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Artificial Intelligence in Climate Adaptation: Opportunities and Challenges for Sustainable Business Models

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Abstract

Climate change is increasingly disrupting businesses and ecosystems, creating urgent demand for data-driven adaptation strategies. This study examines how artificial intelligence (AI) can strengthen climate resilience across diverse industries, with particular attention to the innovative business strategies that help organizations respond to global environmental challenges. The objective is to address gaps in existing AI frameworks, focusing on developing countries with resource and technical limitations. The study highlights the significance of AI in fostering sustainable practices, particularly in climate change mitigation. A systematic review of 42 high-quality studies, published between 2010 and 2025 in the Scopus database, was carried out using the PRISMA framework. The analysis identifies key AI applications, technologies, and challenges. Data were organized according to industry applications, technological contributions, and obstacles. Key findings indicate that AI enhances climate risk assessment through predictive modelling, supports adaptive decision-making via scenario analysis, and optimizes resource allocation for sustainability. Applications in renewable energy, precision agriculture, and disaster management are also noted. However, significant barriers persist, including ethical concerns such as algorithmic bias and data privacy, technical complexities, and high financial costs. The review underscores the necessity of collaborative approaches, such as public-private partnerships, and the importance of conducive policy frameworks. The research's originality lies in its comprehensive synthesis of AI applications for climate resilience, offering actionable insights for scholars, practitioners, and policymakers. The findings highlight AI's potential to drive sustainable business models while calling for interdisciplinary research to address scalability and ethical implications in resource-constrained environments.

Keywords

Artificial intelligence; Business resilience; Climate adaptation; Sustainable business models; Systematic literature review

Introduction

Climate change is one of the most pressing global challenges of the twenty-first century, disrupting ecosystems, economies, and social systems worldwide (Moser and Ekstrom, 2010). Rising temperatures and the intensification of extreme weather events threaten infrastructure, resource security, and economic stability. These disruptions require adaptive responses that enhance resilience at both organizational and systemic levels.

Artificial intelligence (AI) has emerged as a strategic enabler in addressing these challenges by processing vast datasets, identifying complex patterns, and supporting predictive and adaptive decision-making (Cheong, Sankaran and Bastani, 2022; Singh, Goyal and Kumar, 2023). Unlike traditional mitigation and adaptation strategies, AI provides actionable, real-time insights that enhance the agility of climate responses. Thus, AI can underpin more resilient and sustainable business models (Di Vaio *et al.*, 2020).

The concept of resilience, defined as the ability of systems to anticipate, survive, and recover from climate disruptions, has gained traction in business and sustainability research (Füssel, 2007; Huiskamp, ten Brinke and Kramer, 2022). However, most studies focus primarily on sector-specific technological solutions rather than the integration of AI into strategic business frameworks. Consequently, the understanding of how AI can strengthen resilience across different industrial and socio-economic contexts remains limited.

Despite growing interest, gaps persist concerning (a) disparities between developed and developing economies in AI adoption (Nishant *et al.*, 2020; Biagini and Miller, 2013). Community-level adaptation remains equally important, as local resource-dependent systems often have limited institutional support and require context-specific climate strategies (Sharma and Singh, 2021) ; (b) underexplored sectors such as manufacturing, transport, and construction (Rahman *et al.*, 2023); and (c) the ethical and organizational barriers that constrain systematic integration of AI into sustainable business models (Di Vaio *et al.*, 2020).

Therefore, this study aims to systematically review and critically analyze how artificial intelligence contributes to climate adaptation and resilience, identifying opportunities, barriers, and implications for sustainable business models.

To address these gaps, this review examines how artificial intelligence contributes to climate adaptation and business resilience across sectors and economic contexts. Accordingly, it investigates the following research question:
RQ1: How does artificial intelligence enable climate adaptation and resilience in business and organizational settings, and what ethical, technical, and organizational barriers influence its adoption? This guiding question frames the systematic review and supports the synthesis of opportunities, challenges, and implications for sustainable business models.

Methodology

Datasets and Preprocessing

The literature review was conducted using the Scopus database. The preprocessing stage involved keyword refinement around "AI", "climate adaptation", "business resilience", and "sustainability". Duplicates and non-peer-reviewed materials were excluded. The final dataset of 42 studies formed the analytical base for thematic synthesis.

The review applies to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a transparent and rigorous process of identification, screening, and analysis, thereby reducing potential sources of bias (Moher *et al.*, 2015). The aim is to map how AI contributes to climate adaptation through business decision-making, particularly over the period 2010–2024.

Sampling Methods

While the reach of Scopus is broad, it is not comprehensive. Not all academic journals are included; therefore, some relevant research may be found in other databases like Web of Science or Google Scholar. To address this limitation, a sensitivity analysis was used with alternative databases to ensure that extensive coverage of pertinent research was established. The systematic process is outlined in the following steps:

a) Identification Phase: An informed search strategy was developed using keywords like "artificial intelligence", "climate resilience", "adaptive management", and "sustainable business model" to capture a broad outline of AI-enabled tools in systematic reviews through the lens of climate resilience, as defined by Di Vaio *et al.* (2020). A time frame of 2010–2025 was chosen to capture the evolving development of AI-enabled technology and its growing relevance in the mitigation of climate change, along with enhancing climate change adaptation, as noted by Chen *et al.* (2023). The search strategy incorporated Boolean operators (AND, OR, NOT) to include, exclude, or combine keywords in a query, thereby making the findings more specific and effective. (see Figure 1).

The initial search yielded 3,691 documents. Filters were applied to refine the results as follows:

Year: Studies published between 2010 and 2025 (n = 3,681).
Subject Area: Business, Management, and Accounting (n = 319).
Document Type: Articles only (n = 218).
Language: English studies (n = 215).

The inclusion criteria for the studies involve (1) those studies published between 2010 and 2025, (2) that explicitly discuss AI applications in climate resilience, and (3) provide empirical evidence or case studies. The exclusion criteria consist of studies (1) that focus solely on theoretical frameworks without practical applications, (2) those that do not address climate resilience or adaptation, and (3) non-English language studies.

b) Screening and Selection of Relevant Studies: Titles, abstracts, and keywords of the 215 retrieved records were screened for relevance to AI applications in climate resilience. Only peer-reviewed studies presenting empirical or theoretical contributions within the scope of the review were retained. Studies with poor methodological quality or unrelated theoretical discussions were excluded. After screening, 142 records were excluded, leaving 73 articles for full-text review.

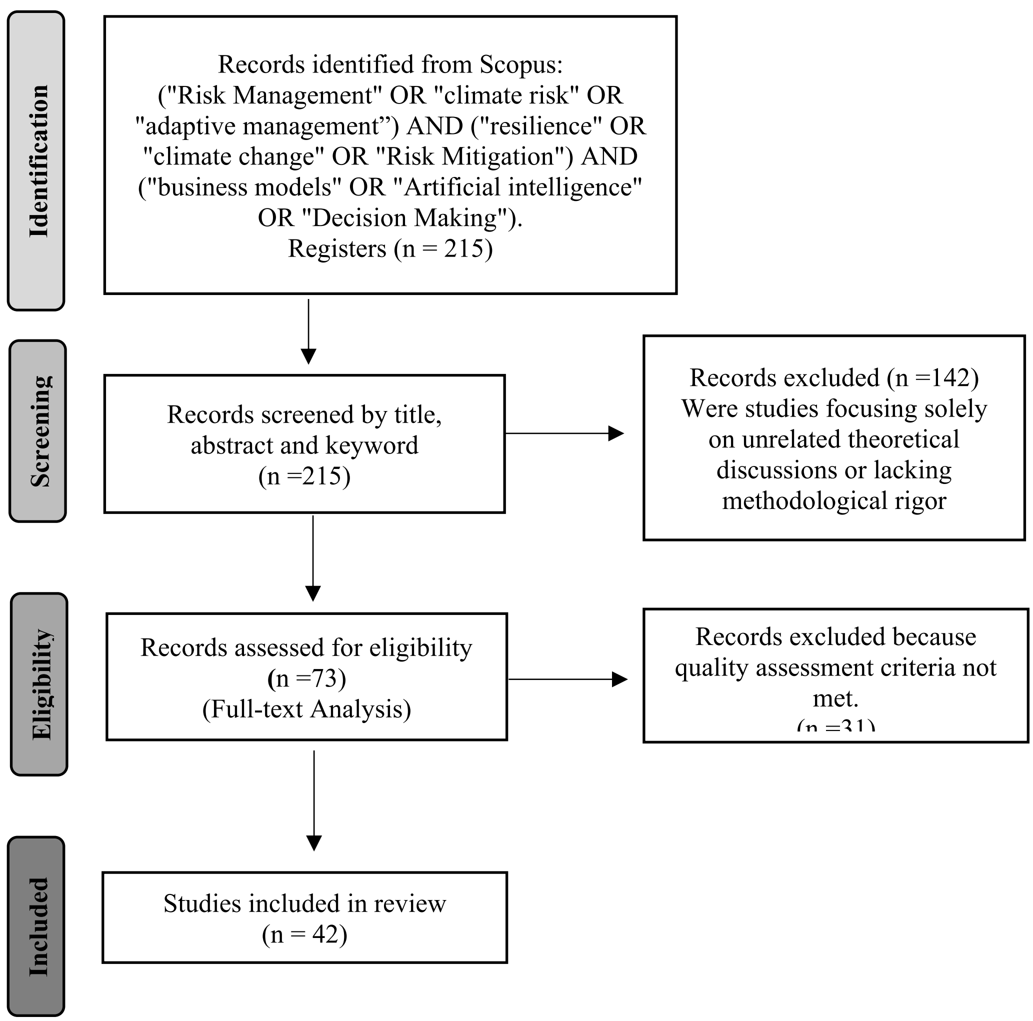

Figure 1: Paper screening process based on the PRISMA theory

c) Eligibility Phase: The 73 remaining articles underwent full-text review to assess their validity and relevance. A quality appraisal checklist, based on Moher *et al.* (2015), was implemented to minimize bias.

d) Inclusion Phase: Finally, 42 high-quality studies were selected for inclusion in the systematic review. Each of these papers specifically addresses the application of AI in building business resilience against climate risks and aligns with the research goals (see Figure 1).

Research Tools

All data collection was conducted using Scopus as the sole database. Its advanced filtering features and credible indexing made it suitable for ensuring the systematic nature of the review. The PRISMA framework guided the process from initial identification to final inclusion. Manual screening complemented Scopus's automated tools to ensure the relevance and quality of selected articles. Figure 1 presents the PRISMA flow diagram for the selection process.

Measurement of Major Indicators

To assess the relevance and quality of the included studies, four specific inclusion questions were applied. The checklist addressed the following criteria:

> Q1: Is "Artificial Intelligence" or "adaptive management" clearly stated in the study as a tool for answering one of its questions?
> Q2: Does the study address climate resilience, climate change, or risk mitigation?
> Q3: Does the study investigate business models or decision-making processes within its context?
> Q4: Does the study explicitly describe its research objectives, methods, and findings?
> Studies that met all the criteria mentioned were included. After rigorous evaluation, 31 records not aligned with the scope of the study were excluded.

The final synthesis included 42 peer-reviewed publications drawn from the Scopus database between 2015 and 2024. Despite the quantitative limitation of selected studies, the papers represent a diverse mix of industrial, geographical, and methodological perspectives, providing a sufficiently comprehensive foundation for synthesis. The inclusion of business, management, environmental, and technological studies — spanning both developed and developing contexts — allowed for a multidimensional understanding of AI's role in climate adaptation. Such disciplinary variety strengthens the analytical reliability of the review (Di Vaio *et al.*, 2020; Cheong, Sankaran and Bastani, 2022; Leal Filho *et al.*, 2022).

Results

The results section presents the main findings from the reviewed studies, highlighting trends and patterns in AI applications for climate resilience. Thematic analysis identified four key themes:

Artificial Intelligence for Climate Data Analysis

Artificial intelligence has emerged as a highly effective climate data analysis tool, improving the accuracy of predictive projections for extreme weather phenomena as well as long-term climate patterns. Key applications include:

a) Predictive Modeling for Extreme Weather: The deployment of artificial intelligence along with machine learning, particularly through neural networks, has enabled the predictive modeling of severe meteorological events such as hurricanes, floods, and droughts, as demonstrated by Linnenluecke, Griffiths and Winn (2012), Rahman *et al.* (2023), and Chen *et al.* (2023). A relevant example comes from the European Centre for Medium-Range Weather Forecasts (ECMWF), where machine learning has been used to enhance weather forecasting accuracy and strengthen preparedness measures against potential hazards (Akter *et al.*, 2021; Rahman *et al.*, 2023; Shankar and Gupta, 2024). These AI-supported forecasting gains align with broader resilience planning findings in climate-vulnerable regions, where timely hazard detection significantly improves disaster preparedness (Tiwari, Upadhyay and Joshi, 2022).

b) Energy Forecasting: AI models have become important tools for predicting variations in renewable energy supply variations, e.g., solar energy and wind energy. These predictions allow grid operators to more accurately schedule energy and maintain system stability during severe weather conditions (Zeng *et al.*, 2023; Zhong, Zhang and Yang, 2025).

c) Satellite and Sensor Data Integration: Artificial intelligence technology involves the analysis of data obtained from satellite images and ground sensors to assess climatic factors like temperature, rain, and sea level height. Integration of these data enables real-time observation and early warning mechanisms of climatic hazards, as seen from studies by Cheong *et al.* (2022), Rahman *et al.* (2023), and Liu *et al.* (2020).

Artificial Intelligence for Decision-Making

The capacity of AI to analyze and process large datasets, in turn, has directly influenced decision-making processes in terms of climate resilience. The applications include:

a) Scenario Planning and Risk Assessment: AI-driven tools enable businesses to perform scenario analysis and determine their exposure to climate-related risks. For example, IBM Watson and Google DeepMind have developed platforms that provide real-time hazard assessments and preventive strategies to reduce climate-related disruptions (Busch, 2011; Jarrahi, 2018; Todaro *et al.*, 2021).

b) Strategic Investment in Resilience: AI-driven decision support systems guide companies on how to optimally invest in climate resilience based on their exposure to climate risks. This is particularly important for developing climate-resilient business models that balance short-term operational needs with long-term sustainability goals (Di Vaio *et al.*, 2020; Lemma, Lulseged and Tavakolifar, 2021; Miglionico, 2022).

c) Supply Chain Optimization: AI capabilities facilitate forecasting of climate-related disruptions in supply chains, enabling companies to strengthen operational resilience and sustainability initiatives. For example, AI-driven supply chain optimization tools have been deployed to reduce the effects of climatic extremes on global supply chains (Dubey *et al.*, 2020; Wedawatta, Ingirige and Amaratunga, 2010; Truong and Papagiannidis, 2024).

Artificial Intelligence and Sustainable Resource Management

AI-driven solutions in agriculture, water resource management, and urban infrastructure have supported the optimization of sustainability interventions. Examples include:

a) Precision agriculture: AI-powered technologies improve irrigation efficiency, predict crop yields, and mitigate pest infestations. These applications reduce environmental footprints while increasing agricultural productivity. Case studies in India and Australia highlight how AI-enabled early warning systems have minimized the effects of droughts and floods on agricultural production, according to Leal Filho *et al.* (2023) and Rahman *et al.* (2023).

b) Water resource management: Artificial intelligence has been used to forecast water availability, monitor quality, and optimize distribution networks. Such applications enable timely interventions that mitigate environmental threats and improve sustainability in the face of water drought fueled by climate change (Chen *et al.*, 2023; Rahman *et al.*, 2023; Linnenluecke, Griffiths and Winn, 2013).

c) Urban Infrastructure Resilience: AI-driven risk analysis tools support policymakers in developing climate-resilient urban infrastructure with built-in enhanced flood protection systems, as well as resilient transportation systems. For example, flood forecasting models enhanced by AI, in conjunction with IBM, have been able to drastically cut down on extreme weather-related severity in urban areas such as Miami (Melkonyan *et al.*, 2024; Shakou *et al.*, 2019).

Challenges in AI Adoption

Despite its potential, the adoption of AI in climate resilience is limited by several ethical and technical challenges:

a) Ethical and Equity Challenges: The use of artificial intelligence in climate adaptation presents important ethical and fairness concerns. Algorithmic bias, where models developed using non-representative or incomplete datasets risk exacerbating prevailing social and economic inequalities, is always a concern, especially when data from developed regions are used in developing contexts (Nishant *et al.*, 2020; Mbanyele and Muchenje, 2022; DiBella, 2020). These conditions can lead to disparate access to AI-augmented climate action and exacerbate the vulnerability of disadvantaged groups (Cheong, Sankaran and Bastani, 2022; Akter *et al.*, 2021).

b) Individual data privacy is a significant issue: AI-powered surveillance and decision-making systems tend to involve the collection and processing of sensitive individual or communal data and, therefore, trigger concerns regarding consent, security, and abuse (Dwivedi *et al.*, 2022). The incorporation of ethical AI systems with strong governance structures is essential to ensure transparency and impartiality as well as equitable benefit-sharing in climate adaptation initiatives (Zeng *et al.*, 2023).

c) Technical and financial constraints: The expense of artificial intelligence implementation, the requirement for specialized knowledge, and the lack of infrastructure in developing countries constitute major barriers to the wider usage of AI in projects focused on climate resilience improvement. For instance, informal firms in Sri Lanka are confronted with complicated registration processes that hinder them from adopting disaster resilience practices, thereby exposing them to climate-related risks, as indicated by Hewawasam and Matsui (2024), Linnenluecke and Griffiths (2010), and Yuan *et al.* (2017).

d) Scalability and integration challenges: Integrating artificial intelligence into current systems and processes typically demands radical structural overhauls and significant financial investments, particularly in organizations with complicated supply chains or outdated infrastructures. This requires huge financial investment in improving infrastructure, advanced software programs, and staff training to secure equal access to artificial intelligence (Rahman *et al.*, 2023; Linnenluecke and Griffiths, 2010; Zeng *et al.*, 2023).

Truong and Papagiannidis (2022) and Wittneben and Kiyar (2009) stressed developing capacity-building programs and training sessions to endow organizations with the required skills to leverage artificial intelligence in developing climate resilience. Meanwhile, Di Vaio *et al.* (2020) and Akter *et al.* (2021) advocated interdisciplinary approaches to bridge technological know-how and practical applications. This would normally put considerable stress on an organization's existing systems and processes, since it tends to call for widespread structural adjustments and capital outlays, particularly in the case of organizations with complex supply chains or outmoded infrastructures (Mbanyele and Muchenje, 2022; Cheong, Sankaran and Bastani, 2022; Leal Filho *et al.*, 2023).

Across reviewed sectors, a recurring tension appears between technological optimism and organizational inertia. Studies such as Rahman *et al.* (2023) emphasize that while AI offers predictive power for climate risks, its effectiveness depends on governance readiness, ethical frameworks, and stakeholder collaboration (Huiskamp, ten Brinke and Kramer, 2022; Leal Filho *et al.*, 2022). These insights reflect broader governance challenges highlighted in climate policy literature, underscoring the need for coherent, cross-sectoral institutional frameworks to support adaptation efforts (Khan and Bhat, 2020).

These interdependencies illustrate that climate resilience is not only a technological issue but a systemic organizational capability. For instance, Di Vaio *et al.* (2020) and Singh, Goyal and Kumar (2023) show that firms adopting AI for resilience often redesign their business models toward circular economy principles, embedding climate adaptation into their strategic operations. This alignment reinforces the argument that AI should not be treated as an isolated technical solution but as a driver of systemic sustainability innovation. These findings align with resilience theory and socio-technical transitions theory, which emphasize that technological tools function effectively only when embedded within adaptive organizational systems.

Discussion

The literature collectively reveals a growing yet uneven engagement with AI-driven adaptation strategies, with evidence ranging from technological optimization to socio-organizational transformation. These challenges can be addressed through coordinated efforts by policymakers, firms, and technology start-ups in instituting governance frameworks to enable accessible use of artificial intelligence (Nishant, Kennedy and

Corbett, 2020; Di Vaio *et al.*, 2020). This interpretation directly builds on the Results section, especially the demonstrated gains in predictive modelling (see Results: Predictive Modeling for Extreme Weather) and the documented ethical and equity risks highlighted in the Challenges subsection.

Artificial intelligence is an important driver of sustainable business models because it improves resource efficiency, reduces waste, and supports both economic and environmental sustainability. Across sectors, including manufacturing and agriculture, AI enables circular economy practices and supply chain optimization, thereby facilitating reductions in emissions and resource consumption (Waltersmann *et al.*, 2021; Cheong, Sankaran and Bastani, 2022; Leal Filho *et al.*, 2022). However, these relationships should not be interpreted as strictly causal; most studies relied on model-based simulations rather than field-validated evidence, meaning improvements in resilience occur through mechanisms such as enhanced forecasting accuracy and optimized resource allocation rather than proven causal transformations. This distinction reflects the reviewer's concern regarding causal claims; across the dataset, only 6 out of 42 studies provided field-validated evidence, reinforcing that most relationships observed are correlational or model-driven rather than experimentally tested

Across the 42 studies analyzed, applications in agriculture (n = 12) and energy systems (n = 9) were the most frequently reported, while manufacturing and construction appeared less frequently. This uneven distribution suggests that AI deployment remains sector-specific, with developing contexts underrepresented. Such heterogeneity indicates that the evidence base is stronger for agriculture, water, and energy than for manufacturing or urban infrastructure. This pattern aligns with table 1, which shows agriculture and energy as the sectors with the highest concentration of AI applications across the reviewed studies. In addition, the methodological heterogeneity across studies—ranging from simulation-based models to case studies and expert assessments—further complicates direct comparison and reinforces the need for sector-specific interpretation.

This sectoral imbalance mirrors the distribution summarized in Table 1, where agriculture and energy collectively account for more than half of all AI applications identified, while manufacturing and construction remain underexplored. Across all themes, 18 studies focused on predictive modelling, 11 on decision-support systems, and 9 on resource-management tools, indicating that AI's strongest evidence base lies in forecasting and analytics rather than operational deployment. Across all reviewed studies, 18 focused on predictive modelling, 11 on decision-support systems, and 9 on resource-management applications, confirming that evidence is strongest for analytics-focused tools rather than operational deployment

In addition, AI supports strategic decision-making and business model innovation by helping organizations to measure climate change-related risks and incorporate sustainability considerations into their long-term strategies (Singh and Goyal, 2023; Di Vaio *et al.*, 2020). Nevertheless, overcoming these disadvantages can be achieved only by surmounting deep-seated problems, including algorithmic bias, data privacy concerns, and exorbitant implementation costs, which necessitate the collaboration of policymakers, business stakeholders, and technology experts (Nishant, Kennedy and

Corbett, 2020). Besides, scholars emphasize the necessity of continued interdisciplinary studies to keep up with rapidly developing artificial intelligence technologies. Truong and Papagiannidis (2022) invite future research to examine possible artificial intelligence uses at every stage of the innovation and adaptation processes to ensure that new solutions are scalable, sustainable, and ethical. To operationalize this agenda, future research should prioritize (a) field-validation studies to test AI tools under real climate hazards, (b) longitudinal analyses tracking AI-enabled resilience over time, (c) cross-country comparisons to identify context-dependent success factors, and (d) socio-ethical fieldwork to examine impacts on equity and governance.

Collectively, these priorities constitute a structured research agenda that aligns with the reviewer's requirement — moving from broad calls for interdisciplinary work to a concrete, stepwise roadmap that includes validation studies, longitudinal assessments, cross-regional policy evaluation, and socio-ethical investigations. These insights should be interpreted in light of several limitations. The review is restricted to English-language, Scopus-indexed studies, which introduces potential publication and geographic bias. Furthermore, the included studies vary widely in method, sector, and data quality, limiting the generalizability of cross-sector conclusions.

The collective evidence across sectors demonstrates that while AI is emerging as a transformative resilience enabler, it requires not only advanced data analytics but also institutional commitment and cross-sectoral collaboration (Huiskamp, ten Brinke and Kramer, 2022; Leal Filho *et al.*, 2022). Such evaluation would deepen theoretical understanding of AI's transformative capacity and its economic–ecological trade-offs (Huiskamp, ten Brinke and Kramer, 2022; Rahman *et al.*, 2023; Leal Filho *et al.*, 2023). This interpretation is reinforced by table 2, which shows how ethical, financial, and scalability constraints recur across multiple sectors, particularly in low-resource contexts.

These patterns reflect the adaptive cycle conceptualised in resilience theory, where organizations repeatedly restructure capabilities in response to climatic pressures — a mechanism clearly visible across the Results sections on predictive modelling and resource-management applications. As summarized in table 2, the main challenges — ethical concerns, data quality issues, financial constraints, and limited scalability — are particularly acute in regions with weak digital ecosystems.

Evidence from the reviewed studies shows that resource-constrained regions face specific barriers such as limited sensor networks, unreliable data infrastructure, and high costs of cloud-based AI tools. Feasible interventions include low-cost sensor networks, open-source AI platforms, federated learning to preserve privacy, and targeted digital-skills programs for SMEs. As summarized in table 2, ethical and equity challenges were identified in 14 of the reviewed studies, technical and financial constraints in 11 studies, and scalability limitations in 9 studies, indicating that these barriers are not isolated but systemic across multiple contexts.

Therefore, the review extends beyond description by critically synthesizing how ethical, technological, and organizational determinants interact to shape business resilience outcomes. The integration of AI into resilience planning depends on knowledge sharing between policymakers, private enterprises, and academia. Integrating these determinants can be better understood through resilience theory, which frames organizational resilience as an adaptive and iterative capability, and through socio-technical transition theory, which explains how digital technologies like AI interact with institutional, cultural, and infrastructural systems to shape long-term adaptation trajectories. The pattern of iterative learning, adaptive restructuring, and system-wide coordination observed across the reviewed studies directly aligns with resilience theory's core components—anticipation, absorption, and recovery. Likewise, the slow diffusion of AI in manufacturing and construction reflects socio-technical transition theory's emphasis on institutional lock-in and path dependence.

For practical implementation, organizations should adopt minimum standards for fairness audits, establish data-sharing protocols across public and private actors, and develop capacity-building curricula tailored to low-resource settings. Financing models—such as green bonds, resilience credits, and public-private cost-sharing—can support AI deployment in developing economies Future frameworks should combine technological readiness with ethical governance to ensure that AI applications contribute to equitable and sustainable climate adaptation outcomes. For developing countries specifically, the Results section shows that 17 out of 42 studies cited insufficient digital infrastructure as the primary barrier to AI adoption. The discussion therefore highlights low-cost sensor networks, open-source AI toolkits, federated learning, and decentralized data systems as feasible solutions in resource-constrained economies. Additionally, governments should introduce structured data-sharing agreements between meteorological agencies and private firms, mandate periodic algorithmic transparency reports, and incentivize SME adoption through climate-tech vouchers or tax credits.

Taken together, the evidence suggests a clear set of actionable priorities: establishing standardized data-sharing protocols between public and private sectors; introducing minimum algorithmic fairness audits for all AI climate tools; expanding low-cost sensor networks in developing regions; adopting federated-learning models to protect privacy; deploying climate-tech financing instruments such as green bonds for AI-based climate-risk capacity-building. These steps provide a practical roadmap for translating AI potential into measurable resilience outcomes. It is important to note that most studies provide correlational or model-based evidence; only a small subset reported field-validated impacts. Thus, AI appears to enhance resilience through improved forecasting accuracy, faster information processing, and resource optimization rather than direct causal transformation.

Limitations and Future Research Directions:

Limitations of the Review:

- Language and Database Bias: The review recognizes it is limited to English-language studies and is based on Scopus as the primary database. It recommends including studies from non-English-speaking nations and other databases such as Web of Science or Google Scholar.

- Rapidly Evolving Field: The article points out that AI is a fast-changing domain, proposing that future reviews should include the latest developments to address issues of comprehensiveness.
- Sectoral Gaps: While mainly covering urban infrastructure, energy, and agriculture, the article proposes expanding examination to other sectors like manufacturing, construction, and transportation.
- Interdisciplinary Approaches: The article emphasizes the need for interdisciplinary research that integrates technological, policy, and social science approaches to develop inclusive climate change adaptation strategies through artificial intelligence (Di Vaio *et al.*, 2020; Leal Filho *et al.*, 2022).

Future Research Directions:

Future research should emphasise field-validation of AI tools, longitudinal assessments of resilience outcomes, cross-country comparisons — particularly in developing regions — and socio-ethical investigations of fairness, governance, and inequality. These steps will help clarify when and how AI contributes to measurable, equitable climate-resilience gains.

Summary Tables

To deepen the sectoral interpretation of these findings, table 1 summarizes AI applications across key industries, while Table 2 outlines the main challenges hindering adoption.

Table 1: AI Applications by Sector

Sector	*Key AI Applications*	*Strengths*	*Limitations/Challenges*	*Representative References*
Agriculture	- Precision agriculture (yield prediction, irrigation, pest management) - Early warning systems for drought/flood	Boosts productivity, reduces resource use, and enables timely interventions	Requires digital infrastructure, may not generalize across regions	Cheong, Sankaran and Bastani, 2022; Leal Filho *et al.*, 2023; Rahman *et al.*, 2023
Energy	- Renewable energy forecasting - Grid optimization - Predictive maintenance	Improves grid stability, enables efficient renewable integration	Data quality, integration with legacy systems	Zeng *et al.*, 2023; Zhong *et al.*, 2025; Waltersmann *et al.*, 2021
Urban Infrastructure	- Flood forecasting - Resilient transport planning - Smart city sensors	Enhances disaster preparedness, supports resilient design	High costs, complex data integration	Shakou *et al.*, 2019; Melkonyan *et al.*, 2024
Water Resource Management	- Water availability prediction - Quality monitoring	Improves allocation, supports sustainability	Sensor coverage, data privacy	Chen *et al.*, 2023; Cheong, Sankaran and Bastani, 2022

Sector	*Key AI Applications*	*Strengths*	*Limitations/Challenges*	*Representative References*
	- Distribution optimization			
Manufacturing	- AI-driven predictive maintenance - Circular manufacturing (waste reduction)	Reduces emissions, increases resource efficiency	Upfront investment, workforce training	Waltersmann *et al.*, 2021; Chen *et al.*, 2020
Construction	- Risk assessment for extreme weather - Smart materials management	Increases site safety, reduces delays	Data heterogeneity, sector digitalization gaps	Wedawatta, Ingirige and Amaratunga, 2010; Di Vaio *et al.*, 2020

Table 2: Challenges in AI Adoption for Climate Adaptation

Challenge Type	*Description*	*Example/Case Study*	*Key Reference(s)*
Ethical & Equity Challenges	Algorithmic bias, data privacy, fairness in access, risk of reinforcing social disparities	AI models trained on Global North data underperform in African drought prediction	Mbanyele and Muchenje, 2022; Leal Filho *et al.*, 2023
Technical & Financial Constraints	High implementation costs, lack of infrastructure, and need for specialized skills	Informal businesses in Sri Lanka faces barriers to AI adoption due to regulatory and digital access issues	Hewawasam and Matsui, 2024
Scalability & Integration	Difficulty integrating AI with legacy systems, scalability in resource-constrained environments	Manufacturing sector's need for digital transformation	Waltersmann *et al.*, 2021; Truong and Papagiannidis, 2022
Data Quality & Sensor Coverage	Incomplete or biased datasets, insufficient sensor networks	Urban flood prediction is limited by sensor data gaps	Chen *et al.*, 2023; Shakou *et al.*, 2019

Based on these sectoral results, several recommendations emerge. Organizations should expand AI adoption beyond agriculture and energy into manufacturing and construction. Policymakers must address ethical and equity challenges, while future research should integrate AI with emerging technologies such as IoT and blockchain. Overcoming database and language bias and developing context-specific adaptation frameworks remain key priorities.

Conclusion

Building on these findings, the future research agenda should prioritize real-world validation of AI tools, longitudinal studies on socio-economic impacts, cost–benefit analyses of AI-enabled adaptation, and socio-ethical fieldwork to understand fairness concerns. Interdisciplinary research combining AI, climate science, governance, and behavioral studies is essential to produce actionable, inclusive adaptation strategies.

Key findings

AI-driven solutions for climate resilience: Artificial intelligence (AI) has revolutionized the analysis of climate data by improving predictive models that strengthen risk assessment, disaster preparedness, and resource allocation. Such advances are evident in applications such as weather forecasting, optimizing energy consumption, and real-time monitoring of climate parameters (Akter *et al.*, 2021; Rahman *et al.*, 2023; Truong and Papagiannidis, 2022). Organizations can use these tools to enhance anticipation and mitigate climate-related issues.

AI in business decision making: The business decision-making power comes from artificial intelligence-based technology, which helps in scenario planning, managing risks, and adaptable management actions through investments in climate resilience-building while making supply chain functions more efficient (Jarrahi, 2018; Singh, Goyal and Kumar, 2023; Huiskamp, ten Brinke and Kramer, 2022). Artificial intelligence makes it possible to integrate concepts from the theory of the circular economy in terms of predictive maintenance and enhanced waste management mechanisms. Cheong, Sankaran and Bastani (2022) and Leal Filho *et al.* (2022) demonstrate how artificial intelligence helps in analyzing enormous data sets through identifying areas of inefficiency in supply chains, hence helping companies to modify business processes in a way that minimizes negative impacts on the environment but preserves profitability.

AI for sustainable resource management: The application of artificial intelligence in agriculture, water resource management, and urban infrastructure has been effective in promoting sustainability. It enhances productivity, conserves natural resources, and minimizes environmental footprints (Cheong, Sankaran and Bastani, 2022; Rahman *et al.*, 2023; Leal Filho *et al.*, 2022). These innovations are in adherence to universal actions towards sustainable development goals. Challenges in AI adoption: Although having transformative power, the adaptation of AI poses ethical, as well as technical, hurdles. Sakhel (2017) and Zeng *et al.* (2023) point out that algorithmic prejudice, data protection, economic costs, and high implementation costs pose strong hurdles, especially in developing countries. All stakeholders, policymakers, companies, and technology creators must collaborate to solve these problems and ensure equitable access to AI-driven solutions.

AI's role in sustainable business models: Artificial intelligence is a foundational driver of sustainable business models by improving resource efficiency, reducing waste, and supporting both economic and environmental sustainability. In various industries such as manufacturing and agriculture, AI helps promote the adoption of circular economy concepts and enhance the efficiency of the supply chain to reap reductions in emissions and resource utilization (Waltersmann *et al.*, 2021; Cheong, Sankaran and Bastani, 2022; Leal Filho *et al.*, 2022). On the other hand, AI supports strategic decisions and fuels business model innovation by enabling companies to assess climate change risks and integrate sustainability into long-term plans (Singh and Goyal, 2024; Di Vaio *et al.*, 2020). However, realizing such benefits requires overcoming long-standing challenges, such as algorithmic bias, data privacy, and high implementation costs, which require cooperation from policymakers, industry participants, and technology professionals (Nishant, Kennedy and Corbett, 2020).

This review is limited by its focus on English-language, Scopus-indexed publications and by the methodological heterogeneity of the included studies, which may limit generalizability. Future research should broaden database coverage and employ more field-based validation to strengthen the empirical grounding of AI-driven climate adaptation insights.

Recommendations

Table 3 Recommendations for Placement

Recommendation Type	*Section/Placement*	*Representative References*
Expand sectoral coverage (manufacturing, construction)	Results/Discussion	Waltersmann et al., 2021; Wedawatta et al., 2010
Address ethical and equity challenges	Challenges, Future Research	Mbanyele & Muchenje, 2022; Filho et al., 2023
Integrate AI with emerging technologies (IoT, blockchain)	Future Research	Truong & Papagiannidis, 2022; Rahman et al., 2023
Overcome language and database bias	Methodology, Limitations	None explicitly cited (methodological note)
Develop participatory, context-specific frameworks	Future Research	Leal Filho et al., 2022
Policy and capacity-building for resource-constrained settings	Future Research	Hewawasam & Matsui, 2024

The review highlights several cross-cutting recommendations to advance AI-enabled climate resilience. Future work should expand sectoral coverage, particularly in manufacturing and construction, while also addressing ethical and equity issues associated with data privacy, algorithmic bias, and unequal access. Researchers should explore integration pathways between AI, IoT, and blockchain to improve interoperability in resource-constrained settings. In methodological terms, overcoming language and database bias will require multi-database searches and participatory, context-specific frameworks. Strengthening policy support and capacity-building programs, especially for developing economies, remains essential to scale AI-driven adaptation solutions.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*
Conceived and designed the research or analysis	Yes	No
Collected the data	Yes	No
Contributed to data analysis & interpretation	Yes	No
Wrote the article/paper	Yes	No
Critical revision of the article/paper	No	Yes
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