

How Digital Development Leverages Sustainable Development

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Abstract

This academic article seeks to clarify the state of the literature on a very pertinent topic that is based on how digital innovation, considering emerging technologies and how they could be used in business management and marketing, could increase sustainable development. The sustainable economy, which should maintain long-term development through efficient resource management, has as allies emerging technologies such as artificial intelligence, blockchain, and the Internet of Things that can help reduce waste, reduce the carbon footprint, and automate tasks. Additionally, they could present themselves as a solution to improve aspects of digital communication between companies and their consumers in remote training, distribution chain, e-commerce, and process optimization in different sectors of activity. These advances will, on the one hand, allow the possibility of conducting a greater amount of professional training, increasing the number of qualified professionals and, on the other hand, facilitate trade exchanges, promoting the economy. Based on a systematic bibliometric review of the literature using the PRISMA framework, this study investigates how digital tools catalyze transformative changes in different sectors of activity. The results indicate that, overall, the academic articles analyzed in this literature review present studies focused on digitalization and sustainability (approximately 50%). In second place are topics related to digitalization and other topics such as: smart cities; Sustainable Development Goals; academia; the digital economy; government policies; academic education; and sustainable communication (29%). Finally, in third place, there are academic articles closely linked to digitalization and the environment, more specifically to sustainable practices and the management of natural resources (21%). The article concludes that digital development, when used wisely, serves as a crucial lever to address the world's most pressing sustainability imperatives. Future research should emphasize interdisciplinary collaboration and adaptive governance to ensure that these digital changes produce lasting impacts for people and the planet.

Keywords: digital development; sustainable; sustainable development



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1. Introduction

Sustainability has emerged as a critical focus on the global agenda. The urgent need to balance economic growth, environmental protection, and social equity continues to drive the concept's popularity [1]. The world is dealing with the impacts of climate change,

resource depletion, and social inequalities. As a result, the need for a holistic approach to development has become evident. This gave rise to the idea of sustainable development, which Harfouche et al. [2] describe as a framework that seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development was formally introduced by the Brundtland Report in 1987 and has since been at the heart of numerous global initiatives [3]. The most notable is the United Nations Sustainable Development Goals (SDGs), which aim to balance economic growth, social inclusion, and environmental protection.

However, achieving sustainable development remains a significant challenge. Harfouche et al. [2] notes that it is not a “straightforward task” and requires “addressing global grand challenges that are inherently complex, multifaceted, and socially embedded” (p. 1989). These challenges include climate change, resource depletion, economic inequalities, and inadequate social services that continue to hinder progress [4,5]. In addition, many countries face difficulties mobilizing the necessary resources and expertise to implement sustainable practices effectively. For example, Iqbal and Pierson [6] note that although developing countries discuss sustainable development, compliance remains poor as they continue engaging in environmentally unfriendly economic practices. These countries prioritize economic growth over environmental, equity, and poverty concerns. These issues pose significant obstacles to realizing a sustainable future, highlighting the need for innovative solutions.

Digital development has emerged as a powerful catalyst for sustainable transformation. Vaishnav [7] explains that digital transformation contributes to sustainability by driving positive social and environmental impacts while ensuring long-term business profitability and viability. The rapid advancement of digital technologies, such as artificial intelligence (AI), big data analytics, blockchain, and the Internet of Things (IoT), offers innovative solutions to longstanding sustainability challenges. Novillo-Ortiz et al. [8] indicate that integrating remote sensors, informatics, and geographic information systems allows the monitoring of environmental changes and the movement of children to schools. Moreover, technologies enhance resource management efficiency, promote transparency in governance, and ensure social inclusion by bridging gaps in education, healthcare, and economic opportunities.

In summary, sustainable development is a concept that seeks to balance economic growth, social inclusion, and environmental protection. In this context, digital technology has played a crucial role, offering innovative solutions that can help achieve these goals.

However, rapid technological advancement and changing social and environmental dynamics make it necessary to continually re-examine the impact of digital technology on sustainable development. Digital technology is constantly evolving and is transforming the way we live and learn. These changes can have significant impacts on sustainable development, both positive and negative. For example, while the IoT can help monitor and reduce energy consumption, it can also lead to an increase in resource consumption due to the production and disposal of electronic devices. Digital technology can be a powerful tool for innovation in sustainability. For example, the use of big data and data analytics can help identify patterns and develop more efficient solutions to environmental and social problems. However, to fully harness this potential, an up-to-date and comprehensive understanding of the impact of digital technology is necessary.

In summary, this literature review highlights that sustainable development is a dynamic process that requires the continuous adaptation of technological innovations and refers to theoretical frameworks that examine areas such as smart home technologies, AI maturity frameworks, blockchain-enabled agricultural practices, and big data analytics for organizational performance [2]. Other studies analyze the importance of technology

in sustainable development by helping companies effectively integrate their digital and green practices, mentioning the unbalanced consumption of natural resources between developed and developing countries and the role of digitalization in promoting sustainable development in various sectors and regions that allows for more efficient resource management by harnessing the power of data analytics, artificial intelligence, and the Internet of Things (IoT) [1,5,6], highlighting the importance of data collection and the need for robust information systems and high-quality data for governments and health organizations make informed decisions and monitor progress towards the SDGs [8] (Novillo-Ortiz et al. (2021)).

Additionally, studies such as George et al. (2021) [4] focus on three main types of entrepreneurship, social entrepreneurship (SE), institutional entrepreneurship (IE), and sustainable entrepreneurship (STE), which according to the authors are related to emerging advances in digital sustainability. They also list the problems related to digital sustainability such as problems of knowing, problems of valuation, problems of communication, problems of coordination and trust, problems of access and reach, and problems of institutions. In this case, we highlight the problem of communication that could use gamification simplification and become a facilitation of attention. In this case, effective communication could help reduce power asymmetries by increasing the empowerment of people.

Leveraging digital innovations supports data-driven decisions that optimize resource use and support environmental stewardship while simultaneously empowering communities to participate more actively in sustainable practices. This research paper examines how digital innovations contribute to the realization of global sustainability goals.

Although the topic addressed in this article is being studied by different authors, the studies that have been carried out are not yet sufficient in clarifying the issue of the impact of digital technology on sustainable development because, according to the literature review, this subject is constantly evolving and there are still many topics that could be addressed in greater depth.

This study aims to analyze whether emerging technologies can contribute to improving the economic and social aspects that the SDGs advocate for. Since academic research is constantly evolving, it makes sense to understand the state of the literature at a time when emerging technologies are being innovated in a greater number of countries. Finally, this study aims to make a unique contribution as it takes a global approach. The findings highlight the transformative potential of technology in building a more resilient and inclusive future.

Below, the research design is presented for a quick and better understanding of the topics studied (Figure 1).



Figure 1. Research design. Source: own elaboration.

2. Materials and Research Methods

In this study, a systematic bibliometric literature review (LRSB) was applied, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The researcher chose this LRSB method because it is a transparent, replicable, and scientific process that reduces bias through a comprehensive literature search [9]. It provides an audit trail that shows the researcher's procedures, decisions, and conclusions, making it easier for readers to determine the quality of the findings presented. Page et al. [10] indicate that incorporating the PRISMA 2020 framework helps address poor reporting in systematic reviews. Haddaway et al. [11] further indicate that using the PRISMA guidelines results in more complete systematic reviews due to its thorough procedures. Thus, combining LRSB and PRISMA enabled a robust and comprehensive synthesis of scholarly literature on how digital innovations leverage sustainable practices.

The LRSB methodology, thoroughly examined in the works of Rosário and Dias [12] as well as Rosário et al. [13], presents a more structured and in-depth approach to analyzing a body of research than conventional literature reviews. Its emphasis lies in the meticulous selection of sources that are directly aligned with the central research question, thereby ensuring heightened levels of transparency.

This technique enhances the credibility and depth of findings by adhering to a well-defined protocol for identifying and selecting relevant studies. By employing a systematic and sequential process, the LRSB method reinforces the robustness and scholarly value of the collected evidence. It unfolds through three primary phases, each comprising a total of six methodical steps, which are detailed in Table 1 and further discussed by Rosário and Dias [12] and Rosário et al. [13].

Table 1. Process of systematic LRSB.

Fase	Step	Description
Exploration	Step 1	Defining the research problem
	Step 2	Identifying relevant sources
	Step 3	Critical evaluation of the reviewed literature
	Step 4	Merging data from selected research
Interpretation	Step 5	Presenting results and suggestions
Communication	Step 6	Delivering the LRSB report

Source: own elaboration.

In order to carry out this study, and with the aim of identifying and choosing the most reliable sources, the Scopus database was chosen, capitalizing on its reputation for indexing high-quality academic and scientific publications. Nevertheless, the exclusive reliance on Scopus presents a potential limitation, as relevant contributions available through alternative databases may have been overlooked. Additionally, this academic research encompasses a time period ending in March 2025, which may have restricted the inclusion of the most up-to-date scholarly developments.

In alignment with the pursuit of methodological rigor and academic integrity, the investigation prioritized peer-reviewed scholarly materials, a practice underscored by Rosário and Dias [12] as well as Rosário et al. [13].

The literature search and screening process was conducted using the Scopus database. The reason why this database was chosen is related to the high number of academic articles published in renowned journals that operate under the peer review system and that have a multidisciplinary focus. The initial search using the keyword “digital development” limited to TITLE-ABS-KEY retrieved 1741 documents. To refine the results, the researcher applied an additional filter combining “digital development” and “sustainable,” narrowing the results to 196 documents. Finally, adding the exact keyword “sustainable development” helped further focus on the intersection between digital innovations and sustainability. This process resulted in 70 relevant documents. These final documents underwent a thorough screening, where duplicates, non-English publications, and articles lacking full-text access were excluded.

To guarantee both the relevance and methodological robustness of the sources incorporated into the final analysis, this study applied a set of clearly established inclusion and exclusion parameters, as outlined in Table 2. The selection process was restricted to peer-reviewed journal articles that specifically investigated how artificial intelligence is applied to optimize marketing strategies within corporate contexts.

In parallel, materials were excluded if they did not explicitly address the role of artificial intelligence, thereby preserving the precision and relevance of the dataset. This rigorous filtering ensured that the selected literature remained closely aligned with the central research objectives. The procedural details of this selection framework are presented in Table 2 and further discussed in the works of Rosário and Dias [12] and Rosário et al. [13].

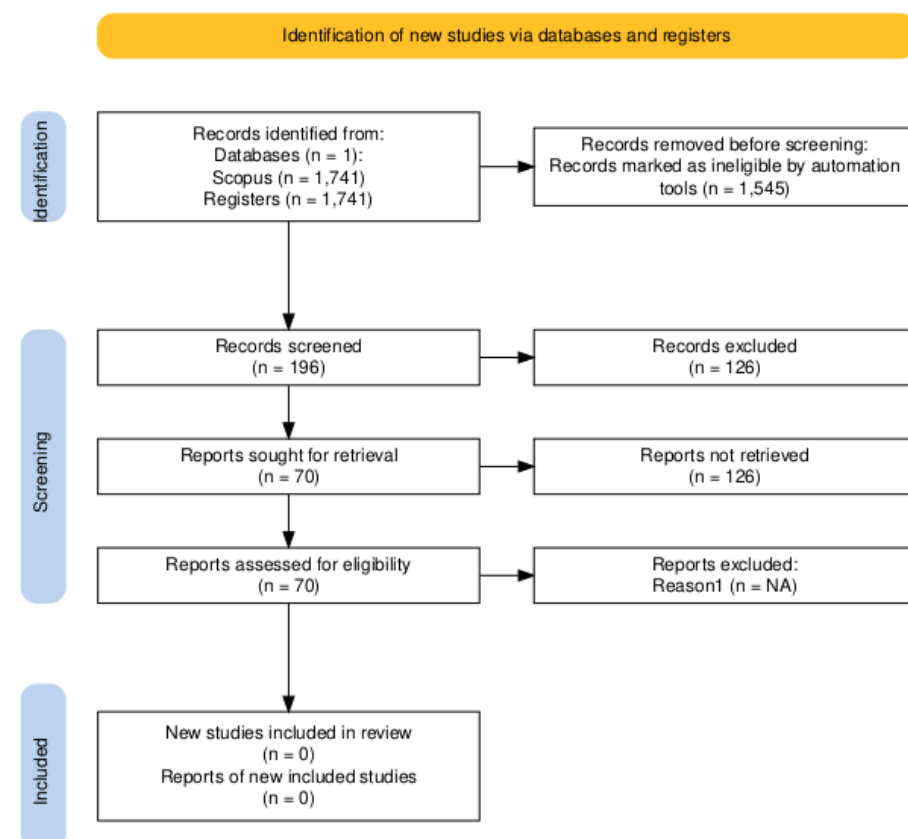
Table 2. Screening methodology.

Database Scopus	Screening	Publications
Meta-search	Keyword: Digital Development	1741
Inclusion Criterion	Keyword: Digital Development, Sustainable	196
Second Inclusion Criterion	Keyword: Digital Development, Sustainable Exact Keyword: Sustainable Development	
Screening	Keyword: Digital Development, Sustainable Exact Keyword: Sustainable Development Until March 2025	70

Source: own elaboration.

At this stage of the study, after collecting the literature resulting from the search carried out using the aforementioned keywords, a rigorous thematic and content analysis was carried out, in accordance with the proposal by Rosário and Dias [12] and Rosário et al. [13] namely, with regard to the level of methodological orientation. A set of well-defined selection parameters were then rigorously applied to ensure that only sources of high relevance and academic level were incorporated.

This stage of source analysis was directed and focused on academic studies that are based on research about how digital development leverages sustainable development, prioritizing those that showed a clear conceptual and empirical connection to the study's key goals. Each document underwent a thorough assessment, evaluating its relevance to the research topic, the strength of its methodology, and its publication in peer-reviewed scholarly journals. Figure 2 provides a visual summary of the selection framework.

**Figure 2.** PRISMA 2020 flow diagram for the systematic literature search [11].

This investigation undertook a comprehensive review of 70 academic and scientific works retrieved from the Scopus database. To ensure a well-rounded examination, the analysis employed a blend of bibliometric techniques and narrative synthesis, promoting a multifaceted interpretation of the selected literature. The methodological design was anchored in the analytical structure proposed by Rosário and Dias [12], along with the enhancements suggested by Rosário et al. [13].

By adopting this dual-method strategy, this study systematically analyzed the content, enabling the recognition of recurring thematic trends directly tied to the primary research questions. This integrative approach not only offered a coherent framework for literature evaluation but also captured the nuances and depth of ongoing scholarly conversations across the field.

Of the 70 documents selected, 43 were articles, 19 were conference papers, 3 were book chapters, 3 were reviews, and 1 was a short survey.

3. Publication Distribution

According to the analysis developed, it is possible to state that the first quarter of 2024 marked the highest number of peer-reviewed publications, registering 23 results. Therefore, it is pertinent to present Figure 3, which visually highlights the literature published in the period from 2005 to March 2025.

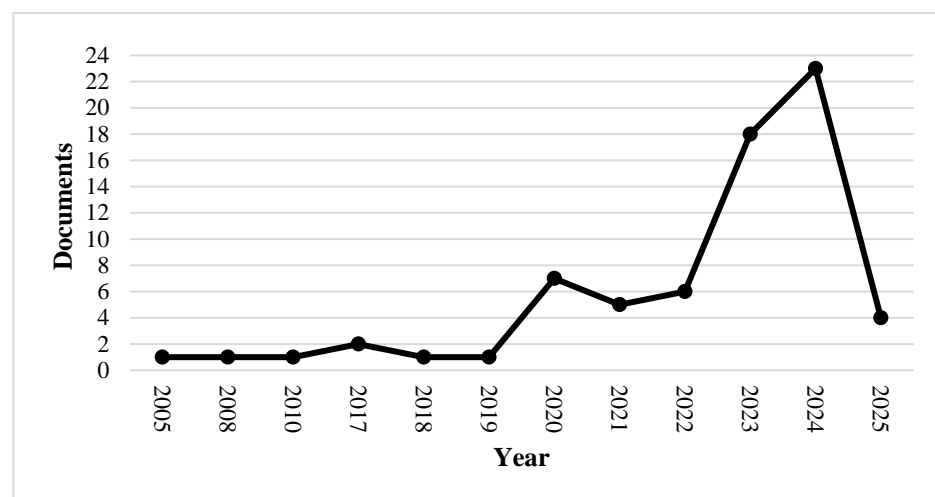


Figure 3. Documents by year.

In this sense, it was necessary to organize the publications as presented below: (12) with two documents (Procedia Computer Science; Lecture Notes In Networks And Systems; E3s Web Of Conferences); and the remaining publications with one document.

Figure 4 illustrates the countries that have made the most substantial academic contributions within specific research areas, highlighting China, Ukraine, Italy, and India as leading sources of scholarly output. The volume of publications originating from these nations reflects their active engagement and influential roles in advancing research and fostering intellectual development within their respective disciplines.

Table 3 and Figure 4 offer a summary of the primary national contributors within the research areas examined. These visuals highlight the ten countries with the highest levels of academic production, underscoring their pivotal role in expanding the body of knowledge on digital development and sustainable progress. This analysis provides insight into the spatial distribution of scholarly engagement, revealing how various countries allocate research efforts and resources toward this domain.

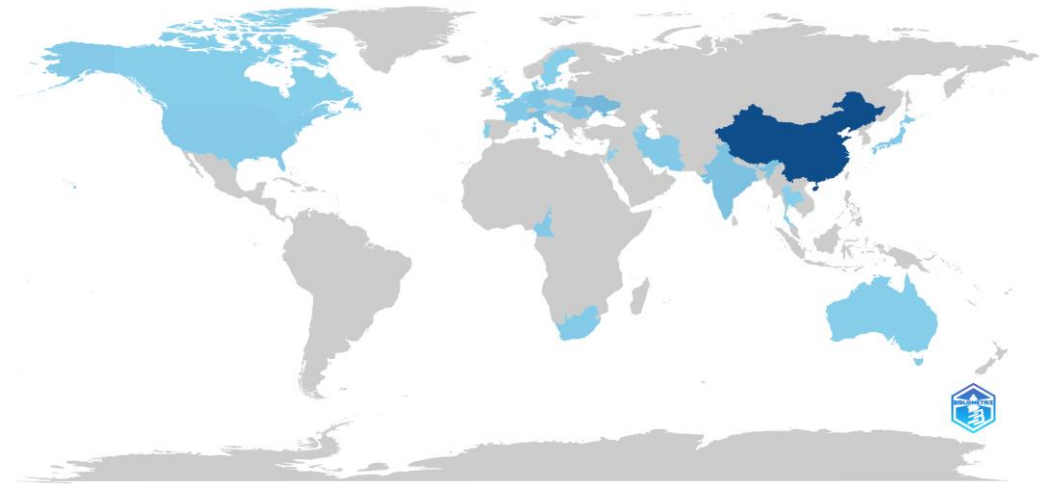


Figure 4. Scientific production by country.

Table 3. Top 10 countries by number of publications.

Country	Number of Publications
CHINA	94
UKRAINE	16
ITALY	13
INDIA	9
GERMANY	8
ROMANIA	8
CAMEROON	4
FRANCE	4
IRAN	4
JAPAN	3

Source: own elaboration.

The findings enable a comparative perspective on international research patterns, drawing attention to regions that have shown sustained interest in exploring digital development and sustainable progress. Through these visualizations, this study brings to the forefront variations in academic emphasis and illustrates how different national research cultures shape ongoing discourse related to the intersection of digital development and sustainable progress.

According to Bradford's law, a core cluster of ten journals—highlighted in Figure 5—emerges as the primary outlets for scholarly work within the studied domain. Collectively, these sources represent around 16% of the total literature produced on the topic. The law posits that as a research field evolves and attracts scholarly interest, a concentrated group of journals typically leads in publishing relevant findings, reflecting their central role in shaping and distributing knowledge in the early stages of the field's development.

As academic attention toward the subject grows, a group of leading journals begins to serve as central pillars within the research community, gradually becoming the dominant sources for foundational insights. Over time, these prominent outlets not only shape the trajectory of scholarly debate but also influence the inclusion of the topic in a broader range of publications.

Among this emerging core, seven journals stand out for their significant impact, with the first six being particularly instrumental in laying the groundwork for theoretical and empirical development. These journals serve as important platforms for academic exchange, allowing scholars to engage with previous studies, so that they can cite important

and relevant work in their field of research and ultimately contribute to the growth of academic knowledge.

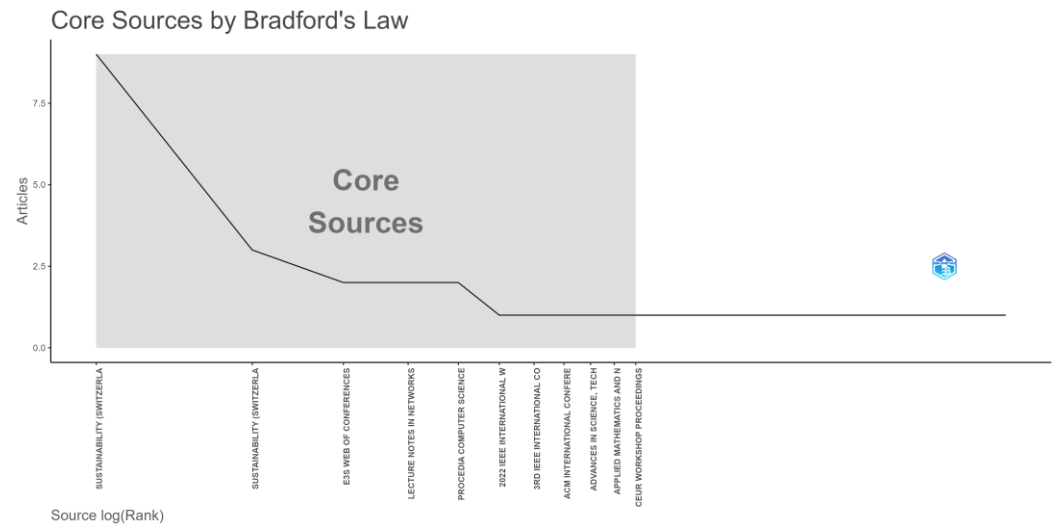


Figure 5. Core sources according to Bradford's law (2002–2025).

The final list of 70 scientific and/or academic articles addresses the following thematic areas: environmental science (31); computer science (31); energy (26); social sciences (24); engineering (16); business, management, and accounting (14); economics, econometrics, and finance (13); earth and planetary sciences (5); decision sciences (4); mathematics (3); psychology (2); agricultural and biological sciences (2); physics and astronomy (1); multidisciplinary (1); materials science (1); biochemistry, genetics, and molecular biology (1); and arts and humanities (1).

The most quoted article was “A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends”, with 222 quotes published in *Trends in Food Science and Technology* which has an SJR of 3.00, which observed the best quartile in (Q1), having registered an h-index (251). The study aims primarily to review and discuss areas of active research, gaps in the current state of research, and future research challenges for CCL.

Figure 6 shows the evolution of the citations of documents published up to March 2025, making it possible to analyze these changes.

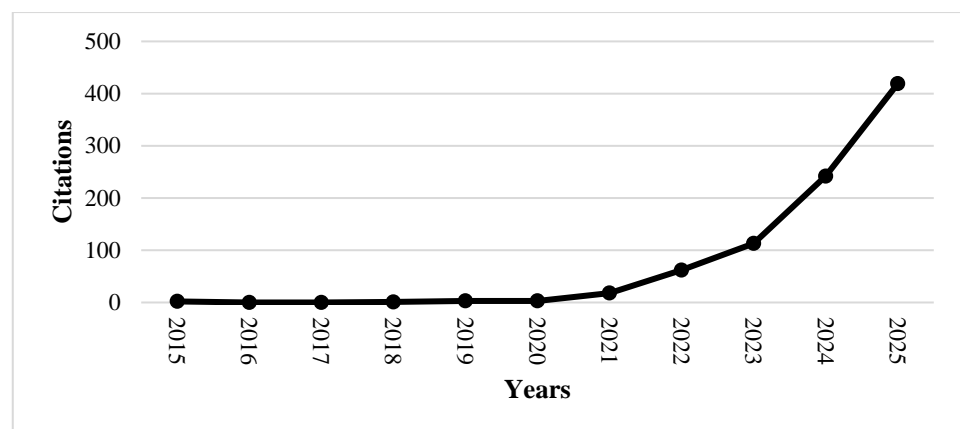


Figure 6. Evolution of citations between ≤ 2015 and 2025.

framework, the code “AU” represents the author, identifying the primary contributor to each publication. This is mapped alongside “CR” (cited references) and “DE” (descriptive keywords provided by the authors), illustrating how individual studies are embedded within and contribute to broader scholarly dialogs.

To explore the relationships among frequently utilized terms in the analyzed literature, a targeted methodological approach was implemented. Through the use of Bilimatrix, a systematic map was constructed to illustrate these interrelationships. The visual output—presented in Figure 8—provides a nuanced view of the conceptual associations and thematic overlaps that characterize academic engagement within this area of study.

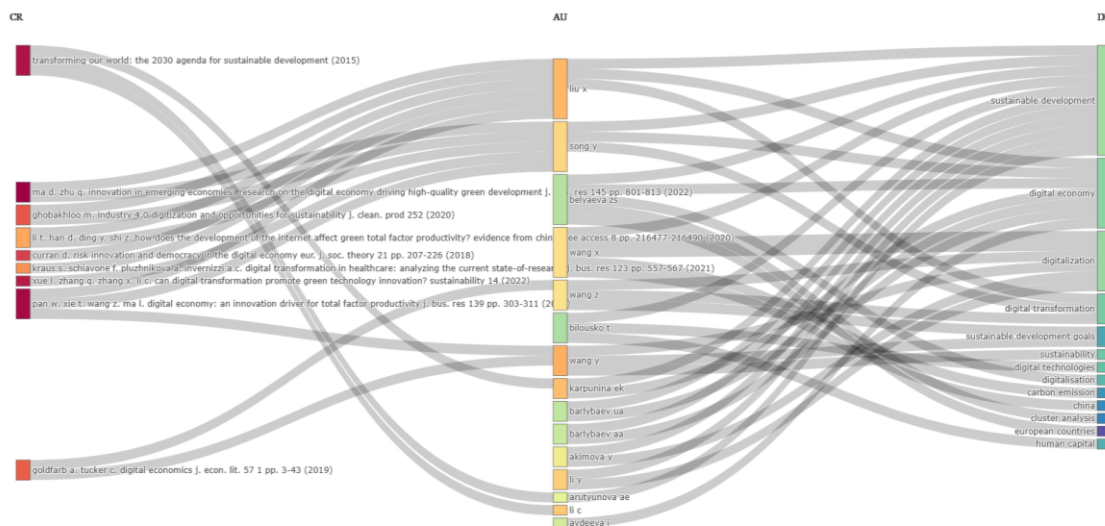


Figure 8. Three-field plot analysis (AU = authors, CR = references, DE = authors keywords).

The Sankey diagram functions as a graphical representation designed to convey the relative weight and prevalence of distinct thematic domains. Each node’s size corresponds to how often a particular concept appears, while the links between them illustrate the thematic relationships and progression. The breadth of each connecting flow denotes the strength of association between the topics. As described by Xiao et al. [14], this technique offers a systematic means of visualizing the development and interconnectedness of foundational ideas within the scholarly landscape.

As illustrated in Figure 8, specific terms stand out as particularly prominent across the dataset. For instance, the term “sustainable development” exhibits eleven incoming associations without corresponding outward links, indicating its central role in the thematic structure. Similarly, “digital economy” reflects seven inbound connections, while “digitalization” and “digital transformation” display five and three incoming links, respectively. These pivotal keywords are strongly associated with the most frequently cited sources, underscoring their foundational influence within the scholarly dialog in this field.

The thematic mapping utilizes specific analytical thresholds: a minimum cluster frequency of 50 (per thousand records), five labels per thematic group, a label size of three, and a scaling factor set at 0.3. A diagonal line is used to represent two key dimensions—relevance (centrality) and maturity (density). As illustrated in Figure 9, the resulting thematic landscape is segmented into four quadrants, each marked by circles of distinct colors to denote thematic intensity.

The upper-right quadrant highlights central themes that are both well established and influential, characterized by high density and strong centrality—indicating that they are driving forces within the field. The lower-right quadrant includes foundational and cross-cutting themes; although these areas show significant relevance (centrality), their

low density suggests limited conceptual development. Meanwhile, the lower-left quadrant points to topics that are either nascent or declining, as reflected by low scores on both dimensions. Lastly, the upper-left quadrant represents mature but isolated topics—those that are conceptually developed (high density) yet peripheral in influence (low centrality), suggesting that they hold limited relevance to broader disciplinary discourse.

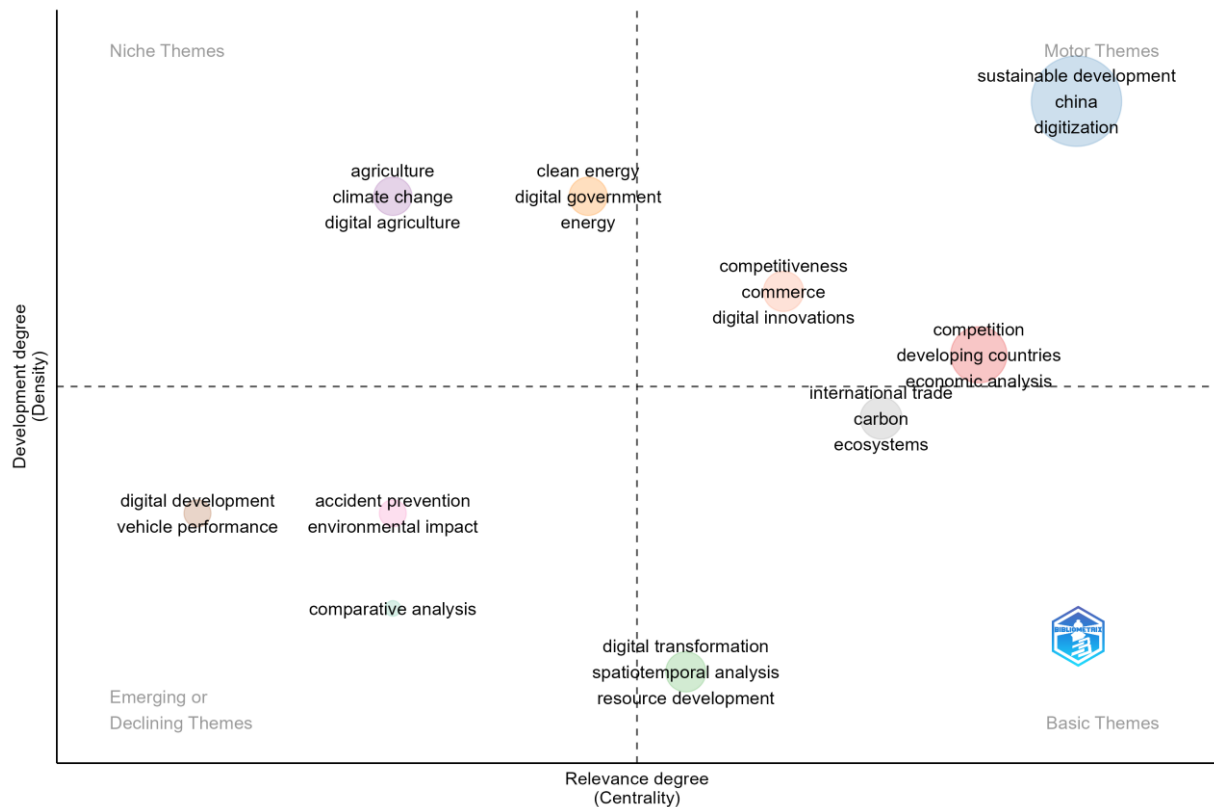


Figure 9. Thematic map analysis. Network of linked keywords.

When we look at Figure 9, which covers 70 documents, we see that, on the lower-right side of the axis, where the basic and transversal research themes of the field in question are concentrated, “international trade”, “carbon”, and “ecosystems” appear as the main themes, followed by aspects such as “digital transformation”, “spatiotemporal analysis”, and “resource development”.

On the upper-right side are the driving themes of the period, in which “sustainable development”, “China”, and “digitization” are the central themes. To a lesser extent, “competitiveness”, “commerce”, and “digital innovation” also appear on that side of the axis.

On the upper-left side of the axis, we see that as a peripheral theme there is “clean energy”, “digital government”, “energy”, and also “agriculture”, supply chains, “climate change”, and “digital agriculture”, and it can be understood that this last theme is on the way to becoming an emerging or declining theme.

On the lower-left side, which corresponds to emerging or declining themes are: “digital development”, “vehicle performance”, “accident prevention”, “environmental impact”, and “comparative analysis” located on the axis leaning against the quadrant of basic and transversal themes; these themes can become strong themes in the area.

Figure 10 presents a comprehensive visual representation of the conceptual interrelations found within the academic literature, emphasizing the linkages between commonly employed terms. This mapping uncovers the principal thematic clusters that define the field and offers a structured overview of the dominant subjects addressed in scholarly

work. Beyond highlighting the prevailing research directions, the visualization also reveals underexplored areas that may warrant additional investigation.

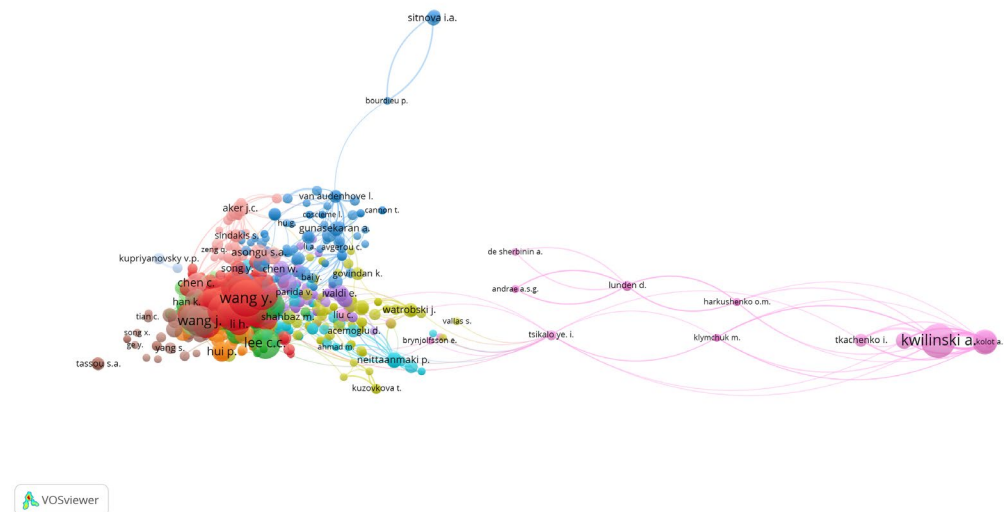


Figure 10. Network of co-citation.

The figure further illustrates an expansive network of co-citation patterns and thematic associations, helping to clarify how individual sources are related. Recognizing these citation dynamics is vital to supporting this study's conclusions, as it uncovers the foundational architecture of academic discourse and the intellectual trajectories shaping current inquiry.

Complementing this, Figure 10 displays an extended citation network that enhances the analytical scope by visualizing how references interconnect within the scholarly ecosystem. This depiction deepens our understanding of academic influence by showcasing the connections among frequently cited works and their broader relevance to the field.

Through the mapping of these interdependencies, the graphical analysis contributes to a more nuanced understanding of citation behavior, reinforcing the coherence and rigor of the literature surveyed. Such an approach is instrumental in pinpointing major contributions and tracing the evolution of thought within the discipline over time.

4. Theoretical Perspectives

The intersection between digital transformation and sustainable development has gained significant scholarly attention in recent years. This reflects the increasing recognition of technology's role in promoting sustainable practices. The evolution of digital innovations offers new opportunities to address global challenges related to economic growth, environmental preservation, and social equity. The convergence of digital development and sustainability initiatives highlights how technologies can contribute to sustainable development [15]. This literature review synthesizes the current research on leveraging digital transformation to advance the Sustainable Development Goals.

4.1. Sustainability and Sustainable Development

Sustainability is a guiding principle and cross-cutting objective that aims to balance economic growth, social equity, and environmental protection to ensure the well-being of present and future generations. This principle is reflected in laws and public policies that aim to respond to global challenges such as climate change, poverty, resource scarcity, disparities, and social inequalities that have intensified in recent years [16]. Sustainability is the ability to meet the needs of current communities without compromising the ability to meet the needs of future generations and, as a result, sustainability has become a central focus for

policymakers, businesses, and communities around the world. Toli and Murtagh [17] argue that sustainability definitions should incorporate various characteristics, including “inter-generational equity, intra-generational equity (social, geographical, and governance equity), conservation of the natural environment, significant reduction in the use of non-renewable resources, economic vitality and diversity, autonomy in communities, citizen well-being, and gratification of fundamental human needs” (p. 2). Thus, sustainability seeks to create a harmonious relationship between human activities and the natural environment, emphasizing responsible resource use, social justice, and long-term economic stability. To effectively address the complexities of modern development, sustainability is typically understood through three interconnected dimensions: economic, social, and environmental.

The economic dimension of sustainability emphasizes the importance of economic growth and stability while minimizing resource depletion and environmental degradation. It advocates for the efficient use of resources, the promotion of green technologies, and the development of sustainable business practices that contribute to long-term economic resilience [16,18]. Sustainable economic strategies also include creating decent work opportunities and inclusive economic development that benefits diverse populations. Social sustainability focuses on equity, social justice, and human well-being, and is associated with a society’s ability to maintain and improve the quality of life of its citizens over time, ensuring equitable access to opportunities, respect for human rights, and dignified living conditions for all. The goal is to create an inclusive, resilient, and participatory society, where everyone has access to basic services such as education, health, housing, sanitation, security, and job opportunities. It addresses issues such as access to quality education, healthcare, and social services while promoting community empowerment, cultural preservation, and reducing social disparities [19]. Environmental sustainability prioritizes protecting natural ecosystems, conserving biodiversity, and mitigating the impacts of climate change. This dimension encompasses sustainable resource management, pollution reduction, and the transition to renewable energy sources [20,21]. These three pillars provide a holistic framework for sustainability, striving to balance human progress with the preservation of the planet’s health.

The concept of sustainable development emerged as a practical application of sustainability principles. It gained global prominence with the Brundtland Report “Our Common Future” in 1987, where it was defined as “. . .development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [22] (p. 3). It entails development that considers the environmental, economic, social, and governance aspects of sustainability. Over the years, sustainable development has become hegemonic, leading to its use in international treaties, national constitutions, and laws [23,24]. In addition, it is used in various industries including business, agricultural production, urban development, and industry. It has also become a foundational concept in most theories, such as circular and green economies.

The United Nations further solidified the importance of sustainable development by introducing the Sustainable Development Goals (SDGs) in 2015. According to Sachs [25], the SDGs aim to provide a holistic approach to the three pillars of sustainability: environmental, economic, and social. The SDGs comprise 17 ambitious objectives designed to address global challenges and promote sustainable growth. These goals encompass a wide range of priorities, including poverty eradication, quality education, clean energy, climate action, and reduced inequalities [20,26]. The SDGs also emphasize partnerships and collaborations to drive collective efforts toward sustainability. Each goal is supported by specific targets and indicators, enabling countries to track progress and develop strategies that address local and global issues.

The adoption of technologies has enhanced the ability of organizations and governments to implement the SDGs. For example, Harfouche et al. [2] introduced the Sustainable Development Impact Through Technological Innovations and Data Analytics (SDITIDA) framework that provides a conceptual lens on aligning technologies with sustainable goals. SDITIDA comprises multiple layers, including stakeholders and context, operational aspects, actions, goals and outcomes, and feedback loops.

The stakeholder and contexts layer represents institutions and organizations that implement sustainability initiatives. These include local, national, and international governments, communities, business organizations, NGOs, and technology innovators. Contexts refer to the environmental, social, and economic components of sustainability [2]. The operational aspects layer focuses on the effectiveness and compatibility of laws and regulations that influence technological innovations like artificial intelligence (AI), big data, and the Internet of Things (IoT). Actions refer to the targeted measures stakeholders take to drive sustainable practices. In this case, they utilize technological tools to gain actionable insights, which are useful in implementing appropriate actions. The goals and SDG outcomes layer represents the core objectives of sustainability, such as reducing carbon emissions and social inclusion. The feedback loops facilitate continuous learning and adaptation by generating actionable insights and responsive strategies. These loops ensure the ecosystem remains resilient and adaptive to changing demands and challenges. As a result, it achieves sustainable development through iterative improvements and data-driven decision making.

4.2. Digital Technologies Driving Sustainable Development

The rapid advancement of digital technologies has significantly transformed how societies address sustainable development challenges. These technologies enhance efficiency and productivity and offer innovative solutions to complex global issues such as climate change, resource management, and social inequality [27,28]. Stakeholders leveraging the potential of emerging technologies can achieve the SDGs more effectively and inclusively. Below are some of the most impactful digital technologies driving sustainable development.

4.2.1. Artificial Intelligence

Artificial intelligence (AI) encompasses various technologies designed to replicate human cognitive functions, such as problem solving, reasoning, and decision making. Martinez [29] (2019) explains that intelligent machines are defined based on their characteristics, including “acting humanely, thinking humanely, thinking rationally, and acting rationally” (p. 1025). Thus, Yigitcanlar and Cugurullo [30] define AI as “machines or computers that mimic cognitive functions that humans associate with the human mind, such as learning and problem solving” (p. 1). AI is typically classified as either narrow or general. Narrow AI is specialized for specific tasks, such as language translation or image recognition, while general AI seeks to emulate broader human cognitive abilities across diverse activities. These systems often incorporate technologies like natural language processing (NLP) to interpret human language and computer vision to analyze visual data. As AI advances, it increasingly mimics human-like intelligence, enabling machines to not only perform tasks but also to adapt, learn, and interact more intuitively. AI thus emerges as a transformative force in sustainable development.

This innovation enhances efficiency, reduces human errors, and facilitates data-driven insights [31]. One of the most significant applications of AI lies in environmental monitoring and conservation. For instance, AI-powered sensors detect air and water pollution levels, sending real-time alerts to environmental agencies [32]. In addition, AI algorithms analyze climate data to predict natural disasters, such as hurricanes or floods. This enables

proactive measures and early warning systems. AI-driven smart grids balance energy supply and demand in the energy sector, optimizing electricity distribution while minimizing waste [30,33]. Furthermore, Evdokimova [34] found that AI applications in agriculture include automated irrigation systems that use predictive analytics to determine the optimal watering schedule, reducing water consumption. AI chatbots and virtual assistants enhance public awareness on the social front by delivering tailored sustainability messages and answering inquiries about eco-friendly practices. These capabilities make AI indispensable in creating a more resilient and sustainable future.

4.2.2. Machine Learning and Deep Learning

Machine learning and deep learning are essential elements of artificial intelligence, enabling systems to process extensive datasets and generate precise predictions. Machine learning employs algorithms to identify patterns and trends, thereby automating decision making and optimizing resource management. Deep learning, as a specialized subset of machine learning, further enhances these capabilities by leveraging multi-layered neural networks to model complex relationships within data. Gao et al. (2023) [35] describe deep learning as a more advanced subset that utilizes neural networks to process and interpret complex data structures. The use of these technologies in sustainable development has revolutionized how organizations monitor environmental changes and enhance resource efficiency [36]. For example, predictive analytics powered by machine learning help forecast climate variations and detect anomalies in weather patterns. This information is crucial for planning disaster responses and mitigating climate-related risks and can be very useful for farmers to be able to plan irrigation systems in agriculture. Moreover, deep learning algorithms support biodiversity monitoring by analyzing satellite images to detect deforestation or habitat loss [37]. Machine learning enhances crop yield predictions and supports precision agriculture by enabling farmers to minimize water and fertilizer use. By processing real-time data, these technologies improve decision making, reduce environmental impacts, and foster sustainable resource management.

4.2.3. Big Data and Analytics

Big data and analytics encompass the technologies and processes for collecting, managing, and analyzing vast, complex datasets that exceed the capabilities of traditional data processing tools. These approaches enable organizations to extract actionable insights from diverse and rapidly generated data sources. Big data is commonly defined by five key characteristics: volume, velocity, variety, veracity, and value [33]. Volume refers to the vast amount of data generated, while velocity is the speed at which data is produced and processed. Variety focuses on a wide range of data types and formats, while veracity refers to the accuracy and trustworthiness of the data, and value is the meaningful insights derived from data analysis [33,38]. Data analytics involves discovering, interpreting, and communicating knowledge gathered from big data to support decision making [39]. Big data and analytics leverage analytical methods like descriptive statistics, predictive modeling, and machine learning algorithms to interpret patterns, forecast outcomes, and support data-driven decision making.

Big data and analytics play a pivotal role by enhancing the ability to monitor, evaluate, and manage progress toward sustainability goals. For example, El-Haddadeh et al. [40] indicate that big data enables the real-time tracking of environmental indicators like air quality, deforestation rates, and energy consumption, providing critical insights for early intervention and policy making. Data collected from sensors, satellites, and weather models in agriculture can optimize crop yields and resource use [41]. This contributes to food security while minimizing environmental impact. Governments and NGOs use

big data to assess social development metrics such as poverty levels, education access, and health outcomes, thereby designing more effective and targeted interventions [16,42]. Furthermore, analytics enable the forecasting of sustainability trends and the simulation of various policy outcomes, supporting stakeholders in making informed decisions. By leveraging big data and analytics, organizations can adopt a data-driven approach to sustainable development, enhancing transparency, efficiency, and scalability in the pursuit of long-term objectives.

4.2.4. Internet of Things

The Internet of Things (IoT) is a network of interconnected devices embedded with sensors, software, and other technologies to collect and exchange data over the internet. The IoT plays a pivotal role in sustainable development by enabling continuous monitoring and data collection in various sectors, such as agriculture, energy, healthcare, and urban planning [30,43]. For instance, IoT devices in smart agriculture help monitor soil moisture, weather conditions, and crop health. This practice provides farmers with data-driven insights to optimize irrigation and reduce chemical usage. In urban environments, IoT-enabled smart grids track energy consumption patterns, allowing for more efficient electricity distribution and minimizing waste [44]. Similarly, smart waste management systems use IoT sensors to detect bin fill levels and schedule waste collection only when needed, reducing fuel consumption and emissions. IoT wearables are used in healthcare to monitor patient health metrics in real time [44,45]. This promotes proactive care and reduces hospital visits. Through real-time data collection and analysis, the IoT enhances resource conservation and operational efficiency, empowering organizations and individuals to make informed decisions that elevate quality of life and advance the Sustainable Development Goals.

4.2.5. Blockchain

Blockchain technology is a decentralized digital ledger that records transactions transparently and securely. Wu and Tran [46] define it as “a new distributed infrastructure and computing paradigm” (p. 3). Its primary appeal lies in its immutability, meaning once data is recorded, it cannot be altered, ensuring data integrity and transparency. This characteristic results from blockchain technology’s architecture comprising various layers. These include the “data layer, network layer, consensus layer, incentive layer, contract layer, and application layer” (p. 4). Moreover, blockchain entails numerous key technologies including smart contracts, consensus mechanisms, distributed data storage, and encryption algorithms. Smart contracts are self-executing digital agreements that automatically enforce terms without the need for intermediaries [47]. Consensus mechanisms are protocols, such as proof of work or proof of stake, that validate and confirm transactions across the network to maintain integrity and trust. Distributed data storage ensures that data is stored across multiple nodes, enhancing transparency, fault tolerance, and resistance to tampering. Encryption algorithms secure data within the blockchain, protecting it from unauthorized access and ensuring privacy while maintaining the integrity of the recorded information.

Blockchain’s potential in sustainable development is vast since it promotes ethical practices, combats corruption, and builds stakeholder trust. A key application of blockchain is enhancing supply chain transparency by enabling the secure and verifiable tracking of goods from production through distribution, ensuring all parties have access to an immutable record of each transaction and movement [47]. Blockchain enables communication with consumers and allows them to trace the entire product journey, providing verifiable evidence of sustainability and compliance with ethical standards such as fair trade and environmentally friendly practices. Blockchain also supports the development of decen-

tralized energy grids by allowing peer-to-peer energy trading, where households with solar panels can sell excess power to their neighbors [46]. This dual capability enhances both supply chain transparency and the transition toward sustainable energy systems. Additionally, blockchain-based carbon credit systems facilitate the accurate tracking and trading of carbon offsets, encouraging industries to reduce emissions. Creating verifiable records and fostering transparency using blockchain technologies enhances accountability in sustainable practices.

4.2.6. Augmented and Virtual Reality

Augmented reality (AR) and virtual reality (VR) technologies offer immersive and interactive experiences that blend the virtual and physical worlds. According to Ebinger et al. [48], AR overlays digital information in real-world environments, while VR creates simulated experiences. Augmented reality (AR) superimposes digital data onto real-world environments, whereas virtual reality (VR) immerses users in simulated settings. Both AR and VR are increasingly recognized for their transformative potential in sustainable development, particularly through their ability to enhance education, training, communication, and public awareness initiatives. These immersive technologies enable experiential learning, foster behavioral change, and make complex sustainability concepts more tangible and accessible. For instance, AR applications in environmental conservation enable users to visualize the impact of human activities on ecosystems [49]. This creates a deeper understanding of sustainability challenges. VR simulations train professionals in crisis management by allowing them to practice disaster response scenarios without real-world risks. Furthermore, AR and VR enhance sustainable urban planning by offering virtual walkthroughs of proposed infrastructure projects, helping stakeholders assess potential environmental impacts before implementation [48,50]. Educational institutions also use AR/VR to teach students about sustainability practices, making abstract concepts more tangible and engaging. These innovations provide realistic and interactive experiences that bridge the gap between theoretical knowledge and practical application [49]. Ultimately, these applications promote long-lasting behavioral change toward sustainability.

4.3. *Emerging Trends Related to Digital Development and Sustainable Development*

The intersection of digital development and sustainable development continues to evolve due to technological advancements and an increasing global focus on sustainability. Emerging trends in this space demonstrate how digital solutions are reshaping industries, enhancing resource efficiency, and promoting environmental and social responsibility [51,52]. These trends are key to achieving the SDGs by leveraging digital innovation for long-term economic, environmental, and societal benefits. This section analyzes some of the most significant emerging trends contributing to a more sustainable future.

4.3.1. Digitalization of Logistics Outsourcing

The digitalization of logistics outsourcing refers to the use of advanced digital technologies such as artificial intelligence (AI), blockchain, and the Internet of Things (IoT) to optimize supply chain and logistics operations. This trend enhances efficiency, transparency, and sustainability by reducing transportation emissions, minimizing waste, and improving inventory management [53,54]. Companies are increasingly adopting cloud-based logistics management systems that provide real-time tracking of goods, predictive analytics for demand forecasting, and automated route optimization to reduce fuel consumption. Moreover, digital freight platforms facilitate more sustainable delivery models by matching cargo with available transport capacity [55]. The digitalization of logistics outsourcing streamlines operations by reducing empty trips and optimizing resource utilization, which in turn lowers carbon emissions and supports more sustainable supply chain manage-

ment. By leveraging digital platforms and real-time data analytics, companies can achieve greater operational efficiency and environmental performance, thereby aligning logistics practices with sustainable development objectives. This transformation not only minimizes the carbon footprint of supply chains but also enhances transparency and accountability throughout the logistics ecosystem.

4.3.2. Automation

Automation is an emerging trend contributing to sustainable development following the increased adoption of advanced technologies like robotics, AI, and machine learning. This trend is revolutionizing industries by increasing efficiency, reducing human error, and optimizing resource utilization [34]. Smart automation minimizes material waste and energy consumption in manufacturing by ensuring precise production processes. Similarly, Rane et al. [49] found that automated warehouses and distribution centers can use AI-driven robotics to improve inventory management, reducing waste and operational inefficiencies. Evdokimova [34] explains that automation also plays a key role in smart agriculture, where AI-powered drones and robotic systems monitor crop health, apply fertilizers with precision, and optimize irrigation. This application reduces chemical runoff and conserves water. Automated systems in the energy sector enhance the efficiency of renewable energy sources by adjusting power grids based on real-time demand and weather conditions [46,56]. Automation opens up new opportunities for reskilling in terms of new emerging technologies, and also allows for the creation of new roles in terms of the digital economy, although it raises concerns about job losses in terms of traditional corporate roles. Integrating automation into sustainable practices enables industries to significantly reduce waste, lower carbon emissions, and increase overall operational efficiency.

4.3.3. Sustainable Rural Industrial Development

Sustainable rural industrial development leverages digital technology to support economic growth in rural areas while preserving environmental and social integrity. Digital solutions such as e-commerce platforms, mobile banking, and blockchain-based supply chain tracking enable small-scale rural enterprises to access broader markets, secure fair prices, and reduce inefficiencies [45]. According to Wang et al. [20], renewable energy technologies, such as solar-powered microgrids, provide sustainable energy solutions to rural industries, reducing the dependence on fossil fuels. Gao et al. [35] indicate that digital training platforms and online education initiatives empower rural populations with technical skills. These practices improve employment opportunities and support innovation in sustainable industries [57,58]. IoT-driven smart farming techniques enable optimized water use, precision farming, fertilizer application, and pest control. All of these improvements help to increase productivity. Integrating digital tools with sustainable rural development strategies can enable countries to implement a new strategy that, with greater technological training and investment in technology, leads to combating poverty, creating resilient local economies and ensuring long-term environmental sustainability.

4.3.4. Smart Cities

Smart cities have emerged as a potential solution to rapid urbanization. Toli and Murtagh [17] estimate that around 66% of the global population will live in cities by 2050, up from 54% today. This increase means that urban areas will expand significantly to accommodate the huge number of people. As a result, this will further increase the pressure on the environment and exacerbate current sustainability issues. This is evidenced by the findings of Toli and Murtagh [17], who show that cities consume more than 75% of natural resources despite occupying only 2% of the Earth's surface. Furthermore, material consumption in cities is expected to increase from 40 billion tons in 2010 to 90 billion tons

by 2050. As a result, such urban development will lead to various problems such as air pollution, resource scarcity, congestion, and poor waste management. Smart cities use advanced technologies to address these challenges, thereby supporting sustainable development. Smart cities incorporate digital technologies to create more sustainable, efficient, and livable urban environments. One of the main goals of smart cities is to reduce energy consumption and waste through AI-based infrastructure management that optimizes electricity use in public buildings and residential areas [28]. IoT-enabled waste management systems help monitor waste bin levels, optimizing collection routes to minimize fuel consumption and emissions. Smart transportation systems integrate public transportation, ride sharing, and autonomous vehicles, such as electric bicycle sharing, to reduce traffic congestion and pollution [59–61]. In addition, smart grids improve energy distribution by integrating renewable energy sources and balancing supply and demand efficiently [17]. Prioritizing technological innovation in urban planning addresses the challenges related to overpopulation, pollution, and resource consumption in smart cities. Implementing strategies such as the use of shared electric bicycles can contribute to better transport management and reduce environmental damage, enabling sustainable urban growth while improving the quality of life of residents.

4.3.5. Green Technology Innovation

Green technology innovation involves developing and applying digital and technological advancements to reduce environmental harm and promote sustainability. This trend encompasses renewable energy technologies, energy-efficient manufacturing processes, and biodegradable materials designed to replace environmentally harmful products [62]. AI-driven energy management systems optimize electricity consumption by analyzing usage patterns and recommending efficiency improvements. In addition, advancements in battery storage technology enhance the viability of renewable energy sources by ensuring a consistent power supply [63]. Digital twin technology, which creates virtual simulations of real-world systems, allows businesses to model and improve sustainability efforts before implementing them physically. Innovations such as carbon capture and storage (CCS) technologies also mitigate climate change by reducing industrial carbon emissions [64,65]. Through ongoing research and development, green technology innovation plays a pivotal role in minimizing ecological footprints, effectively balancing technological advancement with environmental stewardship.

4.3.6. Technology-Driven Emission Reduction

Industries worldwide are striving to reduce their carbon footprints. This has led to the significant adoption of digital technologies designed to reduce emissions. For example, D'Adamo et al. [66] found that AI and machine learning are used to monitor, analyze, and optimize industrial energy consumption. This helps identify inefficiencies and recommend corrective actions. Blockchain technology is effective in enhancing carbon credit trading and providing transparent and verifiable records of emission reductions [62,67]. Governments are investing in smart transportation systems powered by the IoT and real-time data analytics. These systems improve fuel efficiency and minimize emissions in logistics and urban mobility. D'Adamo et al. [66] found that carbon capture and utilization technologies leverage advanced computational models to enhance the efficiency of greenhouse gas removal from the atmosphere. Companies also use cloud-based sustainability dashboards to track and report emissions data, ensuring regulatory compliance and corporate responsibility [68,69]. These digital solutions for emission reduction empower businesses and governments to accelerate the transition to a low-carbon economy.

4.3.7. Energy Sustainability

Energy sustainability focuses on optimizing the generation, distribution, and consumption of energy to meet current needs without compromising future resources. Digital technologies such as AI, blockchain, and the IoT play a crucial role in energy sustainability by enhancing the efficiency and reliability of power systems [28,70]. Smart grids, equipped with AI-driven demand forecasting, allow for dynamic energy distribution, reducing waste and ensuring the efficient utilization of renewable energy sources. Vätavu et al. [71] (2022) explain that blockchain-based decentralized energy trading platforms enable peer-to-peer transactions, allowing households with solar panels to sell excess energy to the grid. Wu and Tran [46] found that smart grid and blockchain technologies are used to support the energy internet, which refers to a power system “with the smart grid as its backbone, and linked by the internet, big data, cloud computing, and other leading information and communication technologies” (p. 8). This energy internet is a next-generation energy system incorporating energy and information systems to create sustainable power systems.

Some energy companies are using digital twins to simulate energy infrastructure scenarios. This enables them to optimize power plants and transmission networks. As a result, Song et al. [72] recognize digital twins as a “promising tool for realizing intelligent power systems” (p. 2). Moreover, digital twins provide innovations that allow energy companies to observe and predict real-world systems. Thus, Bortolini et al. [56] found that digital twinning helps lower maintenance costs alongside monitoring and predicting asset performance. The increasing use of IoT sensors helps to monitor energy consumption patterns in buildings and industries, thus providing insights that promote energy conservation [73,74]. These advancements contribute to a cleaner, more resilient energy system that supports long-term sustainability.

4.3.8. Sustainable Digital Economy

The adoption of digital technologies has spurred on the emergence of a sustainable digital economy, which systematically integrates environmental, economic, and social sustainability principles within the rapidly expanding digital sector. This transformative approach ensures that technological progress aligns with the broader Sustainable Development Goals. A sustainable digital economy includes reducing the carbon footprint of data centers, ensuring ethical labor practices in tech industries, and promoting circular economy models in electronics manufacturing [75,76]. It also promotes green cloud computing initiatives that optimize energy efficiency in data processing and storage. Digital platforms also facilitate sustainable business models, such as the sharing economy, which reduces waste by encouraging resource sharing [77]. For example, a sustainable digital economy encourages consumers to use ride sharing and co-working spaces. Furthermore, digital financial services promote financial inclusion, allowing underserved populations to access banking, loans, and investment opportunities [78,79]. The sustainable digital economy aims to create a balanced approach to economic growth that leverages digital advancements while minimizing negative environmental and social impacts.

4.3.9. Sustainable Urban Transportation

Sustainable urban transportation focuses on reducing carbon emissions, enhancing mobility efficiency, and integrating environmentally friendly alternatives into urban transit systems. Digital technologies are crucial in transforming transportation systems into more sustainable models [61]. For instance, AI and data analytics are being used to optimize traffic flow, reducing congestion and fuel waste through adaptive traffic light systems and real-time navigation apps. In addition, the rise in electric vehicles (EVs) and autonomous transportation reduces the reliance on fossil fuels, cutting down urban air pollution [20].

Consumers are also embracing digital platforms that facilitate Mobility-as-a-Service (MaaS). These platforms integrate multiple transport modes, such as public transit, bike sharing, and ride hailing, into a seamless, app-based system that encourages more efficient and sustainable commuting choices [80,81]. The implementation of smart parking systems significantly reduces vehicle emissions by decreasing the time drivers spend searching for available parking spaces. By adopting these innovations, cities are advancing towards transportation systems that are cleaner, more efficient, and equitable, thereby supporting the achievement of broader sustainability objectives.

4.3.10. Sustainable Agri-Food Systems

Sustainable agri-food systems integrate digital technologies to improve food security, reduce waste, and minimize the environmental impact of agriculture and food production. AI and IoT-driven precision agriculture enables farmers to use real-time data for more efficient water, fertilizer, and pesticide applications [41]. This reduces resource waste and improves yields. Hadizadeh et al. [82] indicate that integrating blockchain technology enhances food traceability, ensures transparency in the supply chain, and reduces food fraud. Furthermore, vertical farming and hydroponics use controlled-environment agriculture (CEA) to produce food with minimal land and water usage, making them viable solutions for urban food security [34,83]. The emergence and popularity of digital marketplaces have helped small-scale farmers connect directly with consumers. As a result, this has reduced food waste and transportation emissions [54,84]. The integration of robotics and automation into food production increases operational efficiency, lowers labor costs, and supports sustainable practices. By harnessing these technologies within sustainable agri-food systems, it is possible to enhance global food security while simultaneously reducing the environmental impact of agricultural activities.

5. Conclusions

Pursuing sustainability and sustainable development remains an important global issue grounded in balancing environmental protection, social equity, and economic progress. These three dimensions are the foundation for achieving long-term well-being for people and the planet. The need to achieve sustainable development led to the establishment of the Sustainable Development Goals (SDGs). The SDGs provide a comprehensive blueprint for tackling global challenges such as poverty, inequality, environmental degradation, and climate change. However, achieving these goals presents complex obstacles, including inadequate resources, infrastructure, limited data, and the lack of coordination. In response, digital development has emerged as a powerful enabler by offering innovative tools and frameworks that align technological adoption with sustainability objectives. Digital transformation supports the operationalization of the SDGs and actively reshapes how sustainability is conceptualized, implemented, and monitored. Thus, the intersection of digital development with sustainable development represents a paradigm shift, where technology becomes both a catalyst and a compass guiding systemic change.

The research findings identify various digital technologies that support sustainable development. These include artificial intelligence, machine learning, the Internet of Things (IoT), blockchain, augmented and virtual reality (AR/VR), and big data analytics. Each of these innovations contribute uniquely to improving efficiency, transparency, and responsiveness across various sectors. They optimize resource use in agriculture, transforming transportation systems and enabling real-time environmental monitoring. Moreover, these technologies empower decisionmakers and communities with timely, data-driven insights. Furthermore, emerging trends such as automation, energy sustainability, green technology innovation, and sustainable digital economies illustrate how digital transformation

is influencing broader structural changes. Innovations like smart cities and sustainable urban transportation reflect the urban ecosystem's evolution through technology-driven design. Areas like agri-food systems and rural industrial development demonstrate the potential for inclusive, decentralized growth. These technologies and trends reveal a dynamic and evolving relationship between digital and sustainable development. They show the possibility of leveraging technologies to create a more equitable and resilient future. As this field evolves, ongoing interdisciplinary research and inclusive policy frameworks will be essential to ensure that technological advancements translate into tangible and lasting sustainability outcomes.

This research introduces a layered conceptual approach that intertwines the advancements in digital technologies with the evolving discourse on sustainable development. Instead of treating technology as a standalone subject, it presents a holistic perspective that weaves together insights from digital change, sustainability strategies, and socio-technical dynamics. Drawing inspiration from the SDITIDA model developed by Harfouche et al. [2], this study illuminates the nuanced interactions between actors, environments, digital processes, and evaluative feedback, providing a tangible framework to interpret the United Nations Sustainable Development Goals (SDGs) through a technological lens.

Crucially, this study reframes digital tools not as passive instruments but as components embedded within social and political value systems—shaped by and shaping institutional behavior, justice, and international agendas. The adoption of a PRISMA-based bibliometric methodology further strengthens the theoretical architecture, as it systematically identifies which digital interventions have demonstrated sustained relevance and impact within the sustainability domain.

On a practical level, this work presents a set of clear strategies that policymakers and institutions can leverage to integrate technologies like blockchain, AI, and IoT into efforts to achieve SDG targets. From precision agriculture to smart grid optimization, this study outlines adaptable, real-world applications. It also emphasizes how regulatory alignment and community-based solutions—especially in low-income regions—can drive inclusive, tech-enabled progress.

As the global push for sustainability intensifies, the integration of digital technologies across regions has emerged as both a promising solution and a complex challenge. However, the success of these tools hinges not merely on innovation but on how they are received and adapted within distinct cultural, political, and economic landscapes. Understanding the varying rates and patterns of technological adoption across countries offers critical insight into what drives—or hinders—sustainable progress. For instance, digital strategies that thrive in urban centers of developed nations may encounter resistance or logistical constraints in rural or economically fragile areas. By drawing comparisons across diverse settings, researchers and practitioners can begin to untangle the factors that influence technology uptake and sustainability outcomes. Looking ahead, a deeper, more grounded understanding of digital innovation's long-term effects is essential. Ongoing observation of how tools like artificial intelligence or blockchain reshape social and environmental dynamics can reveal patterns of transformation or unintended consequences over time. Ethical considerations—ranging from data rights to algorithmic accountability—must also be central to these discussions, particularly as digital systems become more ingrained in public life. Moreover, as global crises such as pandemics and climate emergencies test the resilience of societies, the role of responsive and adaptive technologies will grow increasingly vital.

This article presents the research's limitations, as is the case with other academic studies. Thus, although this study offers valuable insights into the intersection between digital technology and sustainable development, several limitations should be acknowledged

to contextualize its findings and guide future research. Firstly, this research primarily adopts a conceptual and bibliometric approach, synthesizing the existing literature and frameworks rather than conducting extensive empirical fieldwork. As a result, the findings may be more reflective of prevailing academic discourse than of on-the-ground realities, particularly in regions where digital adoption is nascent or uneven. The conceptual layering, while holistic, may not capture all localized nuances or sector-specific challenges. The data and methodological constraints are related, in this case, to the reliance on the published literature and bibliometric analysis (PRISMA-based), which inherently limits the scope to documented and peer-reviewed interventions. Unpublished innovations, informal practices, or region-specific adaptations that have not yet entered the academic literature may be underrepresented. Additionally, the dynamic and rapidly evolving nature of digital technologies means that some recent or emerging trends may not be fully captured in the current dataset. Referring to the contextual variability, this study acknowledges but cannot fully address the vast differences in technological adoption and sustainability outcomes across cultural, political, and economic contexts. Digital solutions that succeed in developed urban centers may face significant resistance or logistical barriers in rural or low-income settings. This research does not provide detailed empirical comparisons across these diverse environments, which may limit the applicability of its recommendations in certain contexts. Furthermore, although this research presents strategies to align digital technologies with the SDG targets, it is not possible to address in depth all of the SDGs and the practical challenges of implementation in this study due to the complexity of the subject.

In summary, while this study offers a robust theoretical framework and valuable strategic insights, its limitations stem from its conceptual focus, reliance on secondary data, and the inherent complexity of the digital–sustainability nexus. These constraints underscore the need for ongoing, context-aware empirical research to validate and extend the findings presented here.

Future research must not only trace the outcomes but also interrogate the frameworks that govern how technology is deployed, ensuring solutions are just, inclusive, and context aware.

Future Research

Empirical Validation Across Diverse Contexts

Future research should prioritize empirical studies that examine the real-world application and outcomes of digital technologies in advancing sustainable development, particularly in underrepresented regions and sectors. Fieldwork in rural, low-income, or technologically nascent environments is essential to capture localized nuances and sector-specific challenges that conceptual and bibliometric analyses may overlook. Comparative studies across different cultural, political, and economic contexts can help identify the drivers and barriers to digital adoption, offering insights into how strategies can be tailored for maximum impact.

Inclusion of Informal and Unpublished Innovations

Given the current reliance on published literature, future investigations should seek to document and analyze informal practices, unpublished innovations, and region-specific adaptations that have not yet entered academic discourse. Collaborations with local stakeholders, practitioners, and community organizations can uncover grassroots solutions and adaptive strategies that may be critical for sustainable development but are currently underrepresented in the literature.

Longitudinal and Dynamic Analysis

As digital technologies evolve rapidly, longitudinal research is needed to track the long-term effects of tools such as artificial intelligence, blockchain, and the IoT on the social, economic, and environmental outcomes. Observing these impacts over time will help identify patterns of transformation, unintended consequences, and the sustainability of digital interventions beyond initial implementation.

Ethical, Regulatory, and Governance Considerations

Future studies should explore the ethical implications of digital transformation in sustainability, including issues of data rights, privacy, algorithmic accountability, and equitable access. Research on regulatory frameworks and governance models that facilitate responsible and inclusive technology adoption will be critical, especially as digital systems become more embedded in public and institutional life.

Integration with Crisis Response and Resilience

Given the increasing frequency of global crises such as pandemics and climate emergencies, research should investigate how digital technologies can enhance societal resilience and adaptive capacity. Case studies and scenario analyses focusing on the role of responsive technologies in crisis management can inform strategies for future preparedness and recovery.

Sector-Specific and SDG-Focused Research

While this study provides a broad overview, future research should delve deeper into sector-specific applications (e.g., agri-food systems, urban transportation, and energy) and address the practical challenges related to the implementation of digital solutions for specific Sustainable Development Goals (SDGs). A detailed empirical analysis of how digital tools contribute to particular SDGs will help refine strategies and measure progress more accurately.

Interdisciplinary and Participatory Approaches

Finally, advancing the digital–sustainability nexus will require ongoing interdisciplinary collaboration and participatory research methods that engage diverse stakeholders, including policymakers, technologists, community leaders, and end users. Such approaches can ensure that technological advancements are both context aware and aligned with broader social and environmental objectives.

By addressing these areas, future research can build on the current study's theoretical foundations, bridging the gaps between conceptual insights and practical, context-sensitive solutions for sustainable development in the digital age.

A more nuanced approach to future research reveals that future research should prioritize empirical studies that examine the application and actual outcomes of digital technologies in advancing sustainable development, particularly in underrepresented regions and sectors.

Comparative studies across different cultural, political, and economic contexts can help identify drivers and barriers to digital adoption, offering insights into how strategies can be adapted for maximum impact.

Collaborations with local stakeholders, practitioners, and community organizations can reveal basic solutions and adaptive strategies that may be crucial to sustainable development but are currently underrepresented in the literature.

In parallel, as digital technologies evolve rapidly, longitudinal research is needed to track the long-term effects of tools such as artificial intelligence, blockchain, and the IoT on social, economic, and environmental outcomes. Observing these impacts over time will

Table A1. Cont.

Documents		≤2015	2016	2017	2018	2019	2021	2021	2022	2023	2024	2025	Total
What business environment element configuration can promote urban digitization development?	2024	0	0	0	0	0	0	0	0	0	0	3	3
Impact of Digital Development and Technology Innovation on the Marine Fishery Economy Quality	2024	0	0	0	0	0	0	0	0	0	0	7	7
How Does the Digital Transformation Affect the Carbon Emissions of Manufacturing Enterprises in China? The Perspective of Green Technology Innovation	2024	2	0	0	0	0	0	0	0	0	0	2	4
Can digital transformation affect coal utilization efficiency in China? Evidence from spatial econometric analyses	2024	4	0	0	0	0	0	0	0	0	0	12	16
Achieving the Sustainable Development Goals Through Water and Sanitation: Do Information and Communication Technologies (ICTs) Matter for Africa?	2024	0	0	0	0	0	0	0	0	0	1	5	6
Problems And Prospects of Implementation of The “Smart Region” Concept in the Coal Mining Regions of the Russian Federation	2024	0	0	0	0	0	0	0	0	0	0	3	3
Digital Transformation in the Context of Sustainable Development of European Countries	2024	0	0	0	0	0	0	0	0	0	0	3	3
Exploring the Role of Digital Transformation and Breakthrough Innovation in Enhanced Performance of Energy Enterprises: Fresh Evidence for Achieving Sustainable Development Goals	2024	0	0	0	0	0	0	0	0	0	0	4	4
Exploring Village Spatial Patterns for Sustainable Development: A Case Study of Diqing Prefecture	2023	0	0	0	0	0	0	0	0	0	0	4	4
Capability of Higher Education in Overcoming Digital Inequality in the Conditions of the Crisis in Ukraine	2023	0	0	0	0	0	0	0	0	0	1	2	3
An acceptability-based multi-objective traffic flow adjustment method for environmental sustainability and equity	2023	1	0	0	0	0	0	0	0	0	0	0	1
The realm of metaverse: A survey	2023	0	0	0	0	0	0	0	0	0	20	19	43
A pathway to sustainable development: Digitization and green productivity	2023	0	0	0	0	0	0	0	0	0	23	58	93

Table A1. Cont.

Documents		≤2015	2016	2017	2018	2019	2021	2021	2022	2023	2024	2025	Total
Can digitalization alleviate multidimensional energy poverty in rural China? Designing a policy framework for achieving the sustainable development goals	2023	0	0	0	0	0	0	0	0	0	3	14	21
The Sustainable Rural Industrial Development under Entrepreneurship and Deep Learning from Digital Empowerment	2023	0	0	0	0	0	0	0	0	0	1	4	5
Research on the Impact of Digital Empowerment on China's Human Capital Accumulation and Human Capital Gap between Urban and Rural Areas	2023	0	0	0	0	0	0	0	0	0	4	6	13
How can corporate culture contribute to emission reduction in the construction sector? An SME case study on beliefs, actions, and outcomes	2023	4	0	0	0	0	0	0	0	0	4	8	16
Directions of the Development of the Digital Economy in the Conditions of Military Conflicts	2023	0	0	0	0	0	0	0	0	0	0	1	1
Sustainability, emission trading system and carbon leakage: An approach based on neural networks and multicriteria analysis	2023	3	0	0	0	0	0	0	0	0	0	8	11
Role of digitalization of logistics outsourcing in sustainable development of automotive industry in China	2023	0	0	0	0	0	0	0	0	0	0	2	2
Cluster Assessment of European Countries in Terms of Digitalisation and Sustainable Development	2023	0	0	0	0	0	0	0	0	0	0	1	1
Digital Development Influencing Mechanism on Green Innovation Performance: A Perspective of Green Innovation Network	2023	0	0	0	0	0	0	0	0	0	5	19	28
Digital development, inequalities & the Sustainable Development Goals: what does 'Leave No-One Behind' mean for ICT4D?	2023	0	0	0	0	0	0	0	0	0	3	10	16
Environmental and digital innovation in food: The role of digital food hubs in the creation of sustainable local agri-food systems	2022	0	0	0	0	0	0	0	0	11	10	11	36
Socio-Cultural Capital of Rural Areas in the Context of the Sustainable Development of the Digital Economy	2022	0	0	0	0	0	0	0	0	0	3	0	3

Table A1. Cont.

Documents		≤2015	2016	2017	2018	2019	2021	2021	2022	2023	2024	2025	Total
Application of a multi-field sensor into an office building	2022	0	0	0	0	0	0	0	0	1	0	0	1
Research on the influence mechanism of the digital economy on regional sustainable development	2022	0	0	0	0	0	0	0	0	7	16	17	45
Digitalization and automation of the agricultural sector	2021	0	0	0	0	0	0	0	1	2	0	0	3
A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends	2021	0	0	0	0	0	0	0	8	37	59	94	219
Be Digital and Responsible: the Case of Grand Est Territory in France	2021	0	0	0	0	0	0	0	0	0	0	1	1
Integral assessment of the state and development potential of info-communication infrastructure for ensuring sustainable digital development	2021	0	0	0	0	0	0	0	0	1	8	3	12
Digital and green economy: Common grounds and contradictions	2021	0	0	0	0	0	0	0	0	1	7	7	16
Influence of the level of development of the digital environment on the trend of gross domestic product in the countries of the European Union	2020	0	0	0	0	0	0	0	0	1	1	2	4
Sustainable digital transformation of disaster risk—integrating new types of digital social vulnerability and interdependencies with critical infrastructure	2020	0	0	0	0	0	0	0	4	3	7	0	16
Global and Ukrainian Labour Markets in the Face of Digitalization Challenges and The Threats of the COVID-19 Pandemic	2020	0	0	0	0	0	0	0	0	3	3	1	7
Parking management for promoting sustainable transport in urban neighbourhoods. A review of existing policies and challenges from a German perspective	2020	0	0	0	0	0	0	6	4	9	10	14	46
Smart city technologies as an innovative factor in the development of the sustainable cities	2020	0	0	0	0	0	0	0	1	0	0	0	1
How to support digital sustainability assessment? An attempt to knowledge systematization	2020	0	0	0	0	0	0	0	4	2	5	4	16

Table A1. Cont.

Documents		≤2015	2016	2017	2018	2019	2021	2021	2022	2023	2024	2025	Total
Dialectics of Sustainable Development of Digital Economy Ecosystem	2020	0	0	0	0	0	0	1	3	4	1	3	12
Realizing the potential of digital development: The case of agricultural advice	2019	0	0	0	0	0	0	9	31	31	47	66	206
Economic security of business structures in the digital economy	2018	0	0	0	0	0	2	1	0	0	0	0	3
Digital strategy of telecommunications development: Concept and implementation phases	2017	0	0	0	0	3	1	0	6	0	0	0	10
Mail-Doc-Web: A technique for faster, cheaper and more sustainable digital service development	2017	0	0	0	0	0	0	1	0	0	0	0	1
Advanced system for the control of work regime of railway electric drive equipment	2010	1	0	0	1	0	0	0	0	0	0	0	2
Challenge future—Technical progress and globalization	2008	1	0	0	0	0	0	0	0	0	0	0	1
	Total	2	0	0	1	3	3	18	62	113	242	419	975

References

- Li, L.; Zhou, H.; Yang, S.; Teo, T.S.H. Leveraging digitalization for sustainability: An affordance perspective. *Sustain. Prod. Consum.* **2022**, *35*, 624–632. [CrossRef]
- Harfouche, A.; Merhi, M.I.; Albizri, A.; Dennehy, D.; Thatcher, J.B. Sustainable development through technological innovations and data analytics. *Inf. Syst. Front.* **2024**, *26*, 1989–1996. [CrossRef]
- Oliveira, J.M.; Gomes, C.F. Leveraging digital transformation on the path to sustainable development: The role of excellence models. *Bus. Process. Manag. J.* **2024**, *30*, 1340–1366. [CrossRef]
- George, G.; Merrill, R.K.; Schillebeeckx, S.J.D. Digital sustainability and entrepreneurship: How digital innovations are helping tackle climate change and sustainable development. *Entrep. Theory Pract.* **2021**, *45*, 999–1027. [CrossRef]
- Arora, L.; Thomas, A.S.; Aggarwal, K.; Pathak, S. Digitization for Sustainable Development: Leveraging Technology for Global Progress. In *Cutting-Edge Solutions for Advancing Sustainable Development: Exploring Technological Horizons for Sustainability-Part 1*; Bentham Science Publishers: Sharjah, Saudi Arabia, 2025; pp. 176–189. [CrossRef]
- Iqbal, I.; Pierson, C. A north-south struggle: Political and economic obstacles to sustainable development. *Sustain. Dev. Law Policy* **2017**, *16*, 16–47.
- Vaishnav, D. Leveraging Digital Transformation for Sustainable Development. *Calif. Rev. Manag.* **2024**. Available online: <https://cmr.berkeley.edu/assets/documents/pdf/2024-07-leveraging-digital-transformation-for-sustainable-development.pdf>. (accessed on 31 March 2025).
- Novillo-Ortiz, D.; Quintana, Y.; Holmes, J.H.; Borbolla, D.; Marin, H.D.F. Leveraging data and information systems on the sustainable development goals. *Int. J. Med. Inform.* **2021**, *152*, 104504. [CrossRef]
- Linnenluecke, M.K.; Marrone, M.; Singh, A.K. Conducting systematic literature reviews and bibliometric analyses. *Aust. J. Manag.* **2020**, *45*, 175–194. [CrossRef]
- Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
- Haddaway, N.R.; Page, M.J.; Pritchard, C.C.; McGuinness, L.A. PRISMA 2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Syst. Rev.* **2022**, *18*, e1230. [CrossRef]

12. Rosário, A.T.; Dias, J.C. Exploring the Landscape of Smart Tourism: A Systematic Bibliometric Review of the Literature of the Internet of Things. *Adm. Sci.* **2024**, *14*, 22. [[CrossRef](#)]
13. Rosário, A.T.; Fernandes, F.; Raimundo, R.G.; Cruz, R.N. Determinants of Nascent Entrepreneurship Development. In *Handbook of Research on Nascent Entrepreneurship and Creating New Ventures*; Carrizo, M., Dantas, J., Eds.; IGI Global Scientific Publishing: Hershey, PA, USA, 2021; pp. 172–193. [[CrossRef](#)]
14. Xiao, Z.; Qin, Y.; Xu, Z.; Antucheviciene, J.; Zavadskas, E.K. The Journal Buildings: A Bibliometric Analysis (2011–2021). *Buildings* **2022**, *12*, 37–52. [[CrossRef](#)]
15. Rosário, A.T.; Figueiredo, J. Sustainable entrepreneurship and corporate social responsibility: Analysing the state of research. *Sustain. Environ.* **2024**, *10*, 2324572. [[CrossRef](#)]
16. Ciacci, A.; Ivaldi, E.; Penco, L.; Testa, G. Measuring Digital Sustainability Paying Attention to the Economic, Social, and Environmental Dimensions: A European Perspective. *Soc. Indic. Res.* **2024**, *177*, 1–29. [[CrossRef](#)]
17. Toli, A.M.; Murtagh, N. The concept of sustainability in smart city definitions. *Front. Built Environ.* **2020**, *6*, 77. [[CrossRef](#)]
18. Zaloznova, Y.; Pankova, O.; Ostafiichuk, Y. Global and Ukrainian labour markets in the face of digitalization challenges and the threats of the COVID-19 pandemic. *Virtual Econ.* **2020**, *3*, 106–130. [[CrossRef](#)]
19. Fekete, A.; Rhyner, J. Sustainable digital transformation of disaster risk—Integrating new types of digital social vulnerability and interdependencies with critical infrastructure. *Sustainability* **2020**, *12*, 9324. [[CrossRef](#)]
20. Wang, Y.; Wang, Z.; Shuai, J.; Shuai, C. Can digitalization alleviate multidimensional energy poverty in rural China? Designing a policy framework for achieving the sustainable development goals. *Sustain. Prod. Consum.* **2023**, *39*, 466–479. [[CrossRef](#)]
21. Wong, X.; Kang, W.; Kim, J.; Xu, Y.; Wang, A. The Criticality of the Digital Economy in Environmental Sustainability: Fresh Insights from a Wavelet-Based Quantile-on-Quantile Approach. *Sustainability* **2025**, *17*, 622. [[CrossRef](#)]
22. Ruggerio, C.A. Sustainability and sustainable development: A review of principles and definitions. *Sci. Total Environ.* **2021**, *786*, 147481. [[CrossRef](#)]
23. Tiron-Tudor, A.; Deliu, D. The Sustainability Performance of SMEs in Industry 5.0: A Proposal for a Synergetic Digital Sustainable Development Maturity Model (SDSDMM). *East. Eur. Econ.* **2024**, 1–45. [[CrossRef](#)]
24. Sohail, M.T.; Ullah, S.; Ozturk, I.; Sohail, S. Energy justice, digital infrastructure, and sustainable development: A global analysis. *Energy* **2025**, *319*, 134999. [[CrossRef](#)]
25. Sachs, J.D. Achieving the sustainable development goals. *J. Int. Bus. Ethics* **2015**, *8*, 53–62.
26. Nchofoung, T.N.; Nkemgha, G.Z.; Fokam, D.N.D.T.; Kengdo, A.A.N. Achieving the Sustainable Development Goals Through Water and Sanitation: Do Information and Communication Technologies (ICTs) Matter for Africa? *J. Knowl. Econ.* **2024**, *15*, 4383–4407. [[CrossRef](#)]
27. Rothe, F.F.; Van Audenhove, L.; Loisen, J. Digital development, inequalities & the Sustainable Development Goals: What does ‘Leave No-One Behind’ mean for ICT4D? *Inf. Technol. Dev.* **2023**, *29*, 9–26. [[CrossRef](#)]
28. Jiang, Y.; Huang, L.; Liu, Y.; Wang, S. Impact of Digital Development and Technology Innovation on the Marine Fishery Economy Quality. *Fishes* **2024**, *9*, 266. [[CrossRef](#)]
29. Martinez, R. Artificial Intelligence: Distinguishing Between Types & Definitions. *Nev. Law J.* **2019**, *19*, 1015–1042.
30. Yigitcanlar, T.; Cugurullo, F. The sustainability of artificial intelligence: An urbanistic viewpoint from the lens of smart and sustainable cities. *Sustainability* **2020**, *12*, 8548. [[CrossRef](#)]
31. Belyaeva, Z.S.; Lopatkova, Y.A. Cluster Assessment of European Countries in Terms of Digitalisation and Sustainable Development. *Econ. Reg.* **2023**, *19*, 1–14. [[CrossRef](#)]
32. Voorneveld, M. AI Technology Adoption & Sustainability Improvement Through Cloud Solutions. In Proceedings of the ICEIS 2024-26th International Conference on Enterprise Information Systems, Angers, France, 28–30 April 2024; Volume 2, pp. 675–687. [[CrossRef](#)]
33. Ojokoh, B.A.; Samuel, O.W.; Omisore, O.M.; Sarumi, O.A.; Idowu, P.A.; Chimusa, E.R.; Darwish, A.; Adekoya, A.F.; Katsriku, F.A. Big data, analytics and artificial intelligence for sustainability. *Sci. Afr.* **2020**, *9*, e00551. [[CrossRef](#)]
34. Evdokimova, Y. Digitalization and automation of the agricultural sector. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2021; Volume 723, p. 032002.
35. Gao, S.; Yang, X.; Long, H.; Zhang, F.; Xin, Q. The Sustainable Rural Industrial Development under Entrepreneurship and Deep Learning from Digital Empowerment. *Sustainability* **2023**, *15*, 7062. [[CrossRef](#)]
36. Gulati, S.; Sharma, S. Challenges and responses towards sustainable future through machine learning and deep learning. In *Data Visualization and Knowledge Engineering: Spotting Data Points with Artificial Intelligence*; Springer International Publishing: Cham, Switzerland, 2019; pp. 151–169.
37. Vinuesa, R.; Sirmacek, B. Interpretable deep-learning models to help achieve the Sustainable Development Goals. *Nat. Mach. Intell.* **2021**, *3*, 926. [[CrossRef](#)]

38. Shrivastava, A.; Mishra, A.; Talreja, P. An Analysis of the Role of ICT in Digitalization of Banking Financial Services & Insurance Sector. In Proceedings of the 3rd IEEE International Conference on ICT in Business Industry and Government, ICTBIG, Indore, India, 8–9 December 2023; IEEE: New York, NY, USA, 2023; pp. 1–6.
39. Sahoo, S.; Kaur, M.; Kaur, A. Role of Information and Communication Technology in Poverty Analysis and Reduction. In Proceedings of the 2024 11th International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India, 28 February–1 March 2024; IEEE: New York, NY, USA, 2024; pp. 945–950.
40. El-Haddadeh, R.; Osmani, M.; Hindi, N.; Fadlalla, A. Value creation for realising the sustainable development goals: Fostering organisational adoption of big data analytics. *J. Bus. Res.* **2021**, *131*, 402–410. [[CrossRef](#)]
41. Sgroi, F.; Marino, G. Environmental and digital innovation in food: The role of digital food hubs in the creation of sustainable local agri-food systems. *Sci. Total Environ.* **2022**, *810*, 152257. [[CrossRef](#)] [[PubMed](#)]
42. Boonmee, C. Mail-doc-web: A technique for faster, cheaper and more sustainable digital service development. In Proceedings of the 17th European Conference on Digital Government, Lisbon, Portugal, 12–13 June 2017; p. 36.
43. Maheswar, R.; Kanagachidambaresan, G.R. Sustainable development through Internet of Things. *Wirel. Netw.* **2020**, *26*, 2305–2306. [[CrossRef](#)]
44. Martínez, I.; Zalba, B.; Trillo-Lado, R.; Blanco, T.; Cambra, D.; Casas, R. Internet of things (Iot) as sustainable development goals (sdg) enabling technology towards smart readiness indicators (SRI) for university buildings. *Sustainability* **2021**, *13*, 7647. [[CrossRef](#)]
45. Chen, L.; Wang, Y.; Yan, Y.; Zhou, Z.; Xie, B.; You, X. Coupling and Coordination Development, Spatiotemporal Evolution, and Driving Factors of China’s Digital Countryside and Inclusive Green Growth in Rural Areas. *Sustainability* **2024**, *16*, 5583. [[CrossRef](#)]
46. Wu, J.; Tran, N.K. Application of blockchain technology in sustainable energy systems: An overview. *Sustainability* **2018**, *10*, 3067. [[CrossRef](#)]
47. Parmentola, A.; Petrillo, A.; Tutore, I.; De Felice, F. Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). *Bus. Strategy Environ.* **2022**, *31*, 194–217. [[CrossRef](#)]
48. Ebinger, F.; Buttke, L.; Kreimeier, J. Augmented and virtual reality technologies in education for sustainable development: An expert-based technology assessment. *TATuP-Z. Für. Tech. Theor. Und Prax./J. Technol. Assess. Theory Pract.* **2022**, *31*, 28–34. [[CrossRef](#)]
49. Rane, N.; Choudhary, S.; Rane, J. *Sustainable Tourism Development Using Leading-Edge Artificial Intelligence (AI), Blockchain, Internet of Things (IoT), Augmented Reality (AR) and Virtual Reality (VR) Technologies*; Elsevier: Amsterdam, The Netherlands, 2023.
50. Hoong, A.L.S.; Mostafa, K.A. Conceptual Study on Utilization of Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR) on Green. In Proceedings of the 2nd International Conference on Intelligent Manufacturing and Robotics, ICIMR 2024: Advances in Intelligent Manufacturing and Robotics, Suzhou, China, 22–23 August 2025; Springer Nature: London, UK, 2025; Volume 1316, p. 270.
51. Andrey, Z.; Evgeniy, K.; Yulia, B.; Zarema, D. Influence of the level of development of the digital environment on the trend of gross domestic product in the countries of the European Union. *E3S Web Conf.* **2020**, *211*, 04006. [[CrossRef](#)]
52. Kolupaieva, I.; Sheiko, I.; Polozova, T. Digital Transformation in the Context of Sustainable Development of European Countries. *Probl. Ekorozwoju* **2024**, *19*, 89–103. [[CrossRef](#)]
53. Bing, X. Risk Assessment for International Trade Finance under Digitization Background Based on Mixed Attention and Residual Network. In Proceedings of the 13th International Conference on Logistics and Systems Engineering, Wuhan, China, 29–30 March 2024; Tong, Z., Zhang, H., Eds.; Aussino Academic Publishing House (AAPH): Sydney, Australia, 2024; pp. 861–868. [[CrossRef](#)]
54. Han, J.W.; Zuo, M.; Zhu, W.Y.; Zuo, J.H.; Lü, E.L.; Yang, X.T. A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends. *Trends Food Sci. Technol.* **2021**, *109*, 536–551. [[CrossRef](#)]
55. Chernova, O.A.; Liu, L.; Wang, X. Role of digitalization of logistics outsourcing in sustainable development of automotive industry in China. *R-Economy* **2023**, *9*, 123–139. [[CrossRef](#)]
56. Bortolini, R.; Rodrigues, R.; Alavi, H.; Vecchia, L.F.D.; Forcada, N. Digital twins’ applications for building energy efficiency: A review. *Energies* **2022**, *15*, 7002. [[CrossRef](#)]
57. Sitnova, I.A.; Barlybaev, A.A.; Ishnazarova, Z.M.; Yantilina, N.T.; Barlybaev, U.A. Socio-Cultural Capital of Rural Areas in the Context of the Sustainable Development of the Digital Economy. In *Advances in Science, Technology and Innovation*; Springer Nature: London, UK, 2022; pp. 127–132. [[CrossRef](#)]
58. Sun, D.; Yu, B.; Ma, J. Research on the Impact of Digital Empowerment on China’s Human Capital Accumulation and Human Capital Gap between Urban and Rural Areas. *Sustainability* **2023**, *15*, 5458. [[CrossRef](#)]
59. Yan, M.; Yang, F.; Pan, H.; Li, C. Research on the Response of Urban Sustainable Development Standards to the United Nations Sustainable Development Goals Based on Knowledge Graphs. *Land* **2024**, *13*, 1962. [[CrossRef](#)]

60. Strelkova, I.A.; Antropov, V.V.; Ivanovckya, Z.V. Smart city technologies as an innovative factor in the development of the sustainable cities. In *E3S Web of Conferences*; EDP Sciences: Les Ulis, France, 2020; Volume 208, p. 04014.
61. Kirschner, F.; Lanzendorf, M. Parking management for promoting sustainable transport in urban neighborhoods. A review of existing policies and challenges from a German perspective. *Transp. Rev.* **2020**, *40*, 54–75. [[CrossRef](#)]
62. Guo, Z.; Yuan, X.; Zhou, K.; Fu, L.; Song, Y. How Does the Digital Transformation Affect the Carbon Emissions of Manufacturing Enterprises in China? The Perspective of Green Technology Innovation. *Sustainability* **2024**, *16*, 3184. [[CrossRef](#)]
63. Zhu, Y. A sustainable mechanism for digitization to promote green technological innovation in enterprises. *Appl. Math. Nonlinear Sci.* **2024**, *9*, 1–13. [[CrossRef](#)]
64. Tan, X.; Jiao, J.; Jiang, M.; Chen, M.; Wang, W.; Sun, Y. Digital Policy, Green Innovation, and Digital-Intelligent Transformation of Companies. *Sustainability* **2024**, *16*, 6760. [[CrossRef](#)]
65. Li, H.Y.; Liu, Q.; Ye, H.Z. Digital Development Influencing Mechanism on Green Innovation Performance: A Perspective of Green Innovation Network. *IEEE Access* **2023**, *11*, 22490–22504. [[CrossRef](#)]
66. D’Adamo, I.; Gastaldi, M.; Hachem-Vermette, C.; Olivieri, R. Sustainability, emission trading system and carbon leakage: An approach based on neural networks and multicriteria analysis. *Sustain. Oper. Comput.* **2023**, *4*, 147–157. [[CrossRef](#)]
67. Isensee, C.; Teuteberg, F.; Griese, K.M. How can corporate culture contribute to emission reduction in the construction sector? An SME case study on beliefs, actions, and outcomes. *Corp. Soc. Responsib. Environ. Manag.* **2023**, *30*, 1005–1022. [[CrossRef](#)]
68. He, D.; Deng, X.; Gao, Y.; Wang, X. How does digitalization affect carbon emissions in animal husbandry? A new evidence from China. *Resour. Conserv. Recycl.* **2025**, *214*, 108040. [[CrossRef](#)]
69. Li, J.; Zhang, S.; Ji, L.; Wang, F. Facilitating or Inhibiting: Digital Transformation and Carbon Emissions of Manufacturing Enterprises. *Sustainability* **2025**, *17*, 360. [[CrossRef](#)]
70. Lee, C.C.; He, Z.W.; Yuan, Z. A pathway to sustainable development: Digitization and green productivity. *Energy Econ.* **2023**, *124*, 106772. [[CrossRef](#)]
71. Vátavu, S.; Lobonț, O.R.; Sitnikov, C.; Costea, F. Digitalisation: A new era in the energy industry for sustainability. In *Contemporary Studies in Economic and Financial Analysis*; Emerald Publishing: Leeds, UK, 2022; Volume 109A, pp. 213–230. [[CrossRef](#)]
72. Song, Z.; Hackl, C.M.; Anand, A.; Thommessen, A.; Petzschmann, J.; Kamel, O.; Braunbehrens, R.; Kaifel, A.; Roos, C.; Hauptmann, S. Digital twins for the future power system: An overview and a future perspective. *Sustainability* **2023**, *15*, 5259. [[CrossRef](#)]
73. Rusu-Anghel, S.; Gârnița, I.; Gavrilă, I.; Panoiu, C.; Panoiu, M.; Mezinescu, S. Advanced System for the Control of Work Regime of Railway Electric Drive Equipment. In *6th WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD 10)*; ResearchGate: Berlin, Germany, 2010; pp. 115–121.
74. Song, Y.; Sun, X.; Cai, X.; Liu, X. Impacts of the digital economy on urban low-carbon sustainable development. *Front. Energy Res.* **2024**, *12*, 1425313. [[CrossRef](#)]
75. Yu, Y.; Ren, F.; Ju, Y.; Zhang, J.; Liu, X. Exploring the Role of Digital Transformation and Breakthrough Innovation in Enhanced Performance of Energy Enterprises: Fresh Evidence for Achieving Sustainable Development Goals. *Sustainability* **2024**, *16*, 650. [[CrossRef](#)]
76. Danik, N.; Rud, I.; Symonenko, O.; Bilousko, T.; Tsikalo, Y. Directions of the development of the digital economy in the conditions of military conflicts. *Financ. Credit. Act. Probl. Theory Pract.* **2023**, *1*, 238–248. [[CrossRef](#)]
77. Karpunina, E.K.; Lapushinskaya, G.K.; Arutyunova, A.E.; Lupacheva, S.V.; Dubovitski, A.A. Dialectics of sustainable development of digital economy ecosystem. In *Scientific and Technical Revolution: Yesterday, Today and Tomorrow*; Springer International Publishing: Cham, Switzerland, 2020; pp. 486–496.
78. Karpunina, E.K.; Yurina, E.A.; Samoylova, S.S. Economic security of business structures in the digital economy. In Proceedings of the 32nd International Business Information Management Association Conference, IBIMA 2018—Vision 2020: Sustainable Economic Development and Application of Innovation Management from Regional Expansion to Global Growth, Seville, Spain, 15–16 November 2018; pp. 3085–3092.
79. Yang, Q.; Ma, H.; Wang, Y.; Lin, L. Research on the influence mechanism of the digital economy on regional sustainable development. *Procedia Comput. Sci.* **2022**, *202*, 178–183. [[CrossRef](#)]
80. Rey-Moreno, M.; Periañez-Cristóbal, R.; Calvo-Mora, A. Reflections on sustainable urban mobility, mobility as a service (MaaS) and adoption models. *Int. J. Environ. Res. Public Health* **2022**, *20*, 274. [[CrossRef](#)] [[PubMed](#)]
81. Ashworth, T.; Catalano, A.; Fabrizio, E.; Filippi, M. Application of a multi-field sensor into an office building. In *2022 IEEE International Workshop on Metrology for Living Environment, MetroLivEn*; IEEE: New York, NY, USA, 2022; pp. 1–6.
82. Hadizadeh, M.; Ghaffari Feyzabadi, J.; Fardi, Z.; Mortazavi, S.M.; Braga, V.; Salamzadeh, A. Digital Platforms as a Fertile Ground for the Economic Sustainability of Startups: Assaying Scenarios, Actions, Plans, and Players. *Sustainability* **2024**, *16*, 7139. [[CrossRef](#)]

83. Fabregas, R.; Kremer, M.; Schilbach, F. Realizing the potential of digital development: The case of agricultural advice. *Science* **2019**, *366*, eaay3038. [[CrossRef](#)]
84. Danskaya, A.V. Digital Transformation of the Labor Market in an Environmentally Oriented Perspective. In *Smart Green Innovations in Industry 4.0*; Springer Climate: Cham, Switzerland, 2023; Volume F1853, pp. 333–339. [[CrossRef](#)]

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