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Review

Artificial Intelligence and Sustainability—A Review

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Abstract: In recent decades, artificial intelligence has undergone transformative advancements, reshaping diverse sectors such as healthcare, transport, agriculture, energy, and the media. Despite the enthusiasm surrounding AI's potential, concerns persist about its potential negative impacts, including substantial energy consumption and ethical challenges. This paper critically reviews the evolving landscape of AI sustainability, addressing economic, social, and environmental dimensions. The literature is systematically categorized into "Sustainability of AI" and "AI for Sustainability", revealing a balanced perspective between the two. The study also identifies a notable trend towards holistic approaches, with a surge in publications and empirical studies since 2019, signaling the field's maturity. Future research directions emphasize delving into the relatively under-explored economic dimension, aligning with the United Nations' Sustainable Development Goals (SDGs), and addressing stakeholders' influence.

Keywords: artificial intelligence; AI; sustainability; systematic mapping study

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1. Introduction

In the past decades, seminal advancements have been made in the field of Artificial Intelligence (AI) [1]. AI has the potential to transform various markets and industries, driving unforeseen change [2,3]. Sectors such as healthcare [4], transport [5], agriculture [6], energy [7], and the media [8] have seen major changes implemented as a result of AI systems. Despite widespread enthusiasm, there exists a notable caution, stemming from both evidence showcasing AI's efficacy and concerns about potential negative effects [9]. For instance, training a state-of-the-art model, especially Natural Language Processing (NLP) models, requires substantial computational resources, imposing significant energy along with associated financial and environmental costs [10]. Furthermore, the rise of AI also sparked new ethical and societal challenges for the economy and society. These challenges include concerns about stagnant real wages for workers [11] and social injustice originating from discriminating AI systems [12,13], as well as the proliferation of fake news [14–16]. Hence, researchers are increasingly interested in examining their impact on sustainability. Comprehending the effects and transformative potential AI can drive, specifically on sustainability, requires a critical review of the topic.

Sustainability can be analyzed by focusing on one of the following three dimensions: economic, social, and environmental [17]. Furthermore, when surveying the current body of literature on AI sustainability, research is often divided between AI as a tool for achieving sustainable goals and the impact of AI on sustainability [18]. However, current studies on this topic often look only at one certain dimension, which might oversimplify the issue at hand, creating a narrow view of what AI sustainability truly entitles.

Given the current non-holistic state of the research outlined above, the primary objective of this paper is to create a Systematic Mapping Study (SMS) that allows for the compilation and analysis of the available literature on the topic, unifying both perspectives across all three dimensions of sustainability. By doing so, this paper intends to identify knowledge gaps and inspire future research endeavors. Moreover, our SMS will allow researchers, policymakers, as well as businesses to have a concise overview of the current findings in the field.

This paper is structured as follows: Section 2 presents our initial literature review, where the fundamental concepts as well as current reviews of research on AI sustainability are introduced. Section 3 elaborates on the methodological approach of the paper by going through the main steps of our SMS. In Section 4, our main research questions are analyzed and answered, along with visualizations based on our data sets. In Section 5, we discuss the limitations of our study, and Section 6 provides the conclusion.

2. Initial Literature Review

Oxford dictionary defines AI as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages". Here, we see the emergence of AI as a system that can act similarly to humans. John McCarthy, widely known as one of the fathers of AI, defined AI as "the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable" [19]. Though in McCarthy's definition, the idea of human-like behavior is present, he goes further by defying the limits of the possibility of AI, differentiating it from human intelligence, and highlighting that its boundaries are not limited by biology.

When it comes to sustainability, we can see an evolution of the concept. Early on, in 1987, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Authors have since added depth to the concept, breaking it down into three different dimensions or pillars: social, economic, and environmental [17].

Ref. [18] points out the dichotomy of using AI to achieve sustainability and sustainability of utilizing AI systems, and hence, the term "Sustainable AI" has been introduced to address the whole socio-technical system of AI.

According to existent literature, the rapid growth of AI has raised concerns about its environmental and social sustainability [20]. To address these issues, there is a need for AI governance and regulation, multidisciplinary collaboration, and building trust in AI applications [21]. AI has the potential to support environmental governance and reduce resource and energy intensity [22]. However, there are challenges, such as over-reliance on historical data, uncertain human behavioral responses, and cybersecurity risks [22]. Ref. [22] also suggests that future research should consider multilevel views, systems dynamics approaches, design thinking, psychological and sociological considerations, and economic value considerations. To portray the big picture of AI sustainability, we analyzed the related previous literature reviews by other researchers in this field with the two aspects described above, i.e., AI for sustainability and sustainability of AI.

2.1. *AI for Sustainability*

The study by [22] argues that AI has the potential to facilitate the development of culturally suitable organizational processes and individual practices that can effectively reduce the ecological footprint of human activities. However, the true significance of AI lies not solely in its capacity to diminish energy, water, and land usage intensities within society, but rather in its ability to enhance and nurture environmental governance at a higher level.

Another literature review of AI for sustainability by Kar et al. [23] focuses on diverse applications across sectors such as construction, transportation, healthcare, manufacturing, agriculture, and water management. The paper highlights the approaches, difficulties, and obstacles regarding adopting AI for sustainable development.

This literature highlights the various methods used to improve sustainable practices on a small to large scale using AI and various future research directions for academic researchers [23].

In short, the state-of-the-art research on AI for sustainability encompasses a wide range of topics, including energy efficiency, climate change mitigation, resource management, biodiversity conservation, and more.

2.2. Sustainability of AI

The review paper by Verdecchia et al. [24] reviews the growing field of Green AI, which addresses the environmental impact of artificial intelligence. It highlights trends like increased interest since 2020, methods for improving model sustainability, and the involvement of academia and industry. The findings suggest a mature field ready for broader adoption in both research and industrial practice.

The study by Natarajan et al. [25] has the main aim of discerning the ongoing research trajectories within the intersection of AI and sustainability. Additionally, the article employs the affordance theory as its conceptual framework, intending to pinpoint the affordances within the realm of sustainable AI.

Notably, the field has exhibited significant growth since 2020. The majority of studies focus on monitoring AI model footprints, fine-tuning hyperparameters to enhance model sustainability, or conducting model benchmarking.

2.3. Combining AI for Sustainability and Sustainability of AI

While the applications of AI and related technologies have the potential for more efficient utilization of land and seascapes, heightened capabilities in environmental monitoring, and enhanced transparency within supply chains, there could also be systemic sustainability challenges emerging as these AI technologies extend to novel social, economic, and ecological domains. Although some recent compilations [18,26] briefly acknowledge these risks, they often provide only brief elaboration on the potential harms and unanticipated social and ecological consequences [27]. In many cases, influential reports outlining the societal impacts of AI either disregard the dimensions of sustainability entirely or downplay the conceivable social, economic, and ecological risks they might pose [28]. In contrast, ref. [29] offers a more holistic overview of the involvement of those technologies in fields which have a relatively greater influence on sustainability in an environmental sense. The study also addresses potential challenges that could jeopardize the sustainability of AI. Besides the unfolding of these underlying challenges, the authors also discuss the limitations of existing research frameworks in effectively tackling sustainability-related AI risks within these sectors [29].

In reviewing existing literature in the field of AI sustainability, it is clear that many tend to focus narrowly on either AI for sustainability or the sustainability of AI. Only a sparse number of works consider both aspects, and even those predominantly emphasize only one or two dimensions, primarily the environmental aspect. This leads to an incomplete understanding of the broader landscape. Our paper aims to address this gap by offering a more comprehensive view of the research filed by integrating both perspectives, at the same time capturing the various dimensions of AI sustainability, i.e., environmental, economic, and social. This approach allows for a deeper understanding of the complexities and interactions within AI sustainability. By doing so, we not only fill a noticeable void in the literature, but also provide a framework for future research. This synthesis enables scholars to grasp the broader context, identify trends, and pinpoint areas for further investigation.

In essence, our goal is to offer a more inclusive exploration of AI sustainability, facilitating a better understanding of this topic. Through this approach, we aim to contribute to the ongoing discourse and inform future research directions.

3. Research Methodology

Our paper employed a Systematic Mapping Study (SMS) as the research methodology to explore the topic of AI sustainability. While Systematic Literature Reviews (SLR) delve deeply into particular research inquiries through empirical studies, SMS takes a broader approach, offering an encompassing view of the literature in emerging research domains. SMS organizes and characterizes literature studies along various dimensions, addressing overarching questions like prevalent research methodologies and publication avenues. Unlike SLR, SMS provides a panoramic view of emerging fields, often employing visual aids like graphs and succinct data summaries for enhanced comprehension. While both methodologies have different strengths, in our study of AI sustainability, which is a relatively emerging study topic, SMS extends distinct advantages to researchers and practitioners, facilitating comprehensive understanding of evolving research areas [30].

We followed the "input–processing–output" approach by Levy and J. Ellis [31], which states the three stages of the effective literature review process. These stages were further delineated into five steps shown in Figure 1. Initially, the focus was on defining the scope and objectives, setting the foundation for the subsequent phases. This was followed by a comprehensive search for relevant literature, ensuring a thorough exploration of existing knowledge within the defined parameters. The third step involved rigorous screening and selection of literature, where meticulous attention was paid to relevance and quality. Moving into the processing phase, the fourth step entailed the development of a classification scheme and systematic map, facilitating the organization and synthesis of gathered insights. Finally, in the output phase, the interpretation of findings and review output occurred, culminating in a coherent and insightful analysis ready for dissemination and application in the relevant domain. Through this structured approach, we aimed to ensure methodical and rigorous execution, ultimately yielding valuable contributions to the existing body of knowledge.

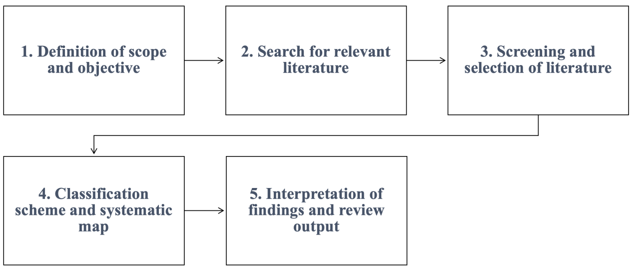

Figure 1. Research Methodology Framework.

3.1. Definition of Scope and Objective

To formulate the scope of the research, we conducted some preliminary research on AI sustainability, across the following three dimensions: environmental, economic, and social. We found out that using AI is accompanied by some major drawbacks. For example, many research papers raise a concern about the harmful impacts of accompanying computational processes on the environment. Specifically, training AI uses large data sets and consumes a tremendous amount of energy, which comes with tremendous greenhouse gas and other emissions [32]. After an examination of existent literature reviews within the research field of AI sustainability, we found that most papers investigate this topic by only summarizing either AI's contribution toward sustainability goals or AI's impact on a specific field. Consequently, we observed a lack of a precise definition of the term, AI sustainability, which acted as our motivation for the first research question (RQ1). In the process of reviewing existing research papers, we observed various trends in relation to their content scope. This intensified our curiosity to explore the maturity quotient of this research field, as it is a relatively new field and inspired us to formulate our second research question (RQ2). Further, the identification of research gaps during our research prompted us to examine adequate strategies to address these gaps. This acted as the motivation for our third research question (RQ3). Thus, aiming to provide novel insights and to address aspects that have potentially remained under-explored in the academic discourse, we formulate the research questions of this paper as follows:

RQ1: How does the existing literature capture AI sustainability? This objective aims to provide a comprehensive understanding of how the current body of literature addresses the concept of AI sustainability. By conducting a systematic review, we can identify key themes, trends, and gaps in the existing research landscape, laying the foundation for further analysis and exploration. Inspired by Heilinger et al. [33], whose paper analyzes the ends and means of "sustainable AI" in social and environmental contexts, we therefore aim to explore in our paper two fundamental facets of AI sustainability, i.e., AI as a tool to achieve sustainability as well as the sustainability concerns of AI itself. Within each aspect, we further investigate three dimensions: environmental, social and economic.

RQ2: What is the maturity level of the research field of AI sustainability? This objective seeks to evaluate the depth and breadth of research conducted in the field of AI sustainability, including the extent of the research interest, the volume of publications, and the evolution of research topics over time. Understanding the maturity level can help gauge the level of advancement, identify areas of strength, and pinpoint emerging trends or areas requiring further investigation. Thus, this research question tries to evaluate the different approaches within the existing literature. What degree of empirical evidence can be observed in the existing literature? Are the majority of research papers on this topic still evaluating the associated problems? Are some solutions regarding the issues currently being implemented?

RQ3: What is the future research agenda of the research field of AI sustainability? This objective aims to propose directions for future research endeavors based on the insights gained from our review and assessment of the current state of the field. Here, we observe the research gaps in the existing literature, and we identify the possible road-map for potential research. By answering this question, we try to deliver some insights to guide researchers and practitioners in further contributing to this field.

3.2. Search for Relevant Literature

A comprehensive and extensive literature search is guaranteed by utilizing diverse sources and employing suitable keywords and search operators.

As the next step in our methodology, we needed to find and analyze relevant literature on our topic. To have a thorough process, we defined our search strategy and also identified sources to find the relevant literature. In our search strategy, we defined a list of keywords that we used to find the relevant literature on our target sources. We used both advanced and manual search techniques to find the relevant literature on our topic. List of databases used:

- Google Scholar
- Science Direct
- IEEE
- Springer Link
- Elicit.org
- ACM Digital Library
- AIS eLibrary

This choice of databases made our list of resources quite holistic, ranging from general platforms like Google Scholar and Science Direct to more information systems-oriented platforms such as ACM Digital Library and AIS eLibrary. Furthermore, we supplemented our research strategy with forward and backward searches. The former requires reviewing all research papers, citing the targeted research paper, and providing a good overview of its contribution, and the latter requires finding all cited references in this targeted research paper. To check the quality of the results, we also tried using different queries on each database. This step also helped us to narrow down our choice of databases.

The keywords used during our literature research were:

- AI Sustainability
- Artificial intelligence sustainability
- Sustainable AI
- AI environmental impact
- AI economic impact
- AI social impact
- Artificial intelligence environmental impact
- Artificial intelligence economic impact
- Artificial intelligence social impact
- AI ethics

To ensure comprehensive coverage of literature relevant to our research topic on AI sustainability, we crafted a set of keywords tailored to capture the nuances of our inquiry. With our research topic delineated into two primary aspects, namely AI for sustainability and the sustainability of AI, each further divided into three dimensions encompassing environmental, economic, and social impacts, our keyword selection process was strategic and iterative. We began by identifying core terms such as "AI sustainability" and "sustainable AI". Building upon this foundation, we expanded our keyword list to encapsulate specific aspects and dimensions, including terms like "AI environmental impact", "AI social impact" and "AI economic impact". Furthermore, we employed synonymous terms, related concepts, and variations in terminology to ensure inclusivity and comprehensiveness in our literature search. Through this approach to keyword formulation, we aimed to cast a wide net, facilitating the thorough exploration and retrieval of literature pertinent to our multifaceted research inquiry into the sustainability implications of AI.

The mandatory condition for the keywords was that each keyword had to cover our review scope. Further, before including it, every keyword was also tested on each database. This step helped us double-check if the keyword used gave relevant results or not. Moreover, during this test, we also took care that if a keyword generated results that had already been covered before, that specific keyword was not included in our analysis. From the initial list, the keywords that did not produce relevant results or represented any sort of search bias were also excluded. While searching for papers on every database with our set of keywords, we looked at the papers up until the point when the relevant papers were coming up to a certain extent. We observed that the relevance of papers was decreasing, the further behind the papers were located in the search results. To make our process more comprehensive, we stored all the useful information from the relevant literature in the form of a Notion database (https://www.notion.so, accessed on 31 August 2023).

3.3. Screening and Selection of Literature

To ensure transparency and establish the credibility of the review, we refined the literature selection by employing explicit inclusion and exclusion criteria.

3.3.1. Inclusion Criteria

- I1: Abstract explicitly highlights the topic of AI sustainability. This criterion helped us to only choose research papers having both components and to remove the papers talking about AI in some other context, and not explicitly stating either AI for sustainability or the impact of AI on sustainability.
- I2: The paper's focus aligns with the chosen research focus. While going through the paper, if the research paper did not cohesively talk about AI sustainability, then that paper was not included in our analysis.
- I3: Abstract and keywords contain key terms related to the topic. Using this, we eliminated papers that contained the keywords of AI sustainability, but whose content was outside the scope of our research.

3.3.2. Exclusion Criteria

- E1: Content focuses only on a specific niche sub-field of research regarding AI sustainability. To have an overall understanding of our topic, papers corresponding to a niche-specific sub-field of research with AI sustainability were not included.
- E2: Publication date before 2000 (or after the first half of 2023). This criterion is useful because very few papers on this topic exist in the year range 2010–2018. Further, the year range 2000–2010 did not give any significant results. Hence, keeping the threshold at 2000 helped us to make our analysis extensive and at the same time a bit more efficient. The cut-off of our search and analysis is the first half of 2023.
- E3: Abstract does not cover AI sustainability. To ensure that the analysis is strictly within the scope of our research, we excluded those papers whose abstracts exhibited a complete absence of any reference to AI sustainability.
- E4: Full paper not accessible. Papers that looked relevant from the title and first information, but were not accessible, were also excluded from our analysis.
- E5: Language not in English. Non-English papers were excluded from our analysis due to limitations in the authors' language proficiency.

Out of 148 candidate papers collected using the list of keywords, a total of 60 were subjected to exclusion by the exclusion criteria, 46 of which were excluded through E3: Abstract does not cover AI sustainability. On the other hand, only one paper was excluded because of E5: Language not in English.

In the end, we included 88 papers, which served as the effective corpus of our literature analysis (see Table 1).

Table 1. List of Selected Literature.

No.	Title	Year	Author
1	The Ethics of Artificial Intelligence	2014	Bostrom and Yudkowsky [34]
2	AI Ethics: Science Fiction Meets Technological Reality	2015	Zeng [35]
3	Artificial Intelligence and Economic Growth	2017	Aghion et al. [36]
4	The Rise of Artificial Intelligence under the Lens of Sustainability	2018	Khakurel et al. [37]
5	Artificial Intelligence: the Global Landscape of Ethics Guidelines	2019	Jobin et al. [38]
6	Principles Alone Cannot Guarantee Ethical AI	2019	Mittelstadt [39]
7	AI Ethics in Industry: A Research Framework	2019	Vakkuri et al. [40]
8	AI Ethics for Systemic Issues: A Structural Approach	2019	van der Loeff et al. [41]
9	What Do Artificial Intelligence (AI) and Ethics of AI Mean in the Context of Research Libraries?	2019	Kennedy [42]
10	Technology Innovation and AI Ethics	2019	Johnson [43]
11	Edge AI based Waste Management System for Smart City	2019	Thwal et al. [44]
12	Economic impacts of artificial intelligence	2019	Szczepanski [45]
13	From What to How: An Initial Review of Publicly Available AI Ethics Tools, Methods and Research to Translate Principles into Practices	2019	Morley et al. [46]
14	Artificial Intelligence (AI) Ethics: Ethics of AI and Ethical AI	2020	Siau and Wang [47]
15	AI Ethics: How Can Information Ethics Provide A Framework To Avoid Usual Conceptual Pitfalls? An Overview	2021	Bruneault and Laflamme [48]

Table 1. *Cont.*

16	AI Ethics: A Strategic Communications Challenge	2020	Lawrence-Archer [49]
17	The Ethics Of AI In Health Care: A Mapping Review.	2020	Morley et al. [50]
18	Artificial Intelligence and Machine Learning in Waste Management and Recycling	2020	Ahmed and Asadullah [51]
19	Artificial Intelligence For Sustainability: Challenges, Opportunities, And A Research Agenda	2020	Nishant et al. [22]
20	The Role Of Artificial Intelligence In Achieving The Sustainable Development Goals	2020	Vinuesa et al. [52]
21	Should AI Be Designed To Save Us From Ourselves?	2020	Lahsen [53]
22	Academic Policy Regarding Sustainability and Artificial Intelligence (AI)	2020	Tanveer et al. [54]
23	Artificial Intelligence And Sustainable Development	2020	Goralski and Tan [55]
24	Artificial Intelligence And Business Models In The Sustainable Development Goals Perspective: A Systematic Literature Review	2020	Di Vaio et al. [56]
25	The Impact of Digitalization on the Economy: A Review Article on the NBER Volume "Economics of Artificial Intelligence: An Agenda"	2020	Santor [11]
26	Application Of Artificial Intelligence On The CO2 Capture: A Review	2021	Cao [57]
27	The Mutual Benefits Of Renewables And Carbon Capture: Achieved By An Artificial Intelligent Scheduling Strategy	2021	Chen et al. [58]
28	AI Ethics: A Call To Faculty	2021	Nourbakhsh [59]
29	A High-Level Overview of AI Ethics	2021	Kazim and Koshiyama [60]
30	AI Ethical Bias: A Case For AI Vigilantism (Ailantism) In Shaping The Regulation of AI	2021	Nwafor [61]
31	Ethical Review in The Age of Artificial Intelligence	2021	Heo [62]
32	AI Ethics In Business–A Bibliometric Approach	2021	Ciobanu and Meșniță [63]
33	Artificial Intelligence: Ethical And Social Considerations	2021	Corea [64]
34	Artificial Intelligence Based E-Waste Management For Environmental Planning	2021	Chen et al. [65]
35	AI Waste Prevention: Time and Power Estimation for Edge Tensor Processing Units	2021	Reif et al. [66]
36	Emerging Role Of Artificial Intelligence In Waste Management Practices	2021	Sharma and Vaid [67]
37	Towards Artificial Intelligence In Urban Waste Management: An Early Prospect For Latin America	2021	Bijos et al. [68]
38	Sustainable AI: AI for Sustainability And The Sustainability Of AI	2021	Van Wynsberghe [18]
39	Artificial Intelligence, Systemic Risks, And Sustainability	2021	Galaz et al. [29]
40	Artificial Intelligence In Research And Development For Sustainability: The Centrality Of Explicability And Research Data Management	2022	Hermann and Hermann [69]
41	AI in Context and the Sustainable Development Goals: Factoring in the Unsustainability of the Sociotechnical System	2021	Sætra [9]

Table 1. *Cont.*

42	Assessing Whether Artificial Intelligence Is An Enabler Or An Inhibitor Of Sustainability At Indicator Level	2021	Gupta et al. [70]
43	The Ethics of Sustainability for Artificial Intelligence	2021	Owe and Baum [71]
44	Sustainability Challenges of Artificial Intelligence and Policy Implications	2021	Rohde et al. [72]
45	Sustainable AI: Environmental Implications, Challenges and Opportunities	2022	Wu et al. [73]
46	Artificial Intelligence for Sustainable Energy: A Contextual Topic Modeling and Content Analysis	2021	Saheb and Dehghani [74]
47	Greening the Artificial Intelligence for a Sustainable Planet: An Editorial Commentary	2021	Yigitcanlar [75]
48	A Panoramic View And Swot Analysis Of Artificial Intelligence For Achieving The Sustainable Development Goals By 2030: Progress And Prospects	2021	Palomares et al. [76]
49	Sustainable Artificial Intelligence: A Corporate Culture Perspective	2021	Isensee et al. [77]
50	Green Artificial Intelligence: Towards an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures	2021	Yigitcanlar et al. [78]
51	Influence of Artificial Intelligence in Civil Engineering toward Sustainable Development—A Systematic Literature Review	2021	Manzoor et al. [79]
52	Artificial Intelligence-Driven Digital Technologies to the Implementation of the Sustainable Development Goals: A Perspective from Brazil and Portugal	2021	Pigola et al. [80]
53	Impact of AI on Environment	2021	Verma et al. [81]
54	Achieving Sustainability with Artificial Intelligence-A Survey of Information Systems Research	2021	Schoormann et al. [82]
55	Application of Disruptive Technologies on Environmental Health: An overview of artificial intelligence, blockchain and internet of things	2021	Kumar et al. [83]
56	Ethics of AI: A Systematic Literature Review of Principles and Challenges	2021	Khan et al. [84]
57	AI Ethics—A Bird's Eye View	2022	Christoforaki and Beyan [85]
58	AI Ethics as Applied Ethics	2022	Hallamaa and Kalliokoski [86]
59	Artificial Intelligence Applications For Sustainable Solid Waste Management Practices In Australia: A Systematic Review.	2022	Andeobu et al. [87]
60	Artificial Intelligence with Earthworm Optimization Assisted Waste Management System for Smart Cities	2023	Rajalakshmi et al. [88]
61	How Can Artificial Intelligence Impact Sustainability: A Systematic Literature Review	2022	Kar et al. [23]
62	How To Realize The Full Potentials Of Artificial Intelligence (AI) In Digital Economy? A Literature Review	2022	Hang and Chen [89]
63	ECO2AI: Carbon Emissions Tracking Of Machine Learning Models As The First Step Towards Sustainable AI	2022	Budennyy et al. [90]

Table 1. *Cont.*

64	Is the future of AI Sustainable? A Case Study of the European Union	2022	Perucica and Andjelkovic [91]
65	A Survey on AI Sustainability: Emerging Trends on Learning Algorithms and Research Challenges	2022	Chen et al. [20]
66	Sustainable AI: An Integrated Model to Guide Public Sector Decision-Making	2022	Wilson and Van Der Velden [92]
67	Managing Sustainability Tensions in Artificial Intelligence: Insights from Paradox Theory	2022	Mill et al. [93]
68	Note: Leveraging Artificial Intelligence To Build A Data Catalog And Support Research On The Sustainable Development Goals	2022	Spezzatti et al. [94]
69	Towards Sustainable Artificial Intelligence: An Overview of Environmental Protection Uses and Issues	2022	Pachot and Patissier [95]
70	A Systematic Mapping of Artificial Intelligence Solutions for Sustainability Challenges in Latin America and the Caribbean	2022	Salas et al. [96]
71	A Framework to Analyze the Impacts of AI with the Sustainable Development Goals	2022	Si [97]
72	Our New Artificial Intelligence Infrastructure: Becoming Locked into an Unsustainable Future	2022	Robbins and Van Wynsberghe [98]
73	Special Issue "Towards the Sustainability of AI; Multi-Disciplinary Approaches to Investigate the Hidden Costs of AI"	2022	Van Wynsberghe et al. [99]
74	Artificial Intelligence and Poverty Alleviation: Emerging Innovations and Their Implications for Management Education and Sustainable Development	2022	Goralski and Tan [100]
75	A Review and Categorization of Artificial Intelligence-Based Opportunities in Wildlife, Ocean and Land Conservation	2022	Isabelle and Westerlund [101]
76	Sustainable Development of Enterprises in Conditions of Smart Ecology: Analysis of The Main Problems and Development of Ways to Solve Them, Based on Artificial Intelligence Methods and Innovative Technologies	2022	Skiter et al. [102]
77	Embedding Artificial Intelligence and Green Ideology in Formulating Corporate and Marketing Strategies	2022	Baqi et al. [103]
78	Artificial intelligence: Catalyst or Barrier on the Path to Sustainability?	2022	Kopka and Grashof [104]
79	On the Impact of Artificial Intelligence on Economy	2022	Solos and Leonard [105]
80	A Systematic Review of Green AI	2023	Verdecchia et al. [24]
81	AI Ethics Principles in Practice: Perspectives of Designers and Developers	2023	Sanderson et al. [106]
82	Waste Classification Using Artificial Intelligence Techniques:Literature Review	2023	Nasir and Aziz Al-Talib [107]
83	Shaping the Future of Sustainable Energy through AI-Enabled Circular Economy Policies	2023	Danish and Senjyu [108]
84	Artificial Intelligence for Waste Management in Smart Cities: A Review	2023	Fang et al. [109]

Table 1. *Cont.*

85	Deploying Digitalisation and Artificial Intelligence in Sustainable Development Research	2023	Leal Filho et al. [110]
86	Applications of Artificial Intelligence in Social Science Issues: A Case Study on Predicting Population Change	2023	Farahani [111]
87	Sustainable Development Goals Applied to Digital Pathology and Artificial Intelligence Applications in Low- to Middle-Income Countries	2023	Piya and Lennerz [112]
88	Research on the Impact of Artificial Intelligence Technology on Green Innovation	2022	Zhang [113]

3.4. Classification Scheme and Systematic Map

We read abstracts and extracted useful information from the selected papers. We also looked for key points and concepts that reflected the contribution of the paper. Then the information was documented in our Notion database and combined to develop a high-level understanding of the nature and contribution of the research. This helped us define a set of categories that is representative of the underlying population. When abstracts alone could not deliver enough information, we also studied the introduction or conclusion sections of the papers. When a final set of information is chosen, they are clustered and used to form the categories for the map [114].

3.5. Interpretation of Findings and Review Output

The findings are one of the main priorities in SMS, which offer an explanation and understanding of the results so that researchers can proceed with their literature study after confirming all these criteria. The analysis of the database is mainly based on the frequency of publications for each category. By doing so, we were able to discover which categories have gained heightened attention and research endeavors, which also made it possible for us to identify potential for prospective research. The results will be more explicitly presented in the following sections of this paper.

4. Results and Visualization

4.1. RQ1: How Does the Existing Literature Capture AI Sustainability?

The literature review conducted led to the identification of distinct categories that provide a nuanced understanding of the multifaceted field of AI sustainability. One noteworthy categorization stems from varying interpretations of AI sustainability—some authors predominantly focus on assessing and mitigating the impact AI has on sustainability, while others explore how existing AI technologies can contribute to achieving sustainable development. This classification, inspired by Van Wynsberghe [18], delineates the 88 mapped papers into two primary categories: Sustainability of AI (43.2%) and AI for Sustainability (43.2%), with a smaller subset (13.6%) adopting a holistic approach addressing both facets simultaneously, as depicted in Figure 2.

The examination of sustainability dimensions, guided by [17], further stratified the literature based on specific niche fields or aspects within each dimension. Some papers focused on only one niche field or specific aspect, while others targeted two or three dimensions.

Figure 3 shows the breakdown of the papers per category. Notably, the Environmental dimension emerged as the most prevalent, encompassing studies that delve into AI's interactions with the natural environment, such as carbon emission measurement, energy consumption optimization, and the energy costs of running large ML models. Following closely is the Social dimension, which explores ethical considerations, educational implications, and issues of equality related to AI. The Economic dimension, although the smallest, is represented by papers investigating economic growth, labor market dynamics, and novel business models. The third-biggest category includes papers that integrate all three dimensions and examine sustainability through a more comprehensive lens, which address its complexity by encompassing a broader perspective.

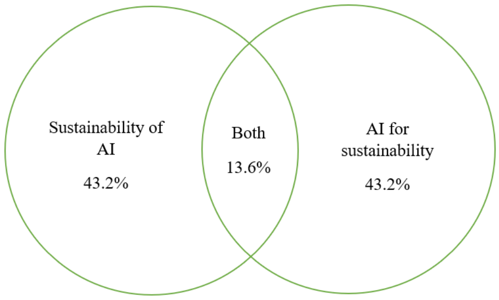

Figure 2. Sustainability of AI vs. AI for Sustainability.

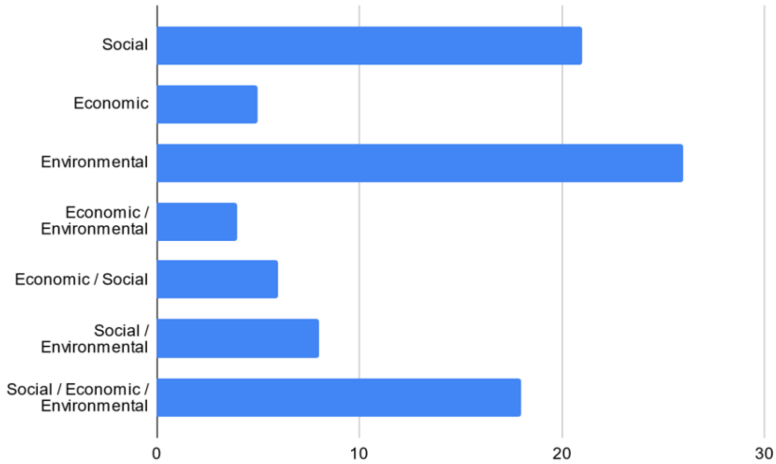

Figure 3. Literature survey on AI Sustainability.

Table 2 offers a comprehensive view of paper distribution across categories, combining both proposed frameworks. Particularly noteworthy is the emphasis of "AI for Sustainability" papers on the environmental dimension, while those categorized under "Sustainability of AI" prioritize the social dimension. The economic dimension, as previously discussed, is comparatively less explored in this domain. Additionally, among the 88 papers reviewed, only five provided an all-inclusive perspective by addressing both "AI for Sustainability" and "Sustainability of AI", and covering all three sustainability dimensions.

Table 2. Overview of Papers on AI Sustainability.

	AI for Sustainability	Sustainability of AI	Both	Total
Social	3	15	3	21
Economic	2	2	1	5
Environmental	16	7	3	26
Economic/Environmental	3	1	0	4
Economic/Social	1	5	0	6
Social/Environmental	4	4	0	8
Social/Economic/Environmental	9	4	5	18
Total	38	38	12	88

The observed fragmentation within the field underscores the ongoing evolution of research, with some papers intentionally unifying disparate dimensions, while others remain focused on specific facets of AI sustainability. This nuanced understanding emphasizes the need for a holistic approach to guide the future development and deployment of sustainable AI practices.

4.2. RQ2: What is the Maturity Level of the Research Field of AI Sustainability?

We utilized the Litmaps platform, designed for generating interactive literature maps that group articles on a given research topic. In our analysis, we choose "Cited-by" on the Y-axis and "Date" on the X-axis. "Cited-by" arranges the papers in the increasing order of their "total number of citations", positioning the most total citations at upper the end of the axis; the "Date" parameter orders by their recency, placing the most recent ones the right end of the axis. As shown in Figure 4, the paper "The global landscape of AI ethics guidelines" by Jobin et al. [38] has the greatest number of total citations in our database (1024 citations). Hence, it is represented as the topmost paper on our map. Furthermore, the paper, "Shaping the future of sustainable energy through AI-enabled circular economy policies" by Danish and Senjyu [108], is the most recent and is located at the extreme right of our map. Moreover, while [35] initially touched on AI sustainability from both AI for sustainability and the sustainability of AI perspectives, it was [18]'s advocacy for differentiating between these two perspectives that spurred an increasing number of papers to adopt this approach in their studies on AI sustainability. Besides, although [37] explored the topic with all three dimensions as early as 2018, it was not until 2021 that several papers followed suit, potentially influenced by [52], the second most cited paper in the field. Remarkably, the map illustrates that only a very small fraction of papers in the field comprehensively address AI sustainability with both perspectives and all dimensions—only five papers [70,71,77,82,98] achieve this, leading to what we called a "non-holistic" approach.

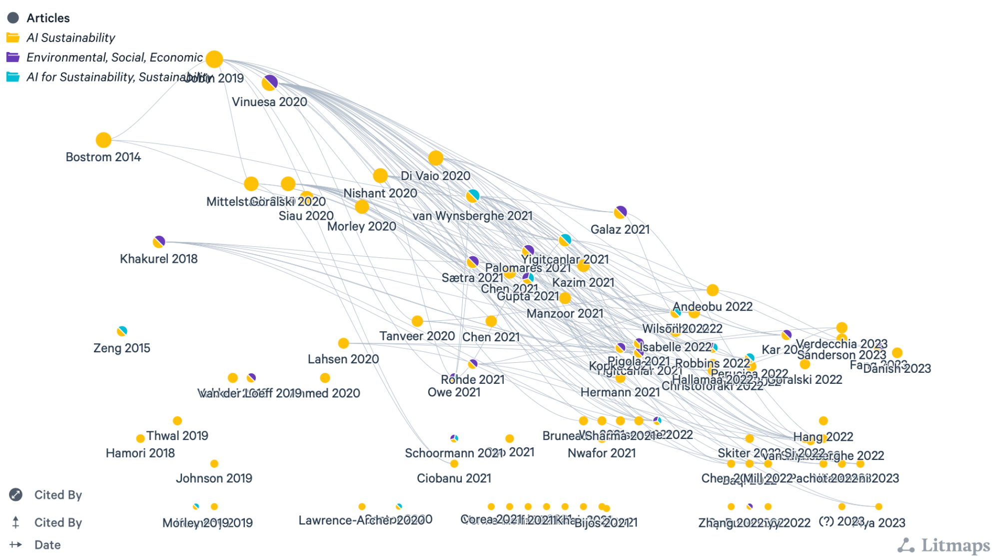

Figure 4. Litmaps Analysis.

To assess the maturity of the field of "AI Sustainability", we adopted the framework proposed by Keathley-Herring et al. [115]. The assessment of maturity in any research field is inherently challenging and often involves subjective evaluation, particularly given that research domains do not follow predictable maturation patterns. Nevertheless, many researchers incorporate maturity analysis into their assessments, recognizing its potential to offer valuable insights and assess the developmental stage of the research field's literature [115]. To address RQ2, we base our analysis mainly on five elements: publication years, contribution types, citations, authorship and breadth of methods. These factors collectively contribute to a comprehensive understanding of the landscape and evolution of this research field.

4.2.1. Publication Years: When Did Research on AI Sustainability Become Active in the Artificial Intelligence Field?

As depicted in Figure 5, within the corpus of 88 papers constituting our data set, only a small portion was published before 2019. The year 2020 witnessed a substantial surge in research on AI sustainability, and this trend persisted with a continued increase in the number of publications in 2021. It is important to note that the lower count of papers published in the year 2023 is attributed to our cut-off in the first half of 2023 and also procedural delays in the review and publication processes.

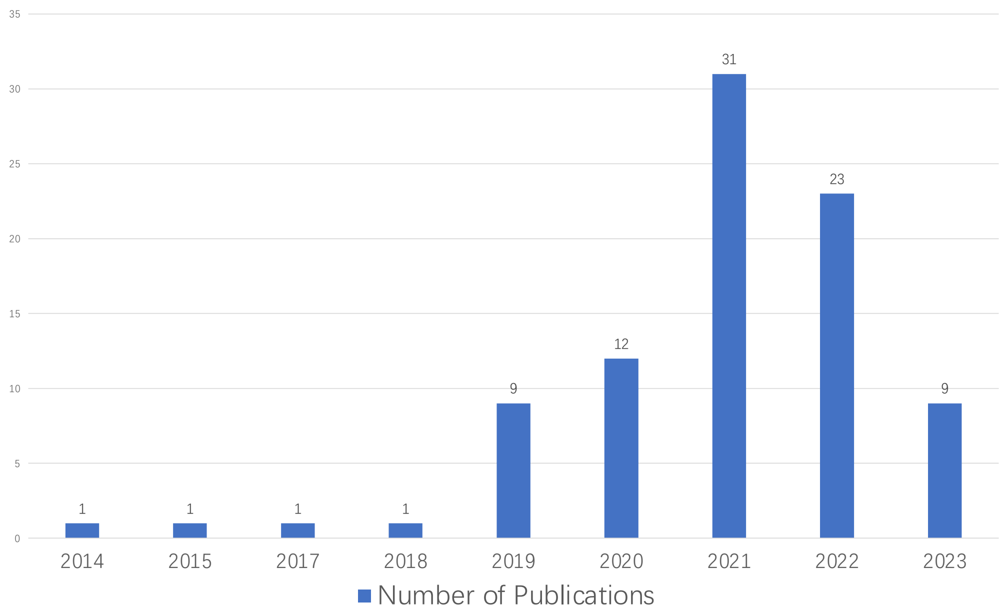

Figure 5. Publications by Year (cut-off at the first half of 2023).

4.2.2. Contribution Types: What Are the Different Approaches in the Existing Literature?

In pursuit of answering this query, we employ a classification scheme based on the contribution types of the papers. This classification scheme draws upon the comprehensive framework originally propounded by Wieringa et al. [116], which provides a robust conceptual underpinning. Additionally, we integrate the explicit evaluation criteria summarized by Petersen et al. [114] in Table 3. Adopting both perspectives, we divide all included papers into six categories.

This classification framework is chosen for its interpretability and applicability. Papers are categorized in one or more types provided they meet the criteria. The primary aim is to facilitate a comprehensive depiction of each paper's contribution within the landscape of this research domain. Within the AI sustainability research field, validation and evaluation research are considered more mature due to their reliance on empirical evidence and data-driven analysis. They involve conducting experiments, surveys, or collecting data to test hypotheses and validate their findings. This empirical foundation lends them a higher level of credibility and maturity. On the other hand, solution proposal, philosophical, opinion, and experience papers might have a lower maturity level because these papers may involve personal opinions, viewpoints, or experiences that are inherently subjective and not as grounded in empirical evidence.

Table 3. Categorization Framework by Petersen et al. [114].

Category	Description
Validation Research	Techniques investigated are novel and have not yet been implemented in practice. Techniques used are, for example, experiments, i.e., work done in the lab.
Evaluation Research	Techniques are implemented in practice and an evaluation of the technique is conducted. That means it is shown how the technique is implemented in practice (solution implementation) and what are the consequences of the implementation in terms of benefits and drawbacks (implementation evaluation). This also includes identifying problems in the industry.
Solution Proposal	A solution to a problem is proposed. The solution can be either novel or a significant extension of an existing technique. The potential benefits and the applicability of the solution are shown by a small example or a good line of argumentation.
Philosophical Papers	These papers sketch a new way of looking at existing things by structuring the field in the form of a taxonomy or conceptual framework.
Opinion Papers	These papers express the personal opinion of somebody on whether a certain technique is good or bad, or how things should be done. They do not rely on related work and research methodologies.
Experience Papers	Experience papers explain what and how something has been done in practice. It has to be the personal experience of the author.

Based on our findings, the existing literature on AI sustainability predominantly encompasses three types of studies: evaluation research, solution proposal, and philosophical papers. As depicted in Figure 6, out of the 88 papers examined in this review, the most prevalent category is philosophical papers, accounting for 29 entries, followed by evaluation research with 23 entries, and solution proposal with 21 entries.

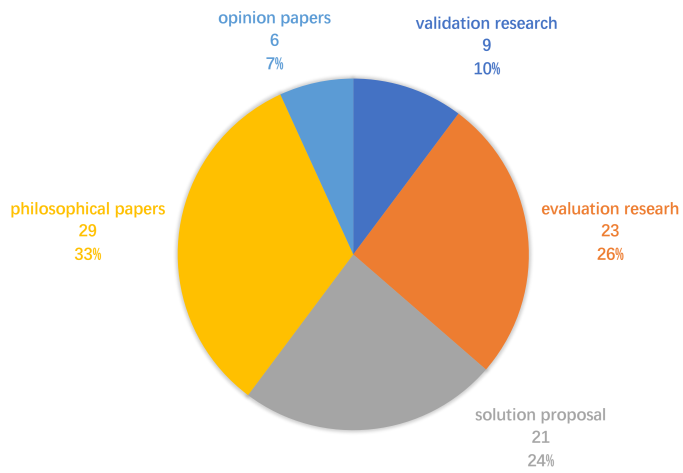

Figure 6. Contribution Types.

In Figure 7, we illustrate the contribution types by year. Analyzing the evolution of contribution types reveals that "Solution Proposals", a relatively mature research category, emerged in 2019 and onward. Additionally, there is a noticeable uptick in the frequency of "Evaluation Research" and "Validation Research". The rise in the visibility of these three categories signifies a positive contribution toward the maturity of this research field.

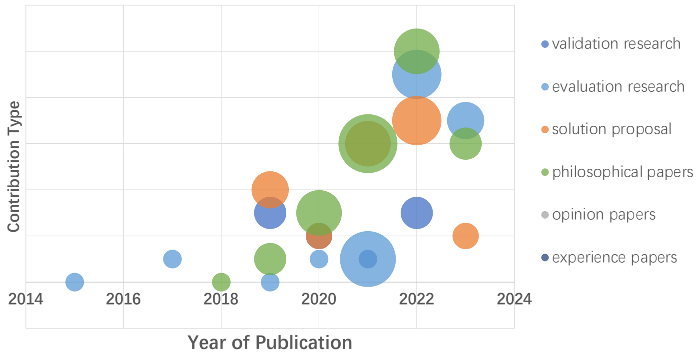

Figure 7. Contribution Type by Year.

4.2.3. Authorship Analysis

To further consolidate our maturity analysis of this research field, we took inspiration from the maturity analysis framework provided by Keathley-Herring et al. [115], focusing on analyzes related to "Authorship" and "Breadth of Research Methods". Authorship analysis is commonly used in literature reviews, and according to Maloni et al. [117], a growing number of diverse authors in a field is a positive sign of maturity. Additionally, examining the Breadth of Research Methods, the prevalence of diverse research methods, mixed methods, and empirical analysis, especially statistical hypothesis testing, acts as another indicator of a research field's maturity [115].

Manually going through the background entries for all 317 authors from the mapped papers, we found that the relevant research fields are as follows:

- **Banking and Finance:** This field consists of backgrounds such as finance, accounting, banking, etc.
- **Business Administration:** The authors in this field have backgrounds related to economics, business administration, management, entrepreneurship, etc.
- **Engineering and Technology:** This field comprises backgrounds such as software engineering, computer engineering, electrical engineering, industrial engineering, information technology, civil engineering, environmental engineering, biomedical engineering, etc.
- **Health Science:** This field consists of authors from backgrounds like health labs, medical institutes, health research centers, Doctor of Medicine candidates, life sciences, etc.
- **Information Systems:** The authors in this field have backgrounds related to artificial intelligence, machine learning, data science, etc. Furthermore, some authors had job titles more suited to the research field of "Engineering and Technology". However, their work profiles were more suited to information systems. Hence, they have been placed in this field.
- **Law:** Authors in this research field are predominantly associated with law faculties or departments.
- **Natural Science:** This field comprises backgrounds such as sustainability, freshwater ecology, energy, climate change, etc.
- **Social Sciences:** The authors in this field have backgrounds related to philosophy, theology, religion and culture, public affairs, social studies, internal and regional studies, etc.

From Table 4, it is evident that the majority of authors possess backgrounds in either "Information Systems (40%)" or "Engineering and Technology (22%)". However, the data also reveals a notable diversity in author backgrounds, with contributions from individuals in fields such as "Social Sciences (13%)" and "Business Administration (11%)". Additionally, authors from varied domains, including "Healthcare, Natural Science, Law, and Banking and Finance" are actively engaged with the topic. This broad spectrum of author backgrounds suggests a keen interest and active participation from researchers across diverse fields, contributing positively to the maturity of the research field [115].

Table 4. Distribution of Authors in Different Fields.

Research Fields	Count of Author	Percentage
Information Systems	126	39.75%
Engineering & Technology	71	22.40%
Social Science	40	12.62%
Business Administration	35	11.04%
Health Science	15	4.73%
Natural Science	13	4.10%
Not Available	8	2.52%
Law	6	1.89%
Banking & Finance	3	0.95%
Total	317	100%

4.2.4. Breadth of Methods Analysis

Conducting the Breadth of Methods Analysis, we systematically examined the presence of empirical studies in our chosen literature, adhering to the methodology proposed by Keathley-Herring et al. [115]. We meticulously reviewed all 88 selected papers, categorizing each as either empirical or non-empirical. Upon completion, we identified 17 papers, or approximately 19% of the selected literature, as empirical studies.

Figure 8 shows the distribution of empirical papers over the years in our selected literature. The first appearance of an empirical paper in our dataset was in 2018, indicating an initial absence in prior years. Subsequently, there has been a consistent rise in the number of empirical papers in the following years, with a slight dip in 2020, possibly attributed to the manual literature synthesis process. As previously noted, the majority of literature on this topic emerged in 2019 and onward, coinciding with the increasing presence of empirical studies. Considering the presence of empirical papers as another indicator for maturity, the result of this analysis further signifies the positive trajectory and rapid development of this research field since 2019.

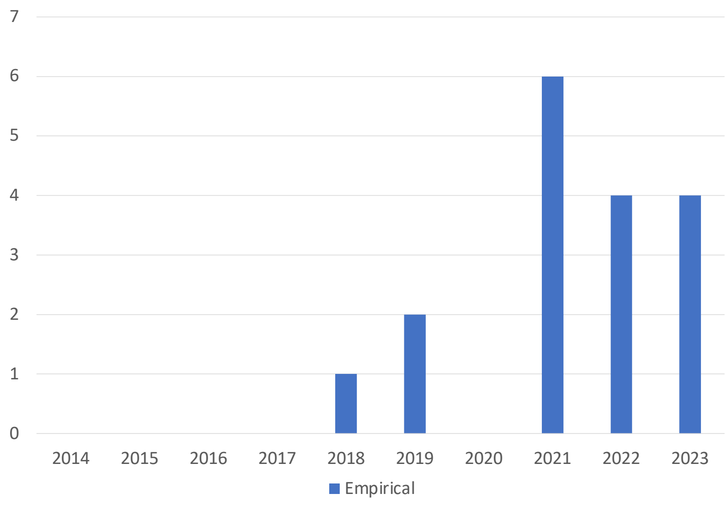

Figure 8. Distribution of Empirical Papers by Year.

In summary, the comprehensive analysis integrating publication trends, contribution types and citations, along with the maturity assessment framework involving authorship and the prevalence of empirical papers, indicates that the research field of AI sustainability was relatively nascent around 2019. However, it has subsequently experienced swift maturation and rapid development in the years that followed.

4.3. RQ3: What is the Future Research Agenda of the Research Field of AI Sustainability?

When looking at the field of AI sustainability, we can see it evolving from a more fragmented one towards a more integrated and holistic field. Approaches of authors evolved, trying to address the full complexity of the topic, and not only restricting it to a niche sub-field. Earlier papers in the field tended to focus on one aspect of AI sustainability, though no single approach was significantly more prominent than the other. As shown in Figure 9, there was a notable surge in research volume around 2019. Importantly, this period also witnessed an emergence of new papers starting to incorporate both approaches.

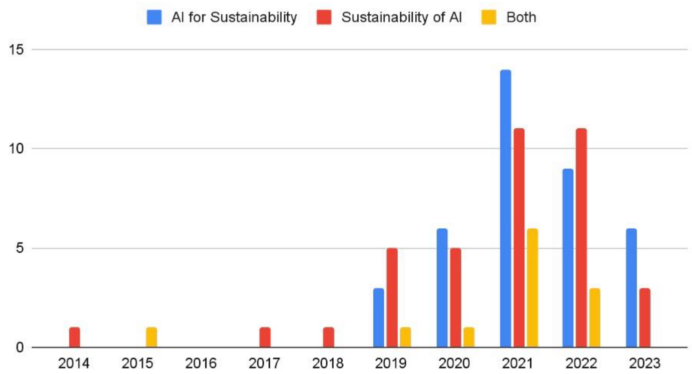

Figure 9. Number of Papers by Year per Approach.

The prevalence of papers adopting this integrated approach experienced a notable increase in 2021, and despite a slight decrease in 2022, they continued to represent a significant portion of the papers within our library. Given the current trajectory, it is anticipated that more papers following this approach will be published in the near future. As this approach gains increasing popularity, researchers should be attentive to both perspectives. Overlooking this dual consideration might lead to inaccurate conclusions about AI sustainability, echoing the notion that AI for Sustainability is not possible without the Sustainability of AI [118]. Examining the sustainability dimensions reveals a parallel trend, as depicted in Figure 10. Initially, papers primarily focused on a single dimension. However, around 2019, a shift towards a more comprehensive approach has emerged. From 2021 on, papers considering more than one sustainability dimension start to constitute the most substantial category of published papers.

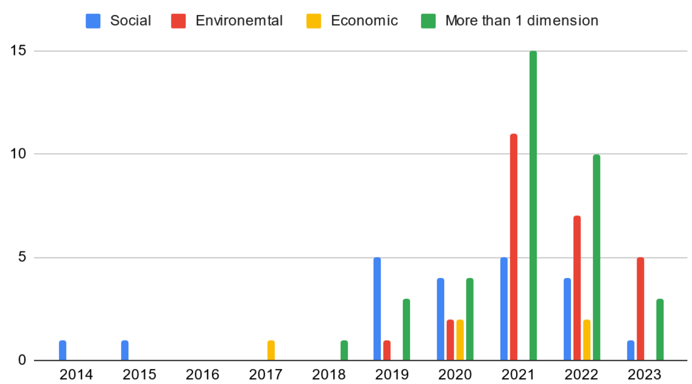

Figure 10. Number of Papers by Year per Dimension.

Future researchers can go beyond the simple comprehension of the potential impacts of AI only within a specific field and comprehend both the positive and negative consequences of social, environmental, and economic dimensions. The United Nations' Sustainable Development Goals (SDGs) could serve as a comprehensive framework to steer this evaluation, offering a multidisciplinary perspective to inform this discourse.

Addressing RQ1 reveals a notable research gap concerning the economic dimension of AI sustainability as there is only little research on AI sustainability from an economic perspective. The interests of the stakeholders propelling the development of AI applications and markets will significantly influence whether and how much AI can contribute to sustainable development. Nonetheless, safeguarding the interests and well-being of consumers is simultaneously imperative. Challenges in tracking potentially problematic decisions made by AI systems may hinder consumers from accessing essential evidence for legal proceedings, emphasizing the need for comprehensive policymaking and regulation of market power and monopolies in AI development [72].

From the insights derived from RQ2, it is evident that the field of AI sustainability is experiencing rapid maturation. Nevertheless, achieving a higher maturity level in the future necessitates the fulfillment of several additional conditions by upcoming research endeavors. The selected literature in our research consists of various types of research papers, as covered in the section contribution types, ranging from philosophical and opinion papers to evaluation research, validation research, and solution proposals. To sustain the maturation of the field in the future, there should be a notable increase in the number of research papers for each research type, coupled with an elevation in the contribution type per year. Moreover, we have observed a rise in the number of empirical papers in recent years. This positive trend should persist, accompanied by an increase in the number of papers conducting analyzes using statistical hypothesis testing and variable testing. These factors can further contribute positively to the field's maturity [115]. On observing the authorship analysis in RQ2, we observe diversity in the background of authors, with authors writing from research fields such as Banking and Finance, Law, Social Sciences, and Health Science. To head in the direction of more maturity, the diversity in author backgrounds should increase along with an increase in the number of authors in various research fields. This evolution is expected in the future research agenda as the field grows.

5. Discussion and Limitations

In this section, we will discuss the limitations of our paper. We mainly consider two types of validity that are potentially affected: construct validity and conclusion validity.

5.1. Construct Validity

Quality of papers: An important consideration in this paper is the quality and depth of the academic papers selected and analyzed. Given that the field of AI sustainability is relatively new, we observed a scarcity of research papers in this field before 2019. This factor posed a limitation to our research, restricting the possibility to capture a comprehensive historical perspective on the development of this field. Further, it made it difficult to analyze long-term trends. Moreover, we observed a relatively smaller percentage of empirical research papers in comparison to the total volume of research publications. This factor limited our ability to capture a diverse range of research methods. Additionally, a selective emphasis on fewer empirical studies could disproportionately represent certain perspectives and introduce biased interpretations. As a result, there may be a lack of in-depth analysis or exploration of certain critical aspects within the research.

Depth of Analysis: Compared to SLR, which involves a more detailed analysis of each included paper, including quality assessment and synthesis of findings, our approach to SMS, on the other hand, may provide a more high-level overview without delving deeply into each study. This could mean that while it covers a larger breadth of literature, our analysis of each individual paper might be less extensive.

Strict and focused analysis: To maintain external validity, a relatively wider inclusion of papers would be more powerful. However, due to limited time and research capacity, the inclusion and exclusion criteria we employed while selecting the papers are strict, e.g., E1: Contents only on a specific niche sub-field of research regarding AI sustainability. While this approach enhances the rigor of the study, it might also limit the generalizability of findings to the broader field of AI sustainability. Another limitation is the necessary and strict cut-off date for our systematic study. For example, a very recent study [119] that proposed a systematic comparison of inference costs of various categories of ML systems, covering both task-specific and general-purpose models with a focus on Natural Language Processing (NLP) and Computer Vision (CV), could not be included in our main Results Section (Section 4).

Qualitative assessment: The process of categorizing papers based on their content involves a certain degree of impreciseness. The absence of explicit criteria and bounded expertise in the specific sub-field of AI sustainability may introduce some bias into the categorization process.

Limited Synthesis of Findings: Since SMS prioritizes breadth over depth, synthesizing findings across studies may be more challenging. While we are able to identify trends, gaps, and themes in the literature, we might not be able to provide as comprehensive a synthesis of research findings compared to an SLR.

5.2. Conclusion Validity

Subjectivity of Authorship Analysis: The assessment of the maturity of the research field of AI sustainability within the included papers involves a certain degree of subjectivity. While efforts were made to maintain objectivity, variations in interpretation might affect the accuracy of conclusions drawn. Within the frame of Authorship Analysis, one debate that we also had during the writing process was whether there is a correlation between popularity and maturity, i.e., whether a higher number and interdisciplinarity of authors and their backgrounds are an indicator of the maturity level of the research field. Despite that, after consulting other similar studies about such assessment, we adopted the framework by Keathley-Herring et al. [115].

Despite the above-mentioned limitations, this research contributes to a broader understanding of AI sustainability and highlights areas for future exploration in this field.

6. Conclusions

The goal of our research was to construct a Systematic Mapping Study (SMS) for a comprehensive analysis of "AI Sustainability". Addressing the limitations observed in current review studies that often present limited perspectives, our study embraced viewpoints from both the sustainability of AI and AI for sustainability, encompassing all three dimensions: environmental, social, and economic. Our exploration of AI sustainability has uncovered a dynamic landscape marked by an increasing trend toward holistic studies, rapid maturation, and a promising research agenda. According to our analysis, the field has matured significantly since 2019, with a surge in publications, diverse contribution types, and empirical studies contributing to its growth. Our findings illuminate a balanced perspective in the field, highlighting equal weighting between sustainability of AI and AI for sustainability. In addition to the perspectives of AI sustainability, more and more recent papers have started to incorporate multiple dimensions in their work. Instead of concentrating solely on one of the three dimensions, such as the environment, these studies now explore a broader spectrum, encompassing multiple dimensions. It is noteworthy, however, that the economic dimension remains relatively under-explored in comparison to the others. This discernible trend is anticipated to persist and gain prominence, aligning with recent research that introduces the Sustainability Criteria and Indicators for Artificial Intelligence Systems (SCAIS) framework as an assessment approach for sustainable AI, explicitly addressing all three dimensions in their work [120]. Future research endeavors are therefore encouraged to delve more into the economic dimension, aligning their goals with the United Nations' SDGs, thereby providing promising avenues for further exploration and contributing to the holistic development of the field. Moreover, it is imperative to acknowledge and address concerns raised by [72] regarding the potential influence of stakeholders on AI development and its implications for sustainable contributions. Safeguarding consumers' interests and safety is of high importance, especially given the challenges in tracking potentially problematic AI decisions and the potential lack of access to evidence for affected individuals.

As the field continues to mature, collaboration, diversity in authorship, and an unwavering commitment to sustainability will propel AI research toward a more inclusive, impactful, and sustainable future. Our SMS lays the foundation for continued advancements in understanding and promoting AI sustainability, setting the stage for ongoing interdisciplinary dialogues and collaborative efforts in this vital research domain.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
CV	Computer Vision
FSSD	Framework for Strategic Sustainable Development
IoT	Internet of Things
LLMs	Large Language Models
ML	Machine Learning
NLP	Natural Language Processing
SCAIS	Sustainability Criteria and Indicators for Artificial Intelligence Systems
SDGs	Sustainable Development Goals
SLR	Systematic Literature Review
SMS	Systematic Mapping Study

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