Harnessing Technology and Sustainability: The Impact of Climate Smart Cities for Sustainable Future

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Abstract. Climate change is the result of global warming which has a negative impact on people's life activities. Although research related to smart cities has experienced rapid development in recent years, the relationship between smart cities and climate change has rarely been studied specifically. This research aims to (1) Analyze climate smart cities research journey and distribution (2) Analyze most popular keyword and research trend of climate smart cities (3) Analyze network visualization and recommendation climate smart cities research on SDGs This research uses Bibliometric analysis with 2 parts of the research stage, including the selection part and the analyzing part. Based on the result over the past 5 decades research related to climate smart cities has experienced a rapid increase in 2022 with the most active source producing climate smart cities research being Sustainability (Switzerland). The keywords that appear most often in Climate Smart Cities Research include smart city, climate change, sustainability, internet of things, etc. Based on the number of citations of top trending articles related to Climate Smart Cities Research over the last 5 years written by Fatimah et all in 2020 regarding Smart Waste Management. Climate smart cities research is divided into 5 clusters.

Keywords: Technology, Climate Smart Cities, Sustainable Future.

1 Introduction

Climate change is a global transformation in weather or the average of a region, in the last ten years industrial and human activities have caused climate change to gradually accelerate, with an increase in average surface temperature every year. Climate change also has real negative impacts, such as ecosystem changes and desertification, sea level rise, floods and drought [1]. Climate change is caused by global warming and negatively affects people's daily activities. The negative impacts of climate change include rising sea surface temperatures, increased intensity of extreme weather, changes in rainfall patterns, and large waves [2]. Global climate change refers to the alteration in global and regional climate patterns that has been noticeable from the mid to late 20th century onward. This change is associated with rising CO2 concentrations in the atmosphere,

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chiefly due to the burning of fossil fuels [3]. Climate change is a significant issue that presents a serious threat to all people on Earth. This problem cannot be solved on its own without human intervention [4].

SDGs is 17 global objectives to eradicate poverty, protect the environment, and ensure prosperity for all by 2030. The SDGs are interconnected and strive to balance the economic, social, and environmental aspects of sustainable development [5]. The concept of the SDGs is essential as a new development framework that addresses various challenges, including the management of natural resources, environmental degradation, the growing urgency of climate change, social protection, food and energy security, and a more pro-poor approach to development. Unlike the MDGs, which focused solely on developing countries, the SDGs have broader, more universal targets [6].

SDG 13 calls for urgent action to combat climate change, recognizing its critical role in achieving sustainable development. Tackling climate change through adaptation and mitigation can be a powerful catalyst for advancing sustainable development goals outlined in the 2030 Agenda. In many instances, climate action can yield additional positive impacts on sustainable development. It's important to note that climate change is a "cross-cutting issue" that influences the successful implementation of all 17 SDGs, including Goal 11, which focuses on sustainable cities and communities [7].

“Sustainable Cities and Communities,” included in SDG 11 aims to ensure inclusive, safe, resilient, and sustainable human and urban settlements by eliminating slum areas, providing affordable transit solutions, reducing urban sprawl, increasing city government involvement, increasing protection cultural assets, addressing issues of urban resilience and climate change, improving urban management (pollution and waste management), ensuring access for all to safe public places, and improving urban management through improving urban rules and regulations [8]. SDG-11 and prospective innovations and efficient solutions to improve urban policy cohesion include several key sector linkages and urban synergies [9].

Smart Cities represent the efficient integration of physical, digital, and human systems within the built environment to ensure a sustainable, prosperous, and inclusive future. These cities empower citizens to interact with public and private services in ways that best meet their individual needs. By blending physical infrastructure, social capital—including local skills and community institutions—and digital technology, Smart Cities drive sustainable economic development and create an appealing living environment [10]. The concept behind Smart Cities is to provide effective services to residents within the smart city using advanced technology and data analysis on data collected by sensors [11]. The level of intelligence of a city is determined by technology-driven infrastructure, initiatives related to environmental issues, smart public transportation, use of technology to reduce crime and robbery, and provide security to citizens [12].

Smart Cities focus on infrastructure resilience, public health and well-being, accessibility and equity, sustainable systems, and governance to help climate change mitigation and adaptation efforts [13]. The application of Smart Cities in climate change adaptation strengthen a city's competitive advantage by exploiting opportunities and reducing adverse risks [14]. Smart Cities are considered a potential remedy for the issues faced by urbanization and a driver of a sustainable and livable urban future in the era

of global climate change [15]. Smart Cities can help reduce the impact of climate change by implementing strategic technological actions in the fields of economics, sustainability, mobility and governance [16].

Although research related to smart cities has experienced rapid development in recent years, the connection between smart cities and climate change has rarely been studied specifically. While smart cities promise solutions to urban and environmental challenges, such as more resilient infrastructure and more sustainable systems, it is important to understand their role in climate change mitigation and adaptation efforts in greater depth. Further research focusing on the integration of smart solutions in climate change strategies can provide valuable insights for achieving more sustainable cities in the future. *This research question included*

1. *How climate smart cities research journey and distribution?*
2. *How most popular keyword and research trend of climate smart cities?*
3. *How network visualization and recommendation climate smart cities research on SDGs ?*

2 Research Method

Bibliometric is technique for examining and assessing large quantities of scientific data, highlighting developing areas in a specific field [17]. Bibliometric analysis involves applying literature quantitative analysis techniques, with key elements being range of database content, data consistency and correctness, field types, search functionalities, and metric analysis and utilization [18]. This research uses Scopus publications as a database. This research is divided into 2 parts of the research stage, including the selection part and the analyzing part.

In the selection part, select the incoming articles using a Scopus database search with the keywords climate AND smart AND cities (2188). The search process is limited to the period 2019-2024 (1601). After selecting years and studies, the incoming database was analyzed with limited to Journal (844), limited to Conference proceedings (368), limited to Book series (225), and limited to Book (163). The final results of this part selection will be used at the analysis stage using VOSviewer.

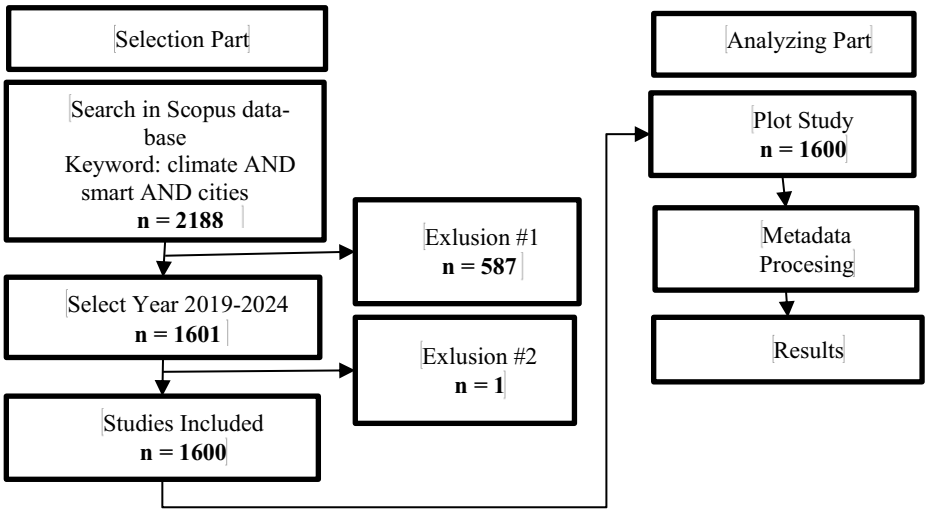

Fig. 1. Stages of Bibliometric Studies

3 Result and Discussion

3.1 Climate Smart Cities Research Journey and Distribution

a. **Climate Smart Cities Research Production**

Based on the analysis that has been carried out, it is known that over the past 5 decades research related to climate smart cities has experienced a rapid increase in 2022. Climate change impacts have worsened over several decades, with slow onset events such as increasing temperatures, glacial retreat, and sea level rise escalating [19]. In the long run, climate change will adverse on the economy and human welfare, with greater negative impacts in poorer, hotter, and lower-lying countries [20]. Climate change has repercussions for biodiversity, ecosystems, and the functions they serve, resulting in changes in productivity, species interactions, vulnerability to biological invasions, and altering the benefits and services provided to society [21].

Apart from experiencing the challenges of climate change, during this decade technological progress has developed rapidly. IoT advancements have reshaped the world through smooth integration of disparate networks and its future prospects [22]. Leveraging IoT and big data can play a pivotal role in fostering and optimizing sustainable environmental practices in smart sustainable cities [23]. IoT enhances public services management in smart cities by detecting and reporting parameters related to health, waste management, agriculture, transportation, and energy [24]. Smart cities using IoT technologies can achieve energy savings and CO2 reductions, but they must ensure that the costs and benefits are shared equally to ensure social justice and sustainability [25].

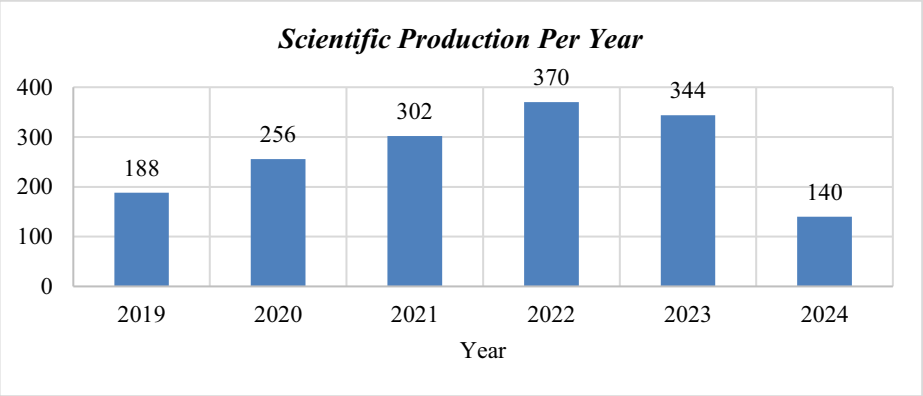

Fig. 2. Climate Smart Cities Research Production

b. **Top Sources Climate Smart Cities Research**

The source that produces the most climate smart cities research is Sustainability (Switzerland). The most popular article on Sustainability (Switzerland) was written by Yigitcanlar T and Cugurullo F in 2020 with 140 citations. The article discusses the growing use of artificial intelligence (AI) in different sectors and its incorporation into urban services. AI plays a significant role in smart urbanism, particularly in the environmental domain. Smart cities aim manage substantial urban and social *issues using information and communication technology (ICT) [26]*

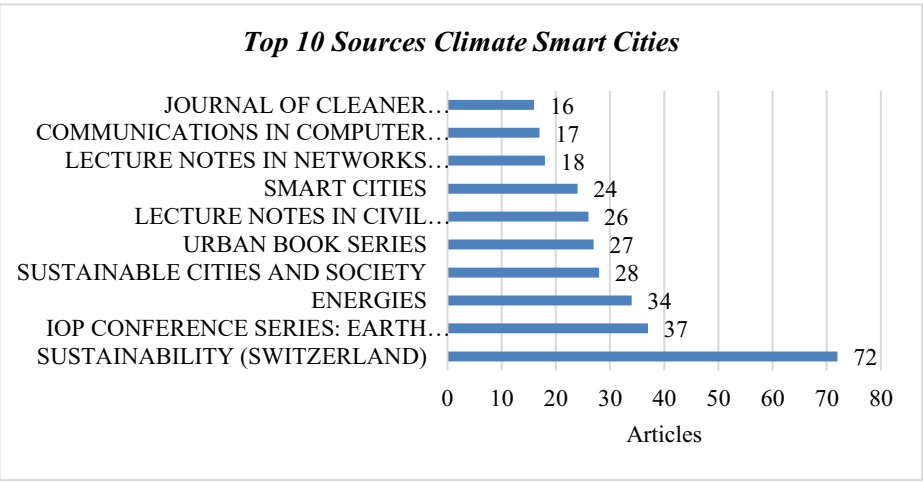

Fig. 3. Top Sources Climate Smart Cities Research

c. **Countries Distribution and Collaboration Climate Smart Cities Research**

The United Kingdom and the United States are the countries that publish the most papers related to Climate Smart Cities. Indonesia has less publications on Climate

Smart Cities research. Indonesia has 98 publications related to Climate Smart Cities in collaboration with Korea, Pakistan, Malaysia, Denmark and Sri Lanka. Indonesia has limited research on optimal and responsive climate change management for urban resilience *[27]. Data availability, spatial and temporal constraints, and lack of a comprehensive understanding of ecological indicators hinder previous research on climate smart cities in Indonesia [28].*

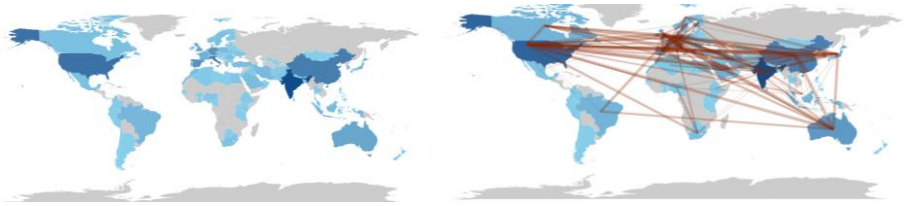

Fig. 4. Countries Distribution and Collaboration Climate Smart Cities Research

3.2 Popular Keyword and Research Trend of Climate Smart Cities

a. **Top Author(s) Keyword in Climate Smart Cities Research**

The keywords that appear most often in Climate Smart Cities Research include smart city, smart cities, climate change, sustainability, internet of things, sustainable development etc. Smart cities are capable of creating *multiple values for various stakeholders, and the Sustainable Development Goals (SDGs) [29].* Smart city frameworks emphasize advanced technologies and intelligence *while urban sustainability frameworks focus on environmental sustainability and social/economic aspects [30]. Smart cities drive eco-friendly electricity by emphasizing energy efficiency* utilizing *renewable energy sources, and comprehensive energy and urban planning strategies [31].*

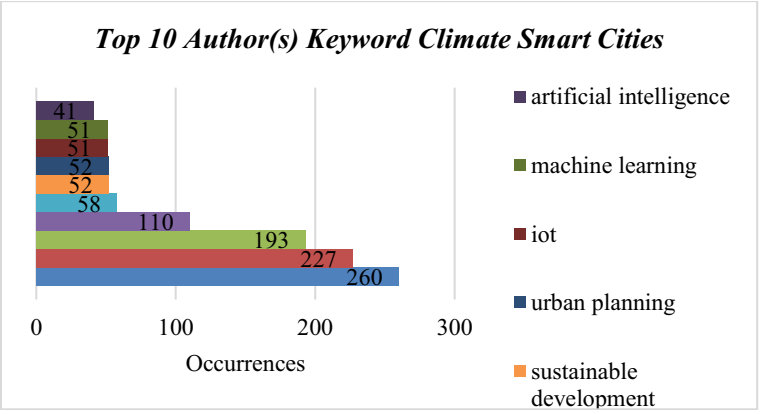

Fig. 5. Top Author(s) Keyword in Climate Smart Cities Research

b. **The most cited Climate Smart Cities Research**

Based on the number of citations of top trending articles related to Climate Smart Cities Research over the last 5 years written by Fatimah et all in 2020. The article discusses the sustainable circular economy approach for smart waste management in Indonesia, aiming to achieve sustainable development goals.

Table 1. The most cited Climate Smart Cities Research

No	Author(s)	Year	Source	Findings	Citation
1	Fatimah Y.A. *et al*	2020	Journal of Cleaner Production	Integration of ICT and IoT to monitor waste, reduce CO2 emissions, and mitigate climate change [32].	324
2	He Q. *et al*	2019	Current Biology	Understanding and incorporating interactions between climate change and local human impacts are crucial for predicting climate change impacts and developing climate-smart conservation actions [33].	317
3	Yigitcanlar T. *et al*	2020	Energies	AI in smart cities optimizes transportation for reduced energy consumption and pollution. The potential impact of AI includes efficiency, sustainability, and transformation in cities [26].	239
4	Aburas M. *et al*	2019	Applied Energy	Studies focus on thermochromic windows for energy efficiency in buildings. Thermochromic windows are deemed more suitable for warm climates [34].	235
5	Liu L. *et al*	2021	Nano Energy	Sustainable and renewable energy supplies are crucial for constructing smart cities. Transition to utilizing plentifully distributed devices in smart cities is driven by the demands for sustainable energy [35].	204

3.3 Network Visualization and Recommendation Climate Smart Cities Research on SDGs

Network Visualization in Climate Smart Cities Research is divided into 5 Clusters with keywords with number of occurrences and total link strength including climate change, smart city, sustainable development, smart cities, internet of things, energy efficiency.

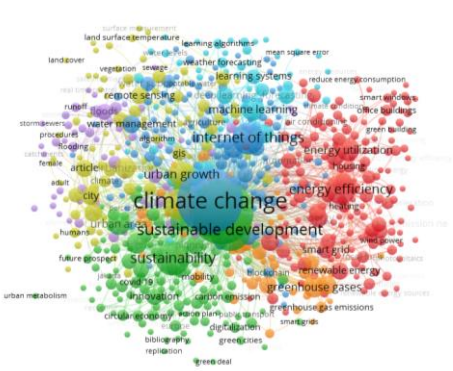

Fig. 6. Network Visualozation

Research related to Climate Smart Cities is closely related to SDGs and sustainability. Smart concepts, such as on-demand buses and smart grids, can help achieve Sustainable Development Goals by balancing social, economic, and environmental sustainability [36]. SDG indicators offer a balanced and integrated approach to monitoring urban sustainability by focusing on environmental sustainability, health, and economic growth. These indicators help assess progress in creating sustainable and resilient urban environments by capturing a comprehensive view of the various factors that contribute to overall urban well-being [37].

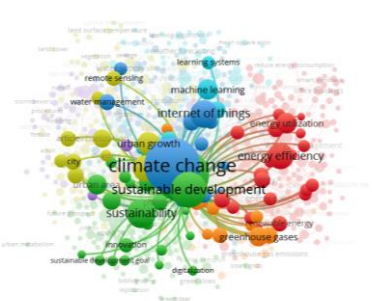

Fig. 7. Network Visualozation of Sustainable Developmet

Smart cities can contribute to SDG 13 climate action by developing simple neighborhood models from building physical parameters and using digital twins to assess policy impact [38]. Smart cities can reduce greenhouse gas emissions by improving green transportation, waste management, and water consumption using technology and

data [39]. Smart Mobility and/or Smart Regulation programs focusing on the environment can help reduce greenhouse gas emissions [40].

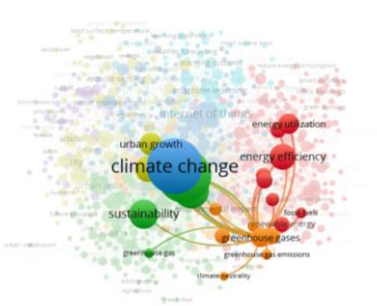

Fig. 8. Network Visualozation of Greenhouses Gases

Smart Cities use technologies like the Internet of Things and machine learning to effectively manage water resources, preferring models with feedback and participation [41]. Local energy and climate actions, such as phasing out fossil fuels, can affect the use of water and land resources locally, nationally, and globally, impacting SDG6 water management [42]. Water smart cities increase irrigation and misting to cope with extreme heat and drought, using alternative water resources such as rainwater tanks, stormwater capture, and recycled sewage wastewater [43].

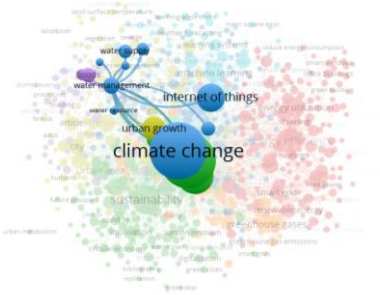

Fig. 9. Network Visualozation of Water Management

Smart city supply chain management strategies can help reduce their carbon footprint, contributing to SDG 7 on air quality and climate change [44]. Integrating renewable sources with the energy frameworks of smart cities aims to achieve a cleaner process and more sustainable development [45]. Implementing smart renewable energy and energy efficiency strategies in economically disadvantaged cities can improve their environment, boost their economy, and create job opportunities, all while contributing to the fight against climate change [46].

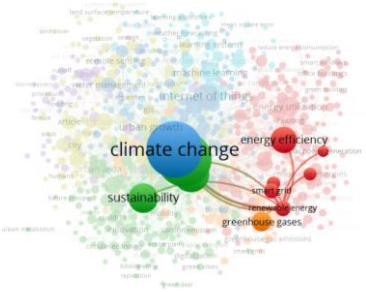

Fig. 10. Network Visualozation of Renewable Energy

Smart technologies in climate smart cities contribute to achieving SDG 11, promoting safe, resilient, inclusive, and sustainable cities [47]. Smart city strategies that focus on 'ubiquitous computing,' 'universal infrastructure,' and 'green technology' can potentially make cities more vulnerable to future social and climatic risks if they are not designed with adaptability and resilience in mind. While these approaches offer significant benefits, it is crucial to ensure that they are implemented with considerations for flexibility and resilience to effectively address emerging challenges [48]. Deep learning technology combined with self-powered sensors on an edge computing platform accurately predicts microclimate indexes in urban blocks, improving the accuracy of climate prediction in smart cities [49].

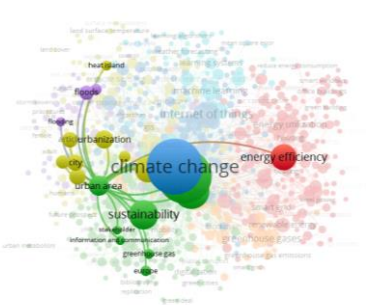

Fig. 11. Network Visualozation of Urban Area

4 Conclusion

Based on the results and discussions that have been carried out, it is known that over the past 5 decades research related to climate smart cities has experienced a rapid increase in 2022 with the most active source producing climate smart cities research being Sustainability (Switzerland). The United Kingdom and the United States are the countries that publish the most papers related to Climate Smart Cities. Indonesia has less publications on Climate Smart Cities research. The keywords that appear most often in Climate Smart Cities Research include smart city, smart cities, climate change,

sustainability, internet of things, sustainable development etc. Based on the number of citations of top trending articles related to Climate Smart Cities Research over the last 5 years written by Fatimah et all in 2020 regarding Smart Waste Management. Climate smart cities research is divided into 5 clusters and is related to SDG 13 (Climate Action), SDG 11 (Sustainable Cities and Communities), SDG 7 (renewable energy) and water management.

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