roles in shaping sustainable practices and regulatory decisions. Ben Nasr et al. (2024) highlight how Smart Home Technologies, by aligning with consumer psychology and sustainable design principles, can bridge the gap between perceived innovation complexity and stakeholder inclusion, fostering adoption and societal value.

The layer **Operational Aspects** focuses on how compatible Policies and Regulations influence innovation technologies such as AI, big data, and IoT to drive sustainable practices by providing actionable insights. For instance, sustainable machine learning design patterns can enhance the development and lifecycle management of AI systems, aligning them with environmental, social, and governance (ESG) standards (Leuthe et al., 2024). Leveraging AI capabilities to optimize supply chains has been shown to significantly enhance organizational sustainability while addressing SDG goals (Fosso Wamba et al., 2024). Similarly, blockchain technology enables transparency and data security in supply chains, fostering sustainable practices in agriculture and other industries (Elhathat et al., 2024). McCarthy et al. (2024) underscore the significance of leveraging digital sustainability platforms to shape energy-efficient behaviors through tailored user representations and the strategic mapping of touchpoints. Their model highlights how personalized feedback and engagement strategies can drive meaningful behavioral change and support broader sustainable goals. Breiter et al. (2024) add depth to the understanding of organizational adaptation by introducing a Twin Transformation Capability Maturity Model (TTCMM). This model bridges digital and sustainability transformations, offering structured pathways and dynamic capabilities for achieving SDG-aligned goals.

These tools enable targeted **Actions**, such as aligning efforts for green supply chains and energy optimization, adapting technologies, and engaging in sustainable efforts as a response to current demands. Targeted actions focus on aligning efforts for sustainable innovation. For instance, Elhathat et al., (2023) demonstrate that green supply chain initiatives supported by machine learning and data analytics can effectively reduce greenhouse gas emissions. Moreover, the integration of big data analytics in organizational operations can drive significant environmental, social, and economic outcomes (Babalghaith et al., 2023).

The layer **Goals & Outcomes** sets clear objectives aligned with SDGs, focusing on tangible outcomes such as reduced carbon emissions and social inclusion. Through analytics-driven feedback, it monitors the success of these actions, guiding continuous improvements within the ecosystem. As outlined in Dennehy et al. (2021b), achieving SDG objectives requires iterative learning and alignment of technologies with evolving societal needs
For example, Hansen et al. (2024) propose an AI Capability Maturity Model (AICMM) that provides a structured approach for evaluating and advancing an organization's AI maturity. This model underscores the necessity of iterative alignment between AI capabilities and organizational goals, which is pivotal for realizing sustainable development impacts. By leveraging the AICMM, organizations can systematically identify maturity gaps, optimize resources, and align AI initiatives with both short-term actions and long-term SDG objectives.

The **feedback loops** link all layers, allowing iterative learning and realignment of policies, technology, and actions. This dynamic process ensures that sustainable development adapts to emerging needs, creating a resilient, cohesive ecosystem over time. The multi-level feedback loops integrate these layers, allowing adaptive learning by aligning institutional policies, technological adaptation, organizational engagement, and community responses with emerging needs. For example, sustainable machine learning design patterns provide structured approaches to incorporating environmental, social, and governance considerations into iterative AI development processes (Leuthe et al., 2024). Blockchain-enabled systems provide feedback that ensures accountability and alignment with sustainable objectives (Elhathat et al., 2023). The maturity model proposed by Breiter et al. (2024) highlights feedback mechanisms essential for continuous improvement across technological and sustainability dimensions.



The multi-level feedback loops emphasize that sustainable outcomes are not merely technological innovations-driven but emerge through iterative alignment of Policy and regulations, technology adaptation, organizations engagement and communitarian response to sustainable emerging needs. This framework addresses the inherent complexity of sustainable development goals (SDGs) by considering how technology innovations are adapted through organizational engagement in sustainable actions across varying levels of interaction between aligned efforts of institutional pressures and contextual emerging needs. Research has demonstrated that the adaptive alignment of organizational efforts and technological solutions is essential for achieving SDG objectives (Fosso Wamba et al., 2024). It emphasizes that sustainable development is a dynamic, non-linear learning process requiring continuous adaptation of technology innovations, organizational daily Sustainable actions, and alignment efforts of Policy and regulations.

This theoretical framework not only provides a cohesive model for understanding the role of technology in sustainable development but also addresses the complexity of implementing and scaling these initiatives. It underscores that sustainable development is a journey of continuous adaptation and alignment across societal layers, highlighting the importance of collaborative, cross-sectoral, and responsive approaches in using technology and analytics to meet the environmental, social and economic benefits of global sustainability goals.

3. The Special Issue

In this special issue, we were particularly interested in theory-building studies and empirically grounded theorising related to technological innovations and data analytics for sustainable development. Following a rigorous review process consisting of a minimum of two and a maximum of four rounds of review, eight articles were selected to be included in this special issue. Of which, two papers were extended versions that were presented at the 2023 *IEEE*

International Symposium on Technology and Society conference hosted at Swansea University, and four papers that were presented at the *MENA Conference on Information Systems (MENACIS 2022*) hosted at *King Fahd University of Petroleum and Minerals.*
Each article offers a distinct perspective on the role of technology and analytics in addressing global challenges, collectively advancing our understanding of the socio-technical dimensions of sustainability and its implications for IS research, IS practice, and society. Below, we summarize the key contributions of these eight articles:

Ben Nasr et al. (2024) delve into the adoption paradox of Smart Home Technologies (SHT), despite their transformative economic, social, and environmental benefits. This study integrates innovation diffusion theory and perceived value theory to investigate how mental imagery, catalyzed by website design, shapes consumer perceptions of SHT benefits and sacrifices, influencing adoption behavior. Empirical findings emphasize the role of imagery processing in enhancing perceived sustainable value, mitigating adoption barriers, and promoting eco-conscious living. Key contributions include the development of a holistic framework bridging psychological, functional, and social dimensions of SHT adoption, underscoring actionable strategies for marketers and policymakers. This research offers critical insights into the nexus of sustainability and digital innovation, advocating for user-centric design in fostering a low-carbon economy.

Gasmi et al., (2024) explore the convergence of development economics, regulatory policies, and public health considerations within the field of IS research, focusing specifically on 5G and 6G mobile technologies. Despite the widespread deployment of these technologies and their potential health implications, there is a limited understanding in IS literature on why countries adopt varying thresholds for radiation regulation. By analyzing data from 124 countries, they uncovered an inverted U-shaped relationship between digital literacy and the rigidity of radiation regulation. This finding reveals that nations with lower digital literacy levels tend to enforce stricter regulations, whereas those with higher literacy levels adopt more relaxed policies. By highlighting how digital literacy, a critical aspect of the digital divide, significantly influences regulatory frameworks in telecommunications, this study contributes to filling the gap in IS research. This underscores the necessity of informed and transparent regulatory decision making, especially in countries with diverse levels of digital literacy. Calling for a multidisciplinary approach to policy formulation, our work enriches the broader discourse in IS research, underlining the pivotal role of digital literacy in shaping both the access and regulatory landscapes of emerging technologies.

Elhathat et al. (2024) address the challenge of tracking greenhouse gas (GHG) emissions in Senegal's groundnut supply chain by leveraging blockchain-enabled off-chain machine learning. Groundnuts, a key agricultural product in Senegal, contribute to significant GHG emissions across cultivation, harvesting, and processing/shipping stages. The authors integrate predictive machine learning models (MLPMs) with a private blockchain framework (Hyperledger Fabric) to enhance data security, transparency, and accountability. Smart contracts were developed to manage emissions data and provide actionable insights. The study also introduces a decision-making dashboard for monitoring emissions, supporting sustainable agricultural practices. This innovative approach demonstrates how blockchain and machine learning can mitigate emissions and offers a replicable framework for other agricultural contexts. Limitations include reliance on existing databases (FAOSTAT, EDGAR) and challenges with data integration, prompting recommendations for future research on broader applicability and secure communication protocols.

McCarthy et al., (2024) highlight that countries have been tasked with reducing energy consumption and lessening their carbon footprint through targeted actions to address climate change. They make the case although digital technologies can support this goal, our understanding of energy practices in a private household context remains nascent. This challenge is amplified by the 'invisible' nature of users' interaction with energy systems and the impact of unconscious habits. The objective of their study is to explore how touchpoints embedded in digital sustainability platforms shape energy-efficiency behaviours among users. Building on data from semi-structured interviews and a co-creation workshop with 25 energy experts in the ECO2 project, a 36-month EU project which sought to design a digital platform for users to increase their energy efficiency. In doing so, they identify three user representations of relevance to such platforms, namely *energy-unaware*, *living in denial*, and *energy-aware and active*. Their findings suggest that 'static' user representations are giving way to socio-cognitive representations that follow users' journeys in energy efficiency. Their study then progresses to the development of a set of design principles to promote sustainable energy behaviours through digital sustainability platforms across *user-owned*, *social/external*, *brand-owned*, and *partner-owned* touchpoints. An analysis of user feedback from the ECO2 project shows support for their design principles across users' journeys.

Leuthe et al. (2024) introduce a pioneering Sustainable Machine Learning Design Pattern Matrix (SML-DPM) to address the sustainability challenges inherent in machine learning (ML) development. By structuring 35 design patterns across four ML development phases and three Environmental, Social, and Governance (ESG) dimensions, the SML-DPM provides a comprehensive framework for enhancing the sustainability of ML practices. This study leverages a design science research methodology, integrating insights from literature, expert interviews, and real-world case studies. Key contributions include actionable patterns for stakeholders and a diagnostic tool that balances environmental responsibility, social equity, and governance standards. The findings underscore the importance of a holistic, lifecycle-oriented approach to ML sustainability, offering a replicable roadmap for researchers and practitioners aiming to mitigate resource consumption and promote fairness in AI systems. This research significantly advances the discourse on sustainable AI development by bridging theory and practice, highlighting actionable strategies to align ML practices with global sustainability goals.

Hansen et al. (2024) investigate how organizations can effectively implement and enhance their Artificial Intelligence (AI) capabilities, moving beyond the hype and focusing on practical integration into business operations. They emphasize that AI adoption is not just a one-time event; rather, it is a gradual process of maturity. The authors conducted a two-phase qualitative case study, which included interviews with AI experts and an examination of three organizations at different stages of AI diffusion. This led to the development of an AI Capability Maturity Model (AICMM) that outlines the stages organizations go through as they mature in their use of AI. The authors identified common challenges organizations face during AI diffusion, such as data management, organizational alignment, and regulatory compliance. Moreover, as AI maturity increases, the nature of these challenges evolves. The paper provides practical tools for professionals to assess their current level of AI maturity and offers strategies for progressing further. It contributes to both academic research by deepening the understanding of AI diffusion and to practical applications by presenting a framework that organizations can use to navigate their AI adoption journey and maximize value.

Babalghaith and Aljarallah (2024) investigate the determinants and consequences of Big Data Analytics (BDA) adoption in small and medium enterprises (SMEs) in Saudi Arabia. Drawing on the Technology-Organization-Environment (TOE) framework and the Resource-Based View (RBV) theory, the study examines how technical, organizational, and environmental factors influence BDA adoption and its impact on SMEs' performance. Using survey data from 233 SMEs, the authors reveal that complexity, compatibility, top management support, organizational readiness, and a data-driven culture are critical drivers for BDA adoption. They also highlight significant relationships between BDA adoption and three performance dimensions: financial, market, and business process. By extending the context of BDA research to SMEs and providing practical insights into how such enterprises can leverage BDA for competitive advantage, this study makes both theoretical and practical contributions to the field of information systems and SME performance optimization.

Fosso Wamba et al. (2024) explore the impact of Artificial Intelligence (AI) capabilities on firm performance, emphasizing the mediating role of a data-driven culture within the context of sustainable development. Anchored in the resource-based theory, the authors propose a high-order model incorporating tangible, intangible, and human resources to define AI capabilities. Using a mixed-method approach combining PLS-SEM and fsQCA, the study identifies AI infrastructure as a pivotal resource and highlights the importance of fostering a data-driven culture to maximize performance. The findings suggest that AI capabilities can directly and indirectly influence firm performance, advancing Sustainable Development Goals (SDGs) 9 (industry, innovation, and infrastructure) and 12 (responsible consumption and production). This research contributes to both the theoretical understanding of AI resource configurations and practical insights for organizations aiming to align AI adoption with sustainability objectives.

Breiter et al., (2024), investigate the duality of digital transformation and sustainability transformation as guidance on how to integrate both digital and sustainability transformation, namely twin transformation, is theoretically underdeveloped. Specifically, they make a compelling case that deeper knowledge about relevant twin transformation capabilities and progress are needed for effective implementation. To enhance the understanding and provide corresponding guidance, they developed a twin transformation capability maturity model focusing on dynamic capabilities required to realize twin transformation. A structured literature review and interviews with 13 experts, and its demonstrated use with a technology service provider forms the basis of their study. They conclude that accounting for organizations' twin transformation starting points in terms of their digitalization and sustainability experience and expertise, we reveal three pathways to becoming a twin transformer. Second, our work provides an overview of 45 relevant twin transformation capabilities structured along six capability dimensions and four maturity stages. The findings have practical implications for supporting organizations in assessing their twin transformation maturity building the foundation for targeted capability development.

In this special issue, the selected articles collectively represent a diverse yet interconnected exploration of how technological innovations and data analytics address key global challenges. By leveraging a range of theoretical lenses and empirical methods, these studies provide fresh insights into the socio-technical dimensions of sustainability. The following table 1 offers a concise summary of each article's focus, methodology, and contributions, underscoring their relevance to both IS research and practice.

Table: Overview of Articles in the Special Issue

Article	Key Focus	Methodology	Theoretical Contributions	Practical Contributions
Ben Nasr et al. (2024)	Adoption of Smart Home Technologies (SHT) through consumer mental imagery and sustainable design.	Quantitative study combining innovation diffusion theory and perceived value theory, leveraging consumer surveys and website design experiments.	Holistic framework integrating innovation diffusion and perceived value theories, emphasizing the psychological, functional, and social dimensions of adoption.	Strategies for policymakers to promote SHT adoption, enhancing eco-conscious living.
Gasmi et al. (2024)	Impact of digital literacy on 5G/6G radiation regulations and sustainability.	Analysis of cross-national data from 124 countries using statistical modeling to explore relationships between digital literacy and regulation thresholds.	Identification of an inverted U-shaped relationship between digital literacy and regulatory thresholds for radiation.	Policy recommendations for tailoring regulatory frameworks based on digital literacy levels.
Elhathat et al. (2024)	Blockchain-enabled machine learning for greenhouse gas emissions tracking in Senegal's groundnut supply chain.	Mixed-methods approach integrating blockchain (Hyperledger Fabric), machine learning, and a decision-making dashboard with data from FAOSTAT and EDGAR databases.	Framework for integrating predictive models and blockchain for sustainable agriculture and GHG emissions traceability.	Decision-making dashboard for emissions reduction strategies, with potential applications in other agricultural supply chains.
McCarthy et al. (2024)	Role of digital sustainability platforms in shaping energy-efficient behaviors in	Multimethod study, including semi-structured interviews and a co-creation workshop with energy experts,	Development of user representation and touchpoint model for sustainable	Design principles for engaging users in energy efficiency through digital platforms.

	private households.	as part of the ECO2 EU project.	energy practices.	
Leuthe et al. (2024)	Sustainable Machine Learning Design Pattern Matrix (SML-DPM) to address sustainability in ML development.	Design Science Research methodology combining literature reviews, expert interviews, and real-world case studies validated with a web-based prototype.	Comprehensive framework of 35 design patterns aligning ML development with environmental, social, and governance dimensions.	Diagnostic tool for practitioners to evaluate and improve sustainability in ML processes.
Hansen et al. (2024)	Development and validation of the AI Capability Maturity Model (AICMM).	Two-phase qualitative case study including interviews with AI experts and cross-case analysis of organizations at different AI maturity levels.	Exploration of AI diffusion as a process of organizational maturity.	Practical tools for assessing and advancing AI maturity in organizational contexts.
Babalghaith & Aljarallah (2024)	Determinants of Big Data Analytics (BDA) adoption in SMEs and its impact on performance.	Survey-based study with data collected from 233 SMEs in Saudi Arabia, analyzed using the TOE framework and Resource-Based View theory.	Integration of TOE framework and Resource-Based View to understand drivers of BDA adoption.	Guidance for SMEs to leverage BDA for enhanced financial, market, and business process performance.
Fosso Wamba et al. (2024)	Role of AI capabilities in firm performance and the mediating effect of a data-driven culture.	Mixed-method approach combining PLS-SEM for hypothesis testing and fsQCA for configuration analysis of AI capability and firm performance.	High-order model linking AI capabilities to sustainable development goals (SDG 9 and SDG 12).	Insights for fostering a data-driven culture to maximize AI-driven organizational performance.
Breiter et al. (2024)	Integration of digital and	Structured literature	Development of a Twin	Practical guidelines for

	sustainability transformations (twin transformation).	review, expert interviews with 13 participants, and case demonstration with a tech provider.	Transformation Capability Maturity Model, identifying pathways and 45 dynamic capabilities.	organizations to assess and enhance their twin transformation maturity.

4. Conclusion

Each of the articles in this special issue contributes to advancing the discourse on how **technological innovations** and **data analytics** can address the global challenges of sustainable development. While these studies provide valuable insights, significant gaps remain in understanding how to systematically align technology with the SDGs. First, future research must prioritize **interdisciplinary collaboration** across fields such as information systems, environmental science, and policy studies to co-create actionable solutions. Second, there is a need to delve deeper into the interplay between **emerging technologies** (e.g., AI, blockchain) and their implications for equitable and resilient sustainable practices. Third, adaptive frameworks should be developed to enable iterative learning and realignment of policies, technologies, and organizational efforts.

We hope this special issue serves as a foundation for advancing the integration of technology and analytics in sustainable development. By bridging theory and practice, this work not only informs scholarly debates but also equips practitioners with actionable strategies to build a more inclusive and sustainable future.

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