UTS UNIVERSITY OF TECHNOLOGY SYDNEY

A New Frontier for Green New Deals: Incorporating Ecosystem Approaches and the Fourth Industrial Revolution in Developing Economies

by Mohammad Zaheer Allam

Thesis submitted in fulfilment of the requirements for the degree of

Master of Sustainable Futures (Research)

under the supervision of Prof. Damien Giurco and Dr. Samantha Sharpe

University of Technology Sydney
Institute of Sustainable Futures

November 2023

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Mohammad Zaheer Allam* declare that this thesis is submitted in fulfilment of the requirements for the award of *Master of Sustainable Futures (Research)*, in the *Institute of Sustainable Futures* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature: Production Note: Signature removed prior to publication.

Date: 19th July 2023

ACKNOWLEDGEMENT

I would like to take this opportunity to express my deep gratitude to Professor Damien Giurco and Dr. Samantha Sharpe for their unwavering support and guidance throughout my master's thesis. Their expertise, constructive feedback, and willingness to engage in thoughtful discussions have been invaluable in shaping the direction and focus of this research.

I would also like to express my sincere appreciation to the Australian Government for awarding me a Research Training Program (RTP) scholarship, which has enabled me to pursue this program.

Finally, I would also like to thank my family and friends for their continuous support and encouragement throughout my academic journey.

LIST OF PEER-REVIEWED PUBLICATIONS PRODUCED AS PART OF THIS THESIS

Item	Title	Journal	Publisher
Paper 1	An overview of climate change adaptation and mitigation research in Africa	Frontiers in Climate	Frontiers
Paper 2	Emerging Trends and Knowledge Structures of Smart Urban Governance	Sustainability	MDPI
Paper 3	Addressing Knowledge Gaps for Global Climate Justice	Geographies	MDPI
Paper 4	Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest Fires	Humanities and Social Sciences Communication	NATURE
Paper 5	Green new deals could be the answer to COP26's deep decarbonisation needs	Sustainable Horizons	Elsevier
Paper 6	On the theoretical conceptualisations, knowledge structures and trends of green new deals **Note:** This paper was cited in the AR6 WG3 IPCC Report	Sustainability	MDPI
Paper 7	The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption	Resources	MDPI
Paper 8	Pandemic and Conflict Could Undermine Climate Action	Frontiers in Climate	Frontiers

OTHER RELEVANT PUBLICATIONS NOT INCLUDED AS PART OF THIS THESIS

1. Zaheer Allam, Can Biyik, Yusra Raisah Takun. A Proposal for the Crypto-Funding of Climate Change Mitigation and Conservation Efforts. *The Palgrave Handbook of Global Sustainability*, Springer International Publishing, pp.1-13, 2021,

2. Herron M., Jones D.S., Roös P.B., Allam Z. Creating Revenue Out Of Green Waste: New Perspectives For Municipal Organic Waste Harvesting In Geelong, Australia. *GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY*. 2021;14(1):91-105.

TABLE OF CONTENTS

ABSTRACT

This thesis delves into the intricacies of the Green New Deal to promote equitable sustainability transitions in both developed and low-income economies, taking into account the difficulties posed by the COVID-19 pandemic and persistent geopolitical conflicts. To dissect this multifaceted issue, the study concentrates on the financial hurdles and prospects, technology adoption and transfer, as well as tailor-made strategies for various geographies and economies.

Findings from the eight (8) publications, forming this thesis by compilation, underscore the crucial role of Green New Deals in realizing sustainability objectives and fostering social and economic justice. The research accentuates the importance of crafting these deals to cater to contextual needs and establish social protection frameworks, pinpointing major financial challenges and opportunities in global sustainability transitions. Additionally, it highlights the significance of various stakeholders, such as governments, industries, regulators, and communities, in tackling these challenges.

The thesis sheds light on the potential of technology adoption, transfer, and innovation in hastening sustainability transitions, and probes the necessary support mechanisms to expedite these processes. Furthermore, it examines the detrimental effects of the COVID-19 pandemic and the Russia-Ukraine conflict on technology advancement and transfer, leading to restricted access to green technology for developing nations and Small Island Developing States (SIDS).

Providing an extensive analysis of climate change adaptation and mitigation research in Africa, the study advocates for a Global Planetary Ecosystem Accounting system. It underscores the need for Green New Deals to be structured in a way that addresses contextual requirements and expedites sustainability transitions, complemented by social protection frameworks. This approach ultimately empowers countries to pursue equitable sustainability transitions that prioritize inclusivity and economic fairness.

1. INTRODUCTION

1.1 BACKGROUND

The 21st century has faced numerous global challenges, including increased urban population growth, rapid urbanization, climate change, the COVID-19 pandemic, and the ongoing Russia-Ukraine war. The impacts of climate change have been particularly widespread and alarming, prompting a global push for lasting solutions. The COVID-19 pandemic has intensified the urgency for climate transition policies, as it has demonstrated the vulnerability of our societies and economies to unexpected shocks, underscoring the importance of building resilience through sustainable development (Allam, 2020d).

Climate change impacts have been well documented, leading to political discourses aimed at convincing stakeholders to commit to transitioning to low and/or zero carbon economies. Such discourses have resulted in international agreements such as the Montreal Accord, Kyoto Protocol, and Paris Agreement, with the latter setting a reduction commitment on carbon emissions to ensure that global temperatures remain below 2°C above preindustrial levels (IPCC, 2014).

The ongoing Russia-Ukraine war has further complicated the challenges of sustainability transitions. The conflict has led to disruptions in supply chains, increased energy costs, and a higher cost of green products (Allam et al., 2022a). Consequently, the war highlights the need for adaptive and resilient strategies to promote sustainability under rapidly changing global conditions (Bin-Nashwan et al., 2022).

Global attention on the need to address climate change concerns has gained traction, with industries accelerating their transition to sustainable practices (Baumgartner et al., 2017). Some see decarbonization as an opportunity for competitive advantages and attracting a larger consumer base, as people increasingly demand industries to be more responsive and proactive. Despite the perceived straightforwardness of transitioning to sustainable practices, industries often bear the cost of green premiums, which are then passed on to consumers and end-users through higher prices (Allam, 2020a). However, the Third Industrial Revolution has facilitated increased technological adoption in various sectors, allowing industries to leverage advanced technologies to reduce the costs of going green (Popp, 2010).

International accords like the Paris Agreement have set the pace for the formulation of local, regional, national, and urban policies aimed at low carbon production (Waisman et al., 2019). These policies are also influenced by the Sustainable Development Goals (SDGs) and the New Urban Agenda, which outline how nations and urban areas should work towards achieving

sustainability agendas. However, some policies derived from international accords become diluted in the process and fail to achieve their intended objectives (Kreienkamp et al., 2022). This dilution may result from a lack of cohesive and universally acceptable frameworks linking environmental targets with governmental structures at various scales.

To address these challenges, including the exacerbating factors of the COVID-19 pandemic and the ongoing Russia-Ukraine war, a cohesive model that supports sustainable transitions and aligns with ratified goals is needed. One such movement gaining momentum is the Green New Deal, which emerged in 2006 as a bold and transformative policy framework aiming to tackle climate change, social inequity, and public health crises simultaneously (Allam et al., 2021b). The Green New Deal proposes large-scale public investments in renewable energy, infrastructure, and sustainable technologies to create jobs, reduce greenhouse gas emissions, and promote social justice, while addressing the urgent need for pandemic recovery and geopolitical stability (Green and Healy, 2022).

Comprehensive Green New Deal pathways are required to work effectively in both the Global South and low-income economies, ensuring that the pursuit of sustainability is equitable and inclusive, even amidst the challenges posed by the COVID-19 pandemic and geopolitical conflicts (DOYLE, 2022). This necessitates a context-specific approach, taking into consideration the unique challenges and opportunities faced by these regions, including limited access to resources, vulnerability to climate change impacts, public health concerns, and the need for economic development and resilience against external shocks (Hepburn et al., 2020).

In the Global South, Green New Deal pathways should prioritize climate adaptation and resilience measures, as these regions are often disproportionately affected by climate change and are facing additional pressures from the pandemic and geopolitical tensions (Singh, 2022, Allam et al., 2022b). This includes investing in early warning systems, resilient infrastructure, and climate-smart agriculture to help communities adapt to changing conditions and reduce their vulnerability to climate-related disasters and health crises (Usman, 2022, Allam et al., 2020). Additionally, the Green New Deal should support the development of decentralized renewable energy systems, enabling these regions to leapfrog over carbon-intensive development pathways and gain access to reliable, clean energy sources, even as global supply chains are disrupted by conflict (Jacobson et al., 2018).

In low-income economies, Green New Deal pathways must focus on addressing poverty and inequality, while simultaneously promoting sustainable development and pandemic recovery. This can be achieved through targeted investments in education, healthcare, and social

protection programs, as well as supporting the development of sustainable industries that provide decent jobs and contribute to reducing emissions (Stiglitz et al., 2009). Importantly, these initiatives should be coupled with progressive tax reforms and redistributive policies to ensure that the benefits of the green transition are shared equitably across society, despite the challenges posed by the COVID-19 pandemic and ongoing geopolitical crises (Gore, 2020).

Furthermore, international cooperation and financial support from developed countries are crucial to implementing Green New Deal pathways in the Global South and low-income economies, especially in light of the added burdens from the pandemic and conflicts such as the Russia-Ukraine war (Bloomfield and Steward, 2020b). This includes providing financial and technical assistance, promoting technology transfer, and ensuring fair and just global trade policies that support sustainable development in these regions, while navigating the complex global landscape (UNCTAD, 2020).

This thesis looks at how to recalibrate and encourage contextual Green New Deal policies to accelerate sustainability transitions.

1.2 PREVIOUS RESEARCH IN THIS AREA

Green New Deals (GNDs) have emerged as a critical response to the growing challenges of climate change and economic instability (Green and Healy, 2022). These ambitious policy frameworks aim to simultaneously address environmental and socio-economic issues through sustainable development and economic regeneration (Barbier, 2009). This section evaluates the current state of GNDs research, focusing on their implementation mechanisms, their potential for aiding post-COVID-19 economic recovery, and the complications arising from the Russia-Ukraine conflict. It also underscores the necessity of expanding the GNDs discourse to include the Global South and Africa, as well as recognizing the role of urban centers in sustainable development.

GNDs implementation mechanisms encompass a range of policy instruments, including investment in renewable energy, retrofitting of buildings, and the promotion of clean transportation (Filipović et al., 2022). These measures aim to create green jobs, reduce carbon emissions, and foster economic growth while ensuring a just transition for affected communities (Cha et al., 2022). Such policies have gained momentum, with several countries, such as the United States and the European Union, adopting their versions of GNDs (Allam et al., 2021b).

The COVID-19 pandemic has intensified the need for GNDs, as governments grapple with the dual challenge of economic recovery and climate action (Hepburn et al., 2020). As a result, GNDs have become an integral part of post-pandemic recovery plans, with investments targeted at sustainable infrastructure, clean energy, and green innovation (Kim et al., 2022). However, the ongoing Russia-Ukraine war poses additional challenges, as it disrupts global markets and intensifies geopolitical tensions (Boungou and Yatié, 2022). This conflict underscores the urgency of transitioning to renewable energy sources to promote energy independence and resilience (Emenekwe et al., 2022).

Despite the growing interest in GNDs, there remains a critical gap in the literature regarding their applicability to the Global South and Africa. These regions face unique socio-economic and environmental challenges, necessitating tailored GNDs that address local contexts (Scoones et al., 2020). Moreover, cities play a vital role in sustainable development, as they are responsible for significant greenhouse gas emissions and are often at the forefront of climate adaptation and mitigation efforts (Acuto et al., 2018). Therefore, integrating urban centers into the GNDs discourse is essential for achieving comprehensive sustainability outcomes.

1.2.1 Green New Deals and Sustainability: Implementation Mechanisms

It is important to note that addressing the imperative for sustainability transitions in the context of climate change necessitates a comprehensive understanding of sociotechnical transitions and multi-level perspectives. Sociotechnical systems encompass the intricate interplay between technology, society, and the environment. The multi-level perspective (MLP) offers a lens through which to view these systems, illustrating how niche innovations evolve to disrupt entrenched regimes, particularly within the energy sector, amid overarching landscape pressures such as climate change (Geels, 2002). To ensure these transitions are not ephemeral, it is crucial to support them with robust policies and societal engagement. This includes incentivizing innovation, developing infrastructure, and most importantly, fostering public and private sector collaboration. The Green New Deal aims to provide a blueprint for this, advocating for a decarbonized economy where sustainability and equity align as key principles in this transition (Klein, 2020).

Green New Deals (GNDs) are founded on the notion that environmental preservation and economic growth can be achieved concurrently and can complement each other. Central

elements of GNDs typically involve investments in renewable energy, green infrastructure, and resource efficiency, along with measures to ensure a just transition for affected workers and communities. As a result, GNDs can foster sustainability by catalyzing essential systemic changes to decrease greenhouse gas emissions, advance the circular economy, and enhance social equity (Pettifor, 2020).

Implementation mechanisms for GNDs have been proposed at multiple levels, from national to supranational scales. For instance, the European Green Deal (EGD) of the European Union combines regulatory measures, incentives, and investments to attain climate neutrality by 2050 (Puaschunder, 2021). Similarly, the United States' proposed GND envisions a comprehensive policy package encompassing sector-specific interventions such as clean energy standards and public investments in clean technologies (Galvin and Healy, 2020). These varying implementation mechanisms demonstrate the flexibility and adaptability of GNDs to different socio-political contexts, allowing countries and regions to design their GNDs based on their unique needs and priorities. Moreover, GNDs emphasize the importance of stakeholder engagement, ensuring that policies are co-created and tailored to local circumstances (Newell and Mulvaney, 2013). This collaborative approach fosters ownership and long-term commitment to sustainability goals. Furthermore, GNDs can contribute to achieving the United Nations Sustainable Development Goals (SDGs) by addressing multiple dimensions of sustainable development, including economic, social, and environmental aspects. By integrating these dimensions, GNDs offer a holistic approach to sustainability, facilitating the transition towards a low-carbon, resource-efficient, and socially inclusive future, even in the cases of countries facing conflict (Shevchenko et al., 2021).

1.2.2 Sustainability Pathways in Post-COVID19 Economic Regeneration Policies

The Covid-19 pandemic has led to unprecedented social and economic disruptions, emphasizing the need for a resilient and sustainable recovery. Researchers and policymakers have advocated for the incorporation of GND principles into post-pandemic economic regeneration policies (Boyle et al., 2021). By aligning stimulus packages with sustainability objectives, countries can foster green growth, create jobs, and enhance social welfare (Lee and Woo, 2020).

Various studies have outlined potential sustainability pathways in the wake of the pandemic. For instance, Barbier (2020) suggests a three-pronged approach that includes investing in renewable

energy, enhancing natural capital, and promoting the circular economy. Similarly, the International Renewable Energy Agency highlights the role of renewables in driving a sustainable recovery, emphasizing the need for policies that incentivize their deployment and integration into the broader energy system (Ferroukhi et al., 2020). These approaches underscore the potential of GND-inspired policies to contribute to economic regeneration while advancing sustainability goals.

This is further explored in the publications and in section 2.2.

1.2.3 The Russia-Ukraine War: Implications for Sustainability

The ongoing Russia-Ukraine war has posed significant challenges to global sustainability efforts by disrupting commodity prices and supply chains. The conflict has led to increased volatility in energy markets, with potential knock-on effects on the cost and feasibility of renewable energy projects (Fang and Shao, 2022). Moreover, the geopolitical tensions have strained international cooperation, hampering the collective action needed to tackle global environmental challenges (Raza, 2023).

In this context, GNDs may serve as a critical policy tool for mitigating the adverse effects of the war on sustainability efforts. By prioritizing investments in domestic renewable energy sources and promoting regional cooperation, GNDs can help countries enhance their energy security and reduce their reliance on vulnerable supply chains. Additionally, GNDs can facilitate international collaboration by providing a shared framework for addressing environmental and economic challenges, fostering a more resilient and sustainable global economy (Newell and Mulvaney, 2013).

This is further explored in the publications and in section 2.3.

1.2.4 Expanding the Focus: Global South, Africa, and Cities

Despite the burgeoning interest in GNDs, a significant focus gap remains concerning the Global South and the African continent, where the need for sustainable development is most pressing. Scholars have urged for a more inclusive GND discourse that acknowledges the unique

challenges confronted by developing countries and accentuates the importance of international solidarity (Chohan, 2019, Pollin, 2019). This involves recognizing the differentiated responsibilities of nations in addressing climate change and ensuring that GND policies foster equitable access to resources and opportunities, especially for the global south which does not necessarily have the financial means to implement large scale and indepth reforms in view of economic constraints and geopolitical challenges (Chen and Li, 2021).

Moreover, there is a necessity to integrate cities into the GND narrative, considering their role as primary population centers and engines of economic activity. Urban areas contribute to over 70% of global greenhouse gas emissions and grapple with numerous sustainability challenges related to air pollution, waste management, and more (Allam, 2020c). Additionally, as cities are projected to accommodate 68% of the global population by 2050, they will emerge as crucial nodes of power and, consequently, key players in policy reforms and drivers, even in the case of conflicts and pandemics (UN-HABITAT, 2021).

In this context, GND-inspired policies can support sustainable urban development by promoting compact urban planning, green transportation, and resource-efficient infrastructure (Agyeman, 2005). Furthermore, these policies can advance environmental justice by addressing the disproportionate impacts of climate change and pollution on marginalized urban communities (Schlosberg and Collins, 2014). By engaging city-level actors and fostering multi-level governance, GNDs can facilitate effective, context-specific policy responses that drive sustainable urban transformation (Bulkeley et al., 2014).

1.3 JUSTIFICATION OF THIS STUDY

As much as the Green New Deal is expected to prompt an unprecedented paradigm shift on the discourse of climate change, it is however subject to several notable hurdles. For instance, with first world economies, it is possible to invest in infrastructural programs supporting a relatively quick transition in the next decades (Barbier, 2009). However, this would be very different in the case of developing and low-income economies which experiences numerous financial and technical capacities to invest in such infrastructural programs, noting that financing for basic infrastructure is often lacking and those rank higher in terms of national priority over environmental programs (Gurara et al., 2017). Actually, it is often argued that for most of the least developed and developing economies to reach a point where they can be termed as

economically mature, they would have to overlook environmental concerns and incidentally contributing to carbon emissions in the process (Aye and Edoja, 2017, Frankel, 1999). Additionally, as investments in hard infrastructures and in coal fired power plants are already established, those countries may unfortunately tend to support non-renewable energies in the short and medium term, until an economic maturity is reached for substantial investments in greener industries and means of energy production.

It is possible to counter this hurdle by ensuring that these economies benefit and have access to substantial economic support, to encourage them to align with global sustainable efforts. Such support is expected to come in terms of financial and technical forms as well as through global frameworks that ensure that decarbonisation programs are sufficiently funded. Additionally, as of now, a review of literature showcases that there is no clear framework for Green New Deals that would help encompass both local roadmaps and global financial flows. There is also a need to look into ways in which Green New Deals could be embraced across the political divide and to what extent Green New Deals influence foreign relations. This research thus aligns with the topical need for equitable and inclusive transition pathways.

2. RESEARCH QUESTIONS

This study reviewed the drive to support sustainability transitions through both theory and applied frameworks, and in this line focus on the evolution of the Green New Deal. In this narrative, the pitfalls for least and developing economies were examined so that a better understanding is gained, leading to the design of a sustainability transition pathway.

To this end, 1 primary research question was defined, supported by 3 sub questions:

1. How can the Green New Deal be designed and implemented to ensure equitable sustainability transitions in both (i) developed and (ii) low-income and developing economies, considering the challenges posed by the COVID-19 pandemic and ongoing geopolitical conflicts?

    1.1 What are the key financial challenges and opportunities in the development and implementation of global sustainability transition pathways, and what roles do different levels of government, industry, regulators, and communities play in addressing these challenges?

1.2 How can technology adoption, transfer, and innovation contribute to accelerating sustainability transitions, and what supportive mechanisms are required to facilitate these processes?

1.3 What specific strategies and mechanisms can be developed to address the contextualized challenges and opportunities faced by different geographies and economies in the pursuit of equitable Green New Deal-inspired sustainability transitions?

2.1 RELATIONSHIP BETWEEN PRODUCED PUBLICATIONS AND RESEARCH QUESTIONS

Question 1	Paper 5: Explores the potential of Green New Deals as a critical tool to ensure the attainment of sustainability agendas while pursuing social and economic justice. It emphasizes the importance of designing these deals to address contextual needs and provide social protection frameworks for both developed and developing countries.
	Paper 6: Offers a comprehensive understanding of the Green New Deal's evolution, knowledge structures, and trends through bibliometric analysis and science mapping techniques. This information can be valuable for researchers and policymakers as they develop and implement equitable sustainability transitions in different geographies and economies.
Question 1.1	Paper 3: Analyzes the outcomes of COP26, which provided financial instruments to aid climate mitigation in the global south and compensation avenues for loss and damage. The paper argues that the science rhetoric driving these initiatives may reinforce unjust north/south narratives and calls for a more equitable approach.
	Paper 7: Investigates the challenges posed by the COVID-19 pandemic and the Russia-Ukraine war on climate financing for achieving equitable and just transition mechanisms. It emphasizes the need to review these issues and

	encourage more cooperation for technology development and transfer, despite the current global crises.
Question 1.2	Paper 2: Conducts a bibliometric analysis and uses science mapping techniques to study the concept of smart urban governance, with a focus on the technological and digital domains. The analysis reveals emerging themes that highlight the importance of citizen participation, e-governance, and policy frameworks in accelerating sustainability transitions.
	Paper 7: Explores the impact of the COVID-19 pandemic and the Russia-Ukraine war on technology development and transfer. These crises have resulted in rising commodity and labor prices, negatively affecting global supply chains and making green technology less accessible for developing countries and Small Island Developing States (SIDS).
Question 1.3	Paper 1: Offers a comprehensive review of climate change adaptation and mitigation research in Africa, emphasizing the need for improved understanding and research capacity. The paper identifies priority research topics and themes and discusses the uneven distribution of articles and research focus across the continent.
	Paper 4: Advocates for a Global Planetary Ecosystem Accounting system that economically weights ecologically sensitive areas, equating their preservation with revenue-generating activities. This approach aims to address disparities in resource accounting and management on a planetary scale, allowing for a more equitable and sustainable global ecosystem.
	Paper 5: Stresses the importance of structuring Green New Deals to address contextual needs and accelerate sustainability transitions with social protection frameworks. This approach can help nations pursue equitable sustainability transitions that consider inclusivity and economic equity.
	Paper 8: Calls for a global discourse on how funding flows should be directed towards revitalizing communities during and after conflicts, such as those in

	Ukraine and Russia. The paper highlights the need to address climate change, which is currently being overshadowed by these ongoing conflicts, and discusses the challenges of achieving deep decarbonization and net-zero targets in the affected countries.

3. AIMS AND OBJECTIVES

The primary aim of this thesis was to investigate the potential of the Green New Deal in driving equitable sustainability transitions for both developed and low-income and developing economies. This was achieved through the examination of the evolution of the Green New Deal, its theoretical underpinnings, and applied frameworks, with a focus on the unique challenges and opportunities faced by these different economic contexts. The study analyzed the financing hurdles, the role of technology, and the development of specific mechanisms tailored to individual geographies and contexts.

The following objectives guided this research:

1 Examined the evolution of the Green New Deal and its potential for supporting inclusive sustainability transitions in both developed and low-income and developing economies, while considering the impacts of the COVID-19 pandemic and geopolitical conflicts.

2 Identified and assessed the financing hurdles associated with global sustainability transition pathways, as well as the roles and responsibilities of various stakeholders, including governments, industries, regulators, and communities, in addressing these challenges.

3 Investigated the potential of technology in accelerating sustainability transitions and analyzed the necessary support mechanisms required to facilitate technology adoption, transfer, and innovation.

4 Developed specific mechanisms and recommendations tailored to the contextualized challenges and geographies of both developed and low-income and developing economies, ensuring that the Green New Deal pathways are equitable and responsive to the unique needs and opportunities of these regions.

By addressing these objectives, the thesis aimed to contribute to the ongoing discourse on sustainable development and provide valuable insights for policymakers and stakeholders engaged in the design and implementation of Green New Deal-inspired sustainability transition roadmaps.

3.1 RESEARCH AND POLICY SIGNIFICANCE

The research and policy significance of this thesis lies in its comprehensive examination of the Green New Deal as a framework for driving equitable sustainability transitions in both developed and low-income and developing economies. Amidst the growing urgency to address climate change and its consequences, exacerbated by the COVID-19 pandemic and ongoing geopolitical conflicts, this study offers valuable insights for policymakers, industry leaders, regulators, and communities to design and implement effective and inclusive sustainability transition pathways.

First, by investigating the key financial challenges and opportunities in the development and implementation of global sustainability transition pathways, this thesis contributes to the understanding of the roles and responsibilities of various stakeholders. It will help identify the necessary financial instruments, incentives, and public-private partnerships to overcome the financing hurdles and enable the successful implementation of Green New Deal-inspired policies. The findings of this research can inform decision-makers on how to allocate resources effectively, prioritize investments, and leverage international cooperation and support to ensure that the financial aspects of sustainability transitions are adequately addressed.

Second, the study's exploration of technology adoption, transfer, and innovation in accelerating sustainability transitions provides valuable information on the supportive mechanisms required to facilitate these processes. This includes the identification of key technological advancements, capacity building measures, and enabling environments that promote innovation and technology diffusion. Policymakers and industry leaders can use this information to design targeted interventions, invest in research and development, and foster collaborations that drive technological progress and contribute to a sustainable and resilient future.

Third, by developing specific strategies and mechanisms to address the contextualized challenges and opportunities faced by different geographies and economies, this thesis contributes to the body of knowledge on tailored approaches to sustainability transitions. The research emphasizes the importance of recognizing the unique needs and circumstances of different regions and the potential for context-specific solutions. This can inform policy design and implementation, ensuring that Green New Deal-inspired policies are inclusive, equitable, and responsive to local realities.

Finally, the research and policy significance of this thesis is underscored by its potential to inform the development of effective and inclusive Green New Deal-inspired sustainability transition pathways. By addressing financial challenges, leveraging technology, and developing context-

specific strategies, this study offers valuable insights that can guide decision-makers and stakeholders in the pursuit of a more sustainable and just future for all.

4. LITERATURE REVIEW

4.1 THE GREEN NEW DEAL

The Green New Deal, framed as a pivotal environmental transition policy, is inspired by the New Deal, spearheaded by President Franklin D. Roosevelt. The New Deal was then coined as a series of programs, public work projects and financial and regulatory reforms. This led to the production of over 960,000 miles of roads and several public facilities (Reagan, 1999).

In regards to the climate change and sustainability transition narrative, the Green New Deal movement originated in the United States in 2006, being championed by the Green New Deal Taskforce that was formed to articulate issues of Global Greens (Conte, 2019). The formulation of the Green New Deal was a culmination of active activism by different groups that had begun in the 1970s, especially after the 1973 oil crisis (Bloomfield and Steward, 2020a). The 2006 Green New Deal idea was thus the outcome and fruits of such activism that had seen the political class join the debate and proposing the setting up of a task force. After 2006, the green movement was appealing to a number of politicians, like Jill Stein, who through her Green Party ran for presidential position in 2012 and also in 2016 (D'Souza, 2022).

In 2010, Howie Hawkins, also of Green Party had contested for the gubernatorial position of New York riding on the Green New Deal platform (Hawkins et al., 2020). Later, in 2018, the Green New Deal gained unprecedented attention after the idea was adopted and made a congressional resolution by Representatives Alexandria Ocasio-Cortez and Senator Edward J. Markey (Congress, 2019). The effort of these politicians, supported by their counterparts in congress passed resolutions, which they argued would assist the federal government of the United States to adopt and implement a raft of programs proposed in the resolution, to not only help the country achieve net-zero emissions by 2030, through adoption of renewable energies, but also would help address issues of ‘social injustices’ (Congress, 2019). In Europe, the deal is dubbed the Green Deal, and was championed by the European Commission. In 2019 the EU drafted a proposal for the Green Deal, which has been received warmly; and has also gained substantial support from both the European Council and the European Parliament (European Commission, 2019).

Besides those two regions, the Green Deal has had support from institutions and organisation that represent, virtually every part of the globe. Thus, the deal was thus dubbed, ‘Global Green New Deal’. For instance, since its inception in 2006, the deal has become popular with most of the United Nations Institutions such as UNEP and UNCTAD amongst others, with a converging message from all those calling for actions that would accelerate the achievement of zero

emission by 2030s and beyond. Also, they promote the adoption of the deal to serve as a tool for helping developing and least developed economies grow their economies without necessarily relying on means that compromises the sustainability agenda.

The discourse on decarbonisation is however not unique to the Green New Deal. The debate has been ongoing since the 19th century, after the acknowledgement of severe and abrupt natural changes due to greenhouse gases were identified. However, the Green New Deal idea is an important one for decarbonisation efforts, as it brings in the support of the political class, pushing for a top-down policy approach (D'Souza, 2022). This is important, as such a move would pressurize federal governments to commit resources, formulate new policies and act in a way that is bound to bring measureable results in different aspects related to environmental justice.

It is important to note that the term ‘justice’, within the climate change narrative, interweaves the disproportionate effects of climate change on marginalized communities with broader ethical obligations. As outlined in publications 3 and 7, it insists on rectifying the 'climate debt' owed by industrialized nations, which have historically emitted the majority of greenhouse gases, to those less responsible yet severely impacted. The discourse encompasses ethical dilemmas such as equitable greenhouse gas budget allocation and defining responsibilities across generations and geographies (Stanford Encyclopedia of Philosophy). The debate between treating climate issues in isolation versus an integrated approach that considers climate justice in conjunction with broader social injustices is pivotal, hence extending this narrative to future generations, acknowledging the enduring impact of greenhouse gas emissions and our ethical duty to them.

While the Green New Deal has often been termed as being radical in nature and has thus faced hurdles in its acceptability, there are select resolutions and ideas that can be implemented straight away, in an effort to support the move toward a net-zero carbon economy by 2050. The implementation of renewable energies primarily depends on the commitment of policymakers, where those can create policies to adjust renewable energy pricing, ensuring infrastructure costs are not passed on to consumers. (Fischer and Jacobsen, 2021). In this case, as observed with solar energy policy, a notable $141 billion investment was attracted in the sector in the U.S. (Jaganmohan, **2021**), prompting an increase in its adoption, including in decentralized fashion through rooftops photovoltaic installations in varying geographical locations. Overall, the entire renewable energy sector was projected to experience an additional $1.4 trillion by end of 2022, he was the significant importance clean energy has post-pandemic (Hall, 2022). Going forward, such policies need to encourage to ensure similar frameworks for

industries to invest in R&D, not only in renewable energies, as collectively those actions which would not only help in reducing emissions but serve as frontiers for the creation of sustainable employment opportunities, promotion of social justice, and sustainable economic growth. With effective policy frameworks, it is understood that resources and investments would be channeled effectively to targeted sectors, rather than concentrating on supporting pollution intensive activities. One challenge however remains the associated costs of decarbonisation programs, which can be a burden to low and emerging economies if no appropriate frameworks and support mechanisms exist.

While the need for sustainability transitions is well established, programs like the Green New Deal still face some criticisms. Some argue that the GND is an example of government overreach, and lacking in detail, particularly regarding its financial feasibility and the practicality of its goal to convert all U.S. power to renewable sources within a decade. Additionally, carbon capture, utilization and storage (CCS), and nuclear power, was noted to potentially lead to more cost-effective strategies for decarbonization. There also lies deeper political barriers as the ambitious coupling of climate action with social issues, such as poverty alleviation, could complicate bipartisan support and impede progress toward sustainability (Klein, 2020). However, the prospects of the program far outweigh its negatives, especially noting that the tailor made policies and roadmaps can be generated to benefit specific themes and interests.

4.2 THE IMPACTS OF THE COVID-19 PANDEMIC ON GLOBAL SUSTAINABILITY

The COVID-19 pandemic has had a profound impact on global sustainability, especially in regard to use of fossil fuels. During the height of the pandemic, specially thefirst and second quarters of 2020, significant reduction in emission were reported in many countries, especially the heavy polluters such as China, India and the U.S (Allam, 2020d, Allam, 2020b). Overall, it is reported that global emissions dropped by approximately 6% in 2020, more so due to a 4% reduction in energy demand, and some noticeable levels of growth in renewable energy production and consumption. However, post-pandemic, the celebrated reductions turned to be short-lived. This was instigated by factors like increased demand for energy that prompted a 4.8% increase in consumption of fossil fuels (Davis et al., 2022). This has been seen as detrimental to the sustainability agenda, especially since it is seen to reverse some gains already achieved in pursuit of the Paris Agreement proposed objectives.

While the virus has affected people all over the world, it has been particularly brutal on some economies, especially those that were the least prepared, such as the global south, developing

and least developing economies. This is true in terms of millions of people who have already been pushed into extreme poverty. For instance, it is reported that over 75 million more people pludged into poverty between 2020 and 2022 due to the impacts of the pandemic, coupled with the impacts from the Ukraine-Russia war (United Nations Statistics Division, 2022). In addition, the pandemic has widened socio-economic gaps, especially highlighting disparities between the rich and the poor, and increased global debt to unprecedented levels. For example, African countries experienced a sharp increase in their debt-to-GDP ratios, which increased by approximately 6% in 2020 to reach a high of 58%, according to the International Monetary Fund (IMF) (Georgieva, 2021). It rose to 68% in 2021 and is expected to decrease marginally to 67% in 2023 (African Development Bank Group, 2022).

As a result of the above, the need for regenerative mechanisms has become more urgent than ever. This would help countries to experience some levels of relief from the debt-trap and in their pursuit to raise funds to combat the pandemic, which has put a strain on the already limited resources of some economies (Gautam and Hens, 2020). Regenerative mechanisms, however, need to be fashioned in a manner that promotes long-term sustainability while also addressing immediate needs. For energy production and consumption, the long-term objective should be to focus more on renewable energies, for it is already apparent that the fossil fuels cannot be an option for either short-term or long-term endeavors (Dhunny et al., 2019). Other long-term regenerative mechanisms, such as sustainable agriculture and alternative mobility options, promoting sustainability should be encouraged and financed. The main target should be focusing on supporting urban planning and development programs that seek to reduce resource exploitation and consumption, while increasing service delivery in areas like housing, food security energy and water production and distribution, as well as reduction of waste generated in those areas.

It would also be important to ensure that short-term interventions do not jeopardize the long-term pursuits (United Nations Economic and Social Council, 2021). On this, it is noted that many countries in the least-developed and developing categories are not financially equipped to engage in national sustainability transitions in the aforementioned areas. They would therefore be wary of their contribution to the sustainability agenda, especially in view that they bear the greatest risks and burden of climate change events and impacts.

4.3 THE IMPACTS OF THE RUSSIA-UKRAINE WAR ON GLOBAL SUSTAINABILITY

The Russia-Ukraine war compounded the difficult period that most global economies experienced as a result of the COVID-19 pandemic. Whereas the two countries have been in a state of conflict since 2014, a major escalation became evident on the 24th February 2022, when Russia invaded and took hold of some parts of Ukraine (Bigg, 2023). Like any other war, the extent of destruction, displacements, casualties and disruptions have been immense, especially for the Ukrainians. Unfortunately, a year since the full-scale war began, it is not yet clear when this would stop, as alternative conflict resolution mechanisms seem to bear no tangible fruits.

Whereas it is obvious that most people have focused on the impacts this war has had on people, their livelihoods and properties, there is sufficient evidence that the war has had immeasurable impacts on the economies beyond the borders of the two countries (European Commission, 2022). To begin with, the two countries play a critical role in agriculture and global food security. Russia for instance is amongst the top exporters of farm inputs such as fertilizers, while Ukraine leads the exportation of grains, edible oils and other foodstuff to many countries (Ben Hassen and El Bilali, 2022). With the war, there has been significant disruption in the supply chain of those products, triggering a chain reaction on different sectors of the global economy (Allam et al., 2022a). For instance, there is a raging food insecurity in most countries, with high inflations due to shortages and scarcity (Behnassi and El Haiba, 2022). Scarcity of petroleum products from Russia have further escalated the economic challenges experienced by different countries, especially those reliant on oil importation. For instance, in the better part of 2022, the american economy, and those of many western countries, were substantially derailed by oil shortages. At the global scale, it is reported that the economic growth plummeted by 1% point to 3.2% from what was experienced in 2021, and with the escalation of the war, projections are that the global economic growth may decline to about 2.6% in 2023 (OECD, 2022). Such a drop is poised to have an imaginable ripple effect on different sectors of the economy, with most of the global population being affected.

Besides the economy, the war has had significant impacts on the environment, not only in Ukraine, but at the global level. Of the most profound impacts is the attack on nuclear power plant e.g., the Zaporizhzhia nuclear power plant (Mandler, 2022). Attacking these increases the risks of radiation leaks, which would have devasting impacts on biodiversity as well as people (Pereira et al., 2022). Also, the war is reported to have contributed to increasing emissions, causing deforestation and soil degradation due to bombing, and excavations done on the

landscape of Ukraine. In addition, the debris and harmful components have been finding their way into the water and water bodies, impact the quality thereof (Shumilova et al., 2023).

The overall impacts of the Ukraine-Russia conflicts are not limited to the geographic boundaries of those countries, and hold a significant global bearing, especially on sustainability on all spheres, whether economic, political, environmental, or social. In fact, in the recent past, because of these wars, new political trends and alignments were seen to emerge with significant impacts on the global political landscape, including affecting decision and stands taken on key issues like environments. For instance, the close cooperation between Russia and China that is shaping, at the time of writing of this thesis, may have some implications on the discourse on the climate action and agenda in the future, especially noting that Russia is not in good terms with many countries, including the West and North America which are key players in the climate agenda discourse. The ramification of sanctions on Russia have further had significant sustainability impacts, especially on economies that are oil reliant, with recent trends showing countries shifting from a dollar-reliance to multicurrency in a bid to overcome the dollar shortage prompted by the combined impacts of the pandemic and conflict, among other geopolitical factors (Jha, 2023).

4.4 GREEN NEW DEALS AND SUSTAINABILITY TRANSITION PATHWAYS

Green new deals are generally celebrated for their positions in supporting radical changes across a range of sectors aiding to speed urgent climate action, including numerous social issues, like healthcare, unemployment, inequality, housing, and education amongst many others. The radical nature of these deals is the timelines for their achievement. For instance, the American version proposes that most of the social targets can be achieved before 2030, while the 100 percent transition to renewable energy targeted to be achieved by 2050 (Congress, 2019). The European version on the other hand, proposes that by 2050, ‘there are no new emissions of greenhouse gases’, and that by then, all economic growth pursuits in each of the member states would be decoupled from resource use. It also proposes that by 2027, it will have amassed at least 100 billion Euros to assist those adversely affected by the proposed transition to a greener economic model (European, 2021).

While the proposals captured in the new green deals have emerged principally within the developed economies, their principles can work equally well in developing and in less developing economies, especially in view of current challenges prompted by the impacts of COVID-19 and the ongoing Russia-Ukraine conflict. However, proposals which call for a total paradigm shift have

attracted much criticism, where critics term the proposals as ‘radical’, ‘Trojan horse for socialism’, ‘socialists wish list’ and many other such term (Stepman, 2019, Zak, 2019). Their arguments, which incline more on the capitalist perception is that economies must first be able to satisfy the basic amenities of its community prior to developing environmentally focused programs.

It is perceived that the targeted period for the achievement of some of the proposals, like social interventions are not feasible, as those would require substantial budgetary provisions, which most economies cannot absorb at the moment (Loris, 2021, Jordana, 2021). For instance, Stepman (2019) argue that the American version of new Green Deal would require a minimum of $32.6 trillion within 10 years to facilitate the social intervention. It would also require $5.2 trillion over a 20-year period to transition to 100% renewable energies. Other critics estimate the funding required to actualize it to be up to a high of $93 trillion (D'Souza, 2022). All those figures come against a federal government budget of $4 trillion, which Stepman (2019) argue is partly debt funded, and adopting the new green deal would plunge the economy into more debts, especially if the proposal is to be implemented during this period when the world is grappling with the impacts of both the COVID-19 and the devastating impacts of Russia-Ukraine war. It would then mean increasing taxes, especially on the rich cadre to support the economy, but those groups are a powerful lobbying force and such measures have been seen as being unsuccessful as seen during President Trump’s mandate (Maldonado, 2018). The challenge of costs is not only in America, but also in Europe, where proponents of the deal are criticised for ‘secretly’ trying to address the inequality equation, without making this explicit (European Parliament, 2020). Theeit the positives new green deal programs are expected to bring to the economy, the fears are that it will require at least 2% of the EU’s annual GDP prompting critics to support that the economy cannot support such. Post-pandemic, it has been made explicit that the European Green New Deal will require approximately a third of the region's 1.8 trillion Euro investment budget for the next seven years to make it a reality (European Commission, 2023). However, the European Union have justified this, by arguing that the deal is the region’s lifeline against the impacts of the COVID-19 pandemic.

With those foregoing challenges on the financing of Green New Deals, the question is how such a philosophy which is extremely good can be adopted in developing economies without them enduring such hindrances but to allow them to address the climate challenges that are also live within. As will be showcased in the next section, there exists a substantial number of sustainability transition pathways and economic models that can be adopted to address varying

dimensions. But, the main challenge, especially during the post- COVID-19 pandemic is the source of funds to finance proposed programs.

4.5 FINANCING CHALLENGES FOR SUSTAINABILITY TRANSITIONS IN THE CONTEXT OF THE COVID-19 PANDEMIC AND THE RUSSIA-UKRAINE WAR

The impacts of COVID-19 on the global economy have been severe on almost all sectors, including manufacturing, agriculture, transport, hospitality industries and others (Pak et al., 2020). In a report by the International Labour Organization (ILO) (International Labour, 2021), dated January 2021, an unemployment rate of a magnitude of 114 million is linked to the pandemic. Further, 8.8% -equivalent to 255 million full time equivalent jobs hours (48-hours working week) was lost in 2020, while a further 127 million full time jobs were lost by end of 2021. As a result of those unfortunate occurrences, global labour income loss is estimated to over $3.7 trillion, a figure equivalent to 4.4% of the 2019 total global GDP (International Labour, 2021). In 2021, the labor income lost was approximately $1.3 trillion. The pain of job loss, which had started to ease at the beginning of 2022, was short-lived following the Russia-Ukraine conflict. To put this into context, it was estimated that by the third quarter of 2022, the labor market would have improved significantly, with the deficit from the pre-pandemic levels being only 40 million full-time jobs. However, with the war, the gains were lost, and almost immediately, over 4.8 million jobs were lost in Ukraine alone (International Labour Organization, 2022). These losses are spread from different sectors, especially the manufacturing industry and the entire supply chain, the hospitality and hotel industry, tourism sector and transport sectors that have faced serious challenges from issues like lockdowns, restriction of movements, border restrictions and financial constraints.

On the above, the manufacturing sector, which has been a pivotal pillar in the growth of economies, both in developed and developing economies experienced a 6% contraction during the first and second quarters of 2020 (United Nations Industrial Development, 2020). However, there has been a positive recovery in the sector with records of approximately 9.4% points above the 2019 rates. However, since the Ukraine-Russia escalated to full-scale war, there are reports of unprecedented disruption in the supply chain, which would have significant deep in the manufacturing activities globally.

In the global aviation realm, a report by the International Civil Aviation Organization (ICAO) (Organization, 2021) confirmed that the air transport industry experienced a financial loss of over $370 billion in 2020. The net effect of all these challenges, in different economic sectors,

was financial and operational unsustainability, which ultimately left numerous economies in states of deficit-driven economies. This prompted most of these, from different parts of the world, running to external financiers like the International Monetary Fund (IMF), which stated that since the beginning of the global pandemic, it has issued $250 billion in the form of loans and debt reliefs to different countries, a figure that is approximately a quarter of $1 trillion financing tool available for its member countries (International Monetary, 2021). However, the financial support required across the globe, including in developed economies that need to revive their economies and achieve some growth, after the drawbacks of the pandemic, cannot be met by external lenders only. After all, most of the developed economies do not often turn to those institutions for financial support. In this regard, there is an economic option that developed economies are seen to increasingly contemplate: that of the principle of 'Modern Monetary Theory' (MMT), which highlights that currency-issuing economies cannot theoretically run out of money, and do not necessary rely on taxes to initiate capital-intensive programs (Matthews, 2019). With this financing option, it is therefore theoretically possible for those select developed economies to self-finance social and environmental programs, proposed in new green deals without constraining their tax revenues.

Ocasio-Cortez (Npr, 2021) expressed that noting the MMT option, the government has the liberty to finance green deals through deficit spending. This is because the governments (which control their own currency) have the capacity to spend more than they collect. Therefore, from this perspective, MMT allows some governments to spend beyond their actual tax revenue; a potent option to finance major development projects. While there are inflationary challenges that need to be cautioned and addressed, this option seems feasible, but requires a radical rethinking of both economic and political structures.

However, the MMT option is not applicable to developing economies, as these must rely on either direct tax revenues, or funds from external sources, to actualise their sustainability programs. This, therefore, means that there will be a substantial gap and disparity in financing climate actions, where developed economies will have an unmatched potential in the medium term. This notwithstanding, developed economies, and those with financial capacities, need to extend their support to developing and less developed economies, so that they can initiate post-pandemic recovery programs that are majorly dissociated with non-renewable and unsustainable practices. Otherwise, these may then opt to plunge in unsustainable debts, or they may opt to overlook laid down policies, agreements or accords in line with environmental sustainability. It is possible for developed economies to support their counterparts, by extending

financial support as well as ensuring investment in sustainable environmental and social programs, such that the impacts of climate change, from their ends, are minimized or even eliminated completely. This way, the equity gap, expected as a result of the pandemic, between developed and developing and less developed states will reduce, while making significant strides toward global sustainability.

4.6 INADEQUATE FRAMEWORKS FOR FINANCING SUSTAINABILITY TRANSITION PATHWAYS & ECOSYSTEM CONSERVATION AND RESTORATION

Numerous frameworks have been proposed to guide sustainability transitions, such as socio-technical transitions, strategic niche management, and multi-level perspectives. However, the applicability of these frameworks to developing nations has often been called into question due to various challenges they face (Loewen, 2022, Feola, 2020). This section aims to outline the key challenges and explore the need for a more symbiotic transition pathway that considers both sectoral transitions and ecosystem services, building on the premise and the momentum of the Green New Deal.

4.6.1 Challenges of Applying Sustainability Transition Frameworks to Developing Nations

Sustainability transition frameworks, in general, have been criticized for their lack of applicability to developing nations due to several reasons. Firstly, these frameworks tend to be heavily influenced by the experiences and contexts of developed countries, which can limit their relevance in addressing the unique socio-economic and political challenges faced by developing nations (Rahmani et al., 2022). For example, developing nations often face higher levels of poverty, inequality, and weak institutional capacities (Kates and Parris, 2003, Rees, 1995), which can hinder the effective implementation of transition policies and strategies. Secondly, these frameworks often assume a certain level of technological and infrastructural capabilities, which may not be available or easily accessible in developing nations (Meadowcroft, 2011, Hansen et al., 2018). This can result in a mismatch between the proposed transition pathways and the actual conditions on the ground, leading to sub-optimal outcomes or even exacerbating existing vulnerabilities.

4.6.2 Financing Challenges in Sustainability Transitions

One of the most critical challenges faced by developing nations in implementing sustainability transitions is financing. The transition to a low-carbon and climate-resilient society requires substantial investments in areas such as renewable energy, energy efficiency, and climate adaptation measures. Developing nations often lack the necessary financial resources and access to international funding mechanisms to support these investments (Barua, 2020). Regional grants, carbon offsets, and other financial instruments have been proposed as potential sources of funding for sustainability transitions. However, their implementation has been fraught with difficulties and controversies (Lundsgaarde et al., 2018). For example, the allocation of climate funds often raises tricky questions around fairness and responsibility. China, being one of the largest contributors to CO2 emissions, is also considered a developing nation and thus eligible to receive support from climate funds. This situation highlights the complexities and contradictions inherent in global climate finance and calls for a more nuanced understanding of the responsibilities and needs of different countries in the transition process.

4.6.3 The Need for Integrating Ecosystem Services in Transition Pathways

Another limitation of existing sustainability transition frameworks is their predominant focus on sectoral transitions, such as energy, transport, agriculture, buildings, and others (Kılkış, 2019). While these sectoral transitions are crucial, they often overlook the importance of ecosystem services in achieving deep decarbonization and ensuring a healthy ecosystem balance. Ecosystem services, defined as the benefits that humans derive from ecosystems, play a critical role in supporting human well-being and sustainable development. They include provisioning services such as food, water, and timber, regulating services such as climate regulation and flood control, and cultural services such as recreational and spiritual benefits (Allam et al., 2021a). Incorporating ecosystem services into sustainability transition pathways can help to ensure that the transition process not only reduces greenhouse gas emissions but also enhances the resilience and adaptive capacity of social-ecological systems.

The adoption of ecosystem accounting has the potential to reconfigure policy frameworks at both national and international levels. As it embeds the worth of natural resources and ecosystem services into the economic dialogue, it can stimulate policy emphasis on ecological preservation, sustainable expansion, and green technological advancements. On a global scale, this approach, coupled with other measures, can unveil a pathway for innovative financial structures for Green New Deals.

4.6.4 Towards a Symbiotic Transition Pathway: Building on the Green New Deal

Given the limitations and challenges outlined above, there is a pressing need for a more symbiotic transition pathway that integrates both sectoral transitions and ecosystem services, as well as addresses the specific needs and contexts of developing nations. The Green New Deal, posited as a policy proposal aimed at addressing both climate change and economic inequality, offers a promising starting point for such a pathway. A symbiotic transition pathway can be built on the core principles of the Green New Deal, which emphasize the need for a just and inclusive transition that leaves no one behind. This means taking into account the specific socio-economic and political contexts of developing nations, and ensuring that their unique challenges and vulnerabilities are addressed through tailored policies and strategies.

5. COMPILATION OF PUBLISHED WORKS

5.1 Paper 1 - An overview of climate change adaptation and mitigation research in Africa

5.1.1 Co-authorship form and contribution weightage

Title	An overview of climate change adaptation and mitigation research in Africa	
Journal	Frontiers in Climate	
Publisher	Frontiers	
Status	Published	
Cite as	Baninla Y, Sharifi A, Allam Z, Tume SJP, Gangtar NN and George N (2022) An overview of climate change adaptation and mitigation research in Africa. Front. Clim. 4:976427	
Contribution		
Name	**Share**	**Signature**
Yvette Baninla	40%	Production Note: Signature removed prior to publication.
Ayyoob Sharifi	20%	Production Note: Signature removed prior to publication.
Zaheer Allam	10%	Production Note: Signature removed prior to publication.
Suiven John Paul Tume	10%	Production Note: Signature removed prior to publication.
Ngeh Najibullah Gangtar	10%	Production Note: Signature removed prior to publication.
Ngiamte George	10%	Production Note: Signature removed prior to publication.

5.1.2 Abstract

Research on climate change has increased significantly since the 1970s. There has also been a particular focus on Africa, given its vulnerability to climate change impacts and its urbanization trends that may have massive implications for climate change adaptation and mitigation. Despite the wealth of publications on climate change in Africa, there is a lack of review studies that highlight the overall research landscape. If this status of climate research is clarified, African countries can better deal with climate change. Hence, this paper aims to improve our understanding of the status and trends of research on climate change adaptation and mitigation in Africa. Our review, straddling from 1990 to late 2021, recognizes the foundations that underpin climate change adaptation and mitigation literature. Based on keywords associated with Africa's climate change adaptation and mitigation, we undertook bibliometric research by collecting 3,316 related SCI/SSCI articles. In addition, we provided a thematic evolution over three decades, compartmentalized into four sub-periods (1990–2007; 2008–2014; 2015–2019; 2020–2021). Priority research topics and themes have been dynamic over time, with some core concepts receiving more attention (vulnerability, food, water, and energy security). Although the number of published articles exhibited a rapidly growing trend, their distribution is extremely uneven. Articles were mainly published by institutions from certain parts of the continent, with the University of Cape Town, making the highest contribution. About 72% of the existing studies focused on climate change adaptation, while climate change mitigation was less represented with 22%. The results also showed that researchers have examined not all African countries. South Africa, Ethiopia, and Ghana are hot spots, while most countries are largely neglected. Africa and African countries need to improve their future research ability on climate change mitigation. Assessing climate change risks and measures in African countries should be prioritized.

5.1.3 Publication

Featured in Annex 1

frontiers | Frontiers in Climate

TYPE Review
PUBLISHED 28 October 2022
DOI 10.3389/fclim.2022.976427

OPEN ACCESS

EDITED BY
Bao-Jie He,
Chongqing University, China

REVIEWED BY
Shanshan Chen,
Humboldt University of Berlin, Germany
Jack Ngarambe,
Kyung Hee University, South Korea

*CORRESPONDENCE
Ayyoob Sharifi
sharifi@hiroshima-u.ac.jp

SPECIALTY SECTION
This article was submitted to Climate Adaptation, a section of the journal Frontiers in Climate

RECEIVED 23 June 2022
ACCEPTED 11 October 2022
PUBLISHED 28 October 2022

CITATION
Baninla Y, Sharifi A, Allam Z, Tume SJP, Gangtar NN and George N (2022) An overview of climate change adaptation and mitigation research in Africa. *Front. Clim.* 4:976427. doi: 10.3389/fclim.2022.976427

An overview of climate change adaptation and mitigation research in Africa

Yvette Baninla[1,2], Ayyoob Sharifi[2*], Zaheer Allam[3], Suiven John Paul Tume[4], Ngeh Najibullah Gangtar[1] and Ngiamte George[5]

[1]Department of Geology, Mining and Environmental Science, University of Bamenda, Bamenda, Cameroon, [2]Graduate School of Humanities and Social Science and Network for Education and Research on Peace and Sustainability, Hiroshima University, Hiroshima, Japan, [3]Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW, Australia, [4]Department of Geogrpahy and Planning, University of Bamenda, Bamenda, Cameroon, [5]Pan-African University Life and Earth Science Institute (PAULESI), University of Ibanda, Ibadan, Nigeria

Research on climate change has increased significantly since the 1970s. There has also been a particular focus on Africa, given its vulnerability to climate change impacts and its urbanization trends that may have massive implications for climate change adaptation and mitigation. Despite the wealth of publications on climate change in Africa, there is a lack of review studies that highlight the overall research landscape. If this status of climate research is clarified, African countries can better deal with climate change. Hence, this paper aims to improve our understanding of the status and trends of research on climate change adaptation and mitigation in Africa. Our review, straddling from 1990 to late 2021, recognizes the foundations that underpin climate change adaptation and mitigation literature. Based on keywords associated with Africa's climate change adaptation and mitigation, we undertook bibliometric research by collecting 3,316 related SCI/SSCI articles. In addition, we provided a thematic evolution over three decades, compartmentalized into four sub-periods (1990–2007; 2008–2014; 2015–2019; 2020–2021). Priority research topics and themes have been dynamic over time, with some core concepts receiving more attention (vulnerability, food, water, and energy security). Although the number of published articles exhibited a rapidly growing trend, their distribution is extremely uneven. Articles were mainly published by institutions from certain parts of the continent, with the University of Cape Town, making the highest contribution. About 72% of the existing studies focused on climate change adaptation, while climate change mitigation was less represented with 22%. The results also showed that researchers have examined not all African countries. South Africa, Ethiopia, and Ghana are hot spots, while most countries are largely neglected. Africa and African countries need to improve their future research ability on climate change mitigation. Assessing climate change risks and measures in African countries should be prioritized.

KEYWORDS

climate change, adaptation, mitigation, Africa, bibliometric analysis, urbanization, vulnerability, risk

5.2 Paper 2 - Emerging Trends and Knowledge Structures of Smart Urban Governance

5.2.1 Co-authorship form and contribution weightage

5.2.2

Title	Emerging Trends and Knowledge Structures of Smart Urban Governance	
Journal	Sustainability	
Publisher	MDPI	
Status	Published	
Cite as	Allam, Z.; Sharifi, A.; Bibri, S.E.; Chabaud, D. Emerging Trends and Knowledge Structures of Smart Urban Governance. Sustainability 2022, 14, 5275.	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	50%	Production Note: Signature removed prior to publication.
Ayyoob Sharifi	20%	Production Note: Signature removed prior to publication.
Simon Elias Bibri	30%	Production Note: Signature removed prior to publication.
Didier Chabaud	10%	Production Note: Signature removed prior to publication.

5.2.2 Abstract

The concept of smart cities peaked in 2015, bringing an increased influx of ‘smart’ devices in the form of the Internet of Things (IoT) and sensors in cities. As a result, interest in smart urban governance has become more prevalent in administrative, organisational, and political circles. This is sustained by both local and global demands for an increased contribution to the goals of sustainability through urban governance processes in response to climate change urgencies. Cities generate up to 70% of global emissions, and in light of societal pressures for more inclusivity and democratic processes, the need for sound urban governance is merited. Further knowledge on the theme of smart urban governance is required to better understand the trends and knowledge structures and better assist policy design. Therefore, this study was undertaken to understand and map the evolution of the concept of smart urban governance through a bibliometric analysis and science mapping techniques using VOSviewer. In total, 1897 articles were retrieved from the Web of Science database over 5 decades, from 1968 to 2021, and divided into three subperiods, namely 1978 to 2015, 2016 to 2019, and 2020 to early 2022. Results indicate that the overall emerging themes across the three periods highlight the need for citizen participation in urban policies, especially in relation to smart cities, and for sustained innovation for e-participation, e-governance, and policy frameworks. The results of this study can aid both researchers exploring the concept of urban governance and policy makers rendering more inclusive urban policies, especially those hosting technological and digital domains.

5.2.3 Publication

Featured in Annex 2

sustainability

MDPI

Article

Emerging Trends and Knowledge Structures of Smart Urban Governance

Zaheer Allam [1,2,3,*], Ayyoob Sharifi [4,5], Simon Elias Bibri [6,7] and Didier Chabaud [1]

[1] Chaire Entrepreneuriat Territoire Innovation (ETI), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France; chabaud.iae@univ-paris1.fr
[2] Live + Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia
[3] Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW 2007, Australia
[4] Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan; sharifi@hiroshima-u.ac.jp
[5] Center for Peaceful and Sustainable Futures (CEPEAS), IDEC Institute, Hiroshima University, Hiroshima 739-8529, Japan
[6] Department of Computer Science, Norwegian University of Science and Technology, Sem Saelands Veie 9, NO-7491 Trondheim, Norway; simoe@ntnu.no
[7] Department of Architecture and Planning, Norwegian University of Science and Technology, Alfred Getz Vei 3, Sentralbygg 1, 5th Floor, NO-7491 Trondheim, Norway
* Correspondence: zaheerallam@gmail.com

Abstract: The concept of smart cities peaked in 2015, bringing an increased influx of 'smart' devices in the form of the Internet of Things (IoT) and sensors in cities. As a result, interest in smart urban governance has become more prevalent in administrative, organisational, and political circles. This is sustained by both local and global demands for an increased contribution to the goals of sustainability through urban governance processes in response to climate change urgencies. Cities generate up to 70% of global emissions, and in light of societal pressures for more inclusivity and democratic processes, the need for sound urban governance is merited. Further knowledge on the theme of smart urban governance is required to better understand the trends and knowledge structures and better assist policy design. Therefore, this study was undertaken to understand and map the evolution of the concept of smart urban governance through a bibliometric analysis and science mapping techniques using VOSviewer. In total, 1897 articles were retrieved from the Web of Science database over 5 decades, from 1968 to 2021, and divided into three subperiods, namely 1978 to 2015, 2016 to 2019, and 2020 to early 2022. Results indicate that the overall emerging themes across the three periods highlight the need for citizen participation in urban policies, especially in relation to smart cities, and for sustained innovation for e-participation, e-governance, and policy frameworks. The results of this study can aid both researchers exploring the concept of urban governance and policy makers rendering more inclusive urban policies, especially those hosting technological and digital domains.

Keywords: smart cities; urban governance; smart governance; ICT; IoT; big data analytics; inclusivity; citizen participation; innovation; institutions; democracy

check for updates

Citation: Allam, Z.; Sharifi, A.; Bibri, S.E.; Chabaud, D. Emerging Trends and Knowledge Structures of Smart Urban Governance. *Sustainability* **2022**, *14*, 5275. https://doi.org/10.3390/su14095275

Academic Editor: Wann-Ming Wey

Received: 25 March 2022
Accepted: 22 April 2022
Published: 27 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Cities across the globe have been confronted by several challenges in the past century, including climate change, rapid population growth, and exponential urbanization, amongst others. After the end of World War Two (WW2), it was reported that the economic welfare of many global residents started to grow, especially in urban areas, courtesy of sound urban governance approaches that were adopted [1]. This was prompted by an increase in opportunities for economic growth, education, socialization, and recreation in cities, thereby attracting a sizeable number of people, businesses, and government operations.

5.3 Paper 3 - Addressing Knowledge Gaps for Global Climate Justice

5.3.1 Co-authorship form and contribution weightage

5.3.2 Abstract

The Conference of Parties (COP) 26 highlighted the need for global-level deep decarbonization and provided financial instruments to aid climate mitigation in the global south, as well as compensation avenues for loss and damage. This narrative reiterated the urgency of addressing climate change, as well as aiding advances in green products and green solutions whilst shifting a portion of responsibility upon the global south. While this is much needed, we argue that the science rhetoric driving this initiative continues to be advantageous to the global north due to their capacity to control consumption gaps and to access human knowledge and resource extraction. If not addressed, this will reinforce a continuing unjust north/south narrative, highlighting neo-climate colonialism precepts.

5.3.3 Publication

Featured in Annex 3

geographies

MDPI

Commentary

Addressing Knowledge Gaps for Global Climate Justice

Zaheer Allam [1,2,3,*], David S. Jones [4,5] and Phillip Roös [2]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW 2007, Australia
[2] Live+Smart Research Laboratory, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia; phillip.roos@deakin.edu.au
[3] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France
[4] Wadawurrung Traditional Owners Aboriginal Corporation, Geelong, VIC 3220, Australia; davidsjones2020@gmail.com
[5] Cities Research Institute, Griffith University, Nathan, QLD 4111, Australia
* Correspondence: zaheerallam@gmail.com

Abstract: The Conference of Parties (COP) 26 highlighted the need for global-level deep decarbonization and provided financial instruments to aid climate mitigation in the global south, as well as compensation avenues for loss and damage. This narrative reiterated the urgency of addressing climate change, as well as aiding advances in green products and green solutions whilst shifting a portion of responsibility upon the global south. While this is much needed, we argue that the science rhetoric driving this initiative continues to be advantageous to the global north due to their capacity to control consumption gaps and to access human knowledge and resource extraction. If not addressed, this will reinforce a continuing unjust north/south narrative, highlighting neo-climate colonialism precepts.

Keywords: climate justice; global north; global south; climate change; COP26; science; climate knowledge; mining

check for updates

Citation: Allam, Z.; Jones, D.S.; Roös, P. Addressing Knowledge Gaps for Global Climate Justice. *Geographies* **2022**, *2*, 201–203. https://doi.org/10.3390/geographies2020014

Academic Editors: Luca Salvati and Xu Chen

Received: 14 March 2022
Accepted: 11 April 2022
Published: 14 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Discussions at the Conference of Parties (COP) 26, supported by the latest findings from the IPCC, pointed to the urgent need for global deep decarbonization [1,2]. This is supported by the fact that if all countries committed to their nationally determined contributions (NDC), temperatures could still increase by as much as 2.7 °C, exceeding the Paris Agreement target of 2 °C, preferably 1.5 °C [3]. The Intergovernmental Panel on Climate Change (IPCC) further points to the need for deep rooted policies on climate mitigation and suggests possible pathways, painting a bleak picture if urgent actions are not pursued [1]. This will demand a new focus and an increasing need for new products that can respond to climate needs. With a growing consensus upon the subject from private sector agencies, it can be expected that a race for 'green products' and 'green solutions' will be witnessed to supply the demand for sustainability transitions and mechanisms. The design, purchase and implementation of those products and solutions, however, can be expensive. It will place further demand on access to expertise and raw materials that are inequitably distributed around the world, adding to the challenge of addressing the global north/south disparity. This is a key subject in attaining climate justice and just transitions. It must therefore be at the forefront of global discussions but must not be seen as a linear objective. So, while the subject of climate financing instruments and provisions for loss and damage as addressed in the Glasgow Climate Pact [2] have been well received, there is an equal need to look at the capacity of the global south in developing solutions for an upcoming 'green' race, there being a need for 'green' technology to satisfy increasing market demands.

5.4 Paper 4 - Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires

5.4.1 Co-authorship form and contribution weightage

Title	Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires	
Journal	Humanities And Social Sciences Communications	
Publisher	NATURE	
Status	Published	
Cite as	Allam, Z., Jones, D.S. & Biyik, C. Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires. *Humanit Soc Sci Commun* **8**, 249 (2021).	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	75%	Production Note: Signature removed prior to publication.
David Sydney Jones	15%	Production Note: Signature removed prior to publication.
Can Biyik	10%	Production Note: Signature removed prior to publication.

5.4.2 Abstract

Since the 19th century, rapid urbanisation coupled with a demographic boom has increased pressures on the global exploitation of natural resources leading to an array of issues at planetary scale. Even though there have been significant ecologically driven human policy efforts, with frameworks addressing ecosystem accounting and management, such are principally constricted at sub-global levels; being regionally focussed, and hence lacking both cohesivity and accountability. Resource management viewed through this lens leads to a number of geopolitical factors as demonstrated recently with the Amazon Forest fires. This incident witnessed calls from numerous countries calling for rapid remediation even though their own policies are harbingers of equally damaging the environments through other means. This disparity in resource accounting and management on a planetary scale is apparent from diverse local and regional groups and needs to be addressed in order to sustain a truly sustainable and liveable ecosystem and their failures in realising a viable ecosystem accounting system. This perspective paper explores this theme and proposes a 'Global Planetary Ecosystem Accounting' system based on the principle that ecologically sensitive areas benefiting the global ecosystem need to be economically weighted and its preservation equated to a revenue-generating activity.

5.4.3 Publication

Featured in Annex 4

Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-021-00937-0 OPEN

Check for updates

Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires

Zaheer Allam [1,2,3]✉, David S. Jones[4,5] & Can Biyik[6]

Since the 19th century, rapid urbanisation coupled with a demographic boom has increased pressures on the global exploitation of natural resources leading to an array of issues at planetary scale. Even though there have been significant ecologically driven human policy efforts, with frameworks addressing ecosystem accounting and management, such are principally constricted at sub-global levels; being regionally focussed, and hence lacking both cohesivity and accountability. Resource management viewed through this lens leads to a number of geopolitical factors as demonstrated recently with the Amazon Forest fires. This incident witnessed calls from numerous countries calling for rapid remediation even though their own policies are harbingers of equally damaging the environments through other means. This disparity in resource accounting and management on a planetary scale is apparent from diverse local and regional groups and needs to be addressed in order to sustain a truly sustainable and liveable ecosystem and their failures in realising a viable ecosystem accounting system. This perspective paper explores this theme and proposes a 'Global Planetary Ecosystem Accounting' system based on the principle that ecologically sensitive areas benefiting the global ecosystem need to be economically weighted and its preservation equated to a revenue-generating activity.

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia. [2] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris - Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France. [3] Live +Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia. [4] Wadawurrung Traditional Owners Aboriginal Corporation, 86 Mercer Street, Geelong, VIC 3220, Australia. [5] Cities Research Institute, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia. [6] Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Ankara Yıldırım Beyazıt University, 06010 Ankara, Turkey. ✉email: zaheerallam@gmail.com

5.5 Paper 5 - Green new deals could be the answer to COP26's deep decarbonisation needs

5.5.1 Co-authorship form and contribution weightage

Title	Green new deals could be the answer to COP26's deep decarbonisation needs	
Journal	Sustainable Horizons	
Publisher	Elsevier	
Status	Published	
Cite as	Allam, Z., Sharifi, A., Giurco, D., & Sharpe, S. A. (2022). Green new deals could be the answer to COP26's deep decarbonisation needs. Sustainable Horizons, 1, 100006.	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	70%	Production Note: Signature removed prior to publication.
Ayyoob Sharifi	10%	Production Note: Signature removed prior to publication.
Damien Giurco	10%	Production Note: Signature removed prior to publication.
Samantha Sharpe	10%	Production Note: Signature removed prior to publication.

5.5.2 Abstract

The 2021 Conference of Parties (COP) 26 was expected as a landmark meeting, noting the increased impacts of climate change and the subsequent warning reports by the Intergovernmental Panel on Climate Change (IPCC) and that of the United Nations Framework Convention on Climate Change (UNFCCC). With global temperatures gradually increasing, COP26 underlined the need for deeper commitments, fueling a race to decarbonization. However, Nationally Determined Contributions (NDCs), where countries make their climate pledges, do not reflect the need for just transition models with dimensions of inclusivity and economic equity in mind. A measure that can emerge at national levels post-COP26 is 'Green New Deals,' which can respond to contextual needs while accelerating sustainability transitions with social protection frameworks if carefully designed. With proper structuring, while taking into account immediate, short- and medium-term goals, Green New Deals can be designed as a critical tool to ensure the attainment of sustainability agendas while pursuing social and economic justice.

5.5.3 Publication

Featured in Annex 5

Sustainable Horizons 1 (2022) 100006

Contents lists available at ScienceDirect

Sustainable Horizons

journal homepage: www.elsevier.com/locate/horiz

Green new deals could be the answer to COP26's deep decarbonisation needs

Zaheer Allam [a,b,c,*], Ayyoob Sharifi [d], Damien Giurco [a], Samantha A. Sharpe [a]

[a] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia
[b] Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia
[c] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris – Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, Paris 75013, France
[d] Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan

ARTICLE INFO

Keywords:
COP26
Decarbonization
Green new deals
Climate change
Sustainability
Paris agreement
Global prosperity

ABSTRACT

The 2021 Conference of Parties (COP) 26 was expected as a landmark meeting, noting the increased impacts of climate change and the subsequent warning reports by the Intergovernmental Panel on Climate Change (IPCC) and that of the United Nations Framework Convention on Climate Change (UNFCCC). With global temperatures gradually increasing, COP26 underlined the need for deeper commitments, fueling a race to decarbonization. However, Nationally Determined Contributions (NDCs), where countries make their climate pledges, do not reflect the need for just transition models with dimensions of inclusivity and economic equity in mind. A measure that can emerge at national levels post-COP26 is 'Green New Deals,' which can respond to contextual needs while accelerating sustainability transitions with social protection frameworks if carefully designed. With proper structuring, while taking into account immediate, short- and medium-term goals, Green New Deals can be designed as a critical tool to ensure the attainment of sustainability agendas while pursuing social and economic justice.

Climate talks have been ongoing for three decades since the first Conference of Parties (COPs) in 1992, but negative climate impacts continue to increase both in terms of frequency and intensity. The United Nations Framework Convention of Climate Change (UNFCCC) points out that if all countries commit to their Nationally Determined Contributions (NDC), temperatures could still increase by as much as 2.7 °C (UNFCCC 2021), exceeding the Paris Agreement target of 2 °C, preferably below 1.5 °C. This will demand deep decarbonization and adequate financing needs. Still, it is now understood that wealthy governments will not be fulfilling their pledge of USD 100 billion, aimed at helping developing economies in their pursuit of climate mitigation programs, until at least 2023 (OECD 2021), while it was initially proposed in 2009 and captured in the Paris Agreement (Article 9). The initial target was for the developed economies to raise at least $100 billion by 2020, but, as reported by the OECD (OECD 2020), only $78 billion was noted to have been raised by the end of 2019.

With the frequency and intensity of climate events such as storm surges, flash floods, desertification, and droughts, among others, is on the rise, Developing, Least Developed Countries (LDCs) and Small Island Developing States (SIDS) continue to be exposed. These challenges continue to impact the livelihood of communities in those economies. The resilience gap between these and developed economies can be huge, while developed economies are the largest carbon emitters (Ari and Sari, 2017) that induced climate changes. The inequitable resilience levels contributed to increasing climate migrations. For instance, the number of climate migrants had risen by over 30.7 million by the end of 2020 (UNEP 2014). Additionally, in contrast with the Global North, which has financial means and capacities, SIDS experienced at least four times the costs of infrastructure investments due to high dependency on the importation, prompted by limited inland resources, and low resilience levels climate change (Mycoo and G.Donovan, 2017). This then points to a disproportionally high budgetary need to warrant investing in projects that match anticipated climate risks, as well as capacities to promote adaptability, resilience, and economic growth.

The challenges for building economic resilience are made more complex when computing the realities of COVID-19, prompting a need for new strategies. The World Meteorological Organization (World Meteorological Organization 2021) highlights that during the height of the pandemic in 2020, emissions had significantly reduced due to widespread global lockdowns and reduced economic activities. However, as countries eased restrictions and gradually resumed economic activities, an increase in emission levels was noted, reaching an all-time

* Corresponding author.
E-mail address: zaheerallam@gmail.com (Z. Allam).

https://doi.org/10.1016/j.horiz.2022.100006
Received 26 November 2021; Received in revised form 6 January 2022; Accepted 9 January 2022

5.6 Paper 6 - On the theoretical conceptualisations, knowledge structures and trends of green new deals

5.6.1 Co-authorship form and contribution weightage

Title	On the theoretical conceptualisations, knowledge structures and trends of green new deals	
Journal	Sustainability	
Publisher	MDPI	
Status	Published	
Cite as	Allam, Z., Sharifi, A., Giurco, D., & Sharpe, S. A. (2021). On the theoretical conceptualisations, knowledge structures and trends of green new deals. Sustainability, 13(22), 12529.	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	50%	Production Note: Signature removed prior to publication.
Ayyoob Sharifi	30%	Production Note: Signature removed prior to publication.
Damien Giurco	10%	Production Note: Signature removed prior to publication.
Samantha Sharpe	10%	Production Note: Signature removed prior to publication.

5.6.2 Abstract

The increasing impacts of climate change, coupled with the Greta Thunberg effect, the findings of the Intergovernmental Panel on Climate Change (IPCC) reports, and varied environmental policy documents, are pointing to the need for urgent and cohesive climate action and mitigation frameworks. One potent solution, gaining global acceptance, is that of the Green New Deal (GND), positioned as a radical rethinking of political and economic structures in view of pushing sustainability at the forefront of national, regional, and global issues. With the model rapidly gaining ground in various geographies, and in different forms in view of contextualization needs, there is a need to better understand its evolution, knowledge structures, and trends. This paper thus sets forth to provide an understanding of the evolution and implementation of GND through a bibliometric analysis and science mapping techniques using VOSviewer and CiteSpace to identify the thematic focus of 1174 articles indexed in the Web of Science since 1995. To understand the thematic evolution of the field over time, we divided the study period into three sub-periods, namely 1995–2014, 2015–2019, and 2020–2021. These sub-periods were determined considering important milestones related to GNDs. Term co-occurrence analyses were then conducted to understand thematic focus and associated trends. Also, co-citation analysis and bibliographic coupling were other methods applied to identify major sources, authors, publications, and countries that have made more contributions to the development of research on GNDs. The findings of this paper can help both researchers and policy makers understand the evolution and trends of GNDs to better formulate GNDs strategies and policies in accordance with varying needs and geographies.

5.6.3 Publication

Featured in Annex 6

sustainability

MDPI

Review

On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals

Zaheer Allam [1,2,3,*], Ayyoob Sharifi [4], Damien Giurco [1] and Samantha A. Sharpe [1]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia; Damien.Giurco@uts.edu.au (D.G.); Samantha.sharpe@uts.edu.au (S.A.S.)
[2] Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong 3220, Australia
[3] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France
[4] Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan; sharifi@hiroshima-u.ac.jp
* Correspondence: zaheerallam@gmail.com

Abstract: The increasing impacts of climate change, coupled with the Greta Thunberg effect, the findings of the Intergovernmental Panel on Climate Change (IPCC) reports, and varied environmental policy documents, are pointing to the need for urgent and cohesive climate action and mitigation frameworks. One potent solution, gaining global acceptance, is that of the Green New Deal (GND), positioned as a radical rethinking of political and economic structures in view of pushing sustainability at the forefront of national, regional, and global issues. With the model rapidly gaining ground in various geographies, and in different forms in view of contextualization needs, there is a need to better understand its evolution, knowledge structures, and trends. This paper thus sets forth to provide an understanding of the evolution and implementation of GND through a bibliometric analysis and science mapping techniques using VOSviewer and CiteSpace to identify the thematic focus of 1174 articles indexed in the Web of Science since 1995. To understand the thematic evolution of the field over time, we divided the study period into three sub-periods, namely 1995–2014, 2015–2019, and 2020–2021. These sub-periods were determined considering important milestones related to GNDs. Term co-occurrence analyses were then conducted to understand thematic focus and associated trends. Also, co-citation analysis and bibliographic coupling were other methods applied to identify major sources, authors, publications, and countries that have made more contributions to the development of research on GNDs. The findings of this paper can help both researchers and policy makers understand the evolution and trends of GNDs to better formulate GNDs strategies and policies in accordance with varying needs and geographies.

Keywords: green new deal; green growth; bibliometric analysis; environmental policy; decarbonization; COVID-19; sustainability; climate change; negative externalities

Citation: Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals. *Sustainability* **2021**, *13*, 12529. https://doi.org/10.3390/su132212529

Academic Editor: Marc A. Rosen

Received: 21 October 2021
Accepted: 9 November 2021
Published: 12 November 2021

1. Introduction

The increasing impacts and challenges of climate change are more apparent and have been widely documented, with consequences ranging from increasing incidences of heatwaves and increased precipitation, leading to flashfloods, such as those lately witnessed in Western Europe where over 200 deaths were reported in July 2021 alone [1]. Climate change is also credited for the increasing incidences of drought, especially in sub-Saharan Africa, affecting regions are experiencing food insecurity, increased cases of water shortage and numerous challenges amongst pastoralists as vast lands experience desertification [2,3], and, amongst others, visible water sea-levels threatening some coastal regions with submersion and increases in vector diseases, to name a few [4].

5.7 Paper 7 - The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption

5.7.1 Co-authorship form and contribution weightage

Title	The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption	
Journal	Resources	
Publisher	MDPI	
Status	Published	
Cite as	Allam, Z.; Bibri, S.E.; Sharpe, S.A. The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption. Resources 2022, 11, 99.	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	60%	Production Note: Signature removed prior to publication.
Simon Elias Bibri	30%	Production Note: Signature removed prior to publication.
Samantha Sharpe	10%	Production Note: Signature removed prior to publication.

5.7.2 Abstract

This perspective paper explores the rising impacts of the COVID-19 and the Russia–Ukraine war from different perspectives, with an emphasis on the role of climate financing in achieving equitable and just transition mechanisms and that of peace in expediting this pursuit and sustaining this drive. It is motivated by the realization that there is an urgent need for accelerating the decarbonisation agenda, as highlighted in pre-COP26 debates and in the resulting Glasgow Climate Pact, through the mitigation measures that can be unpacked at both cost and scale. This is further reiterated in the third instalment of Assessment Report 6 (AR6) the Intergovernmental Panel on Climate Change (IPCC) report, dwelling on Mitigation of Climate Change, underlining the required policy shifts and technology developmental needs. Green technology, however, comes at a green premium, being more expensive to implement in geographies that cannot absorb its cost in the immediate short term. This engenders an inequitable and unjust landscape, as those that require green technology are unable to have access to it but are most often on the frontlines of the impacts of climate change. While it is urgent to review this issue and to encourage more cooperation for technology development and transfer, the COVID-19 pandemic and the Russia–Ukraine war are posing mounting challenges for achieving these objectives. These two crises are causing an unprecedented rise in commodities and labour pricing, with further knock-on impacts on global supply chains for technology. This is in turn rendering green technology unattainable for developing and less developed countries and Small Island Developing States (SIDS).

5.7.3 Publication

Featured in Annex 7

resources

MDPI

Perspective

The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption

Zaheer Allam [1,2,*], Simon Elias Bibri [2,3] and Samantha A. Sharpe [1]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia
[2] Network for Education and Research on Peace and Sustainability, Hiroshima University, Higashi-Hiroshima 739–8530, Japan
[3] The Swiss Federal Institute of Technology Lausanne (EPFL), School of Architecture, Civil and Environmental Engineering (ENAC), Civil Engineering Institute (IIC), Visual Intelligence for Transportation (VITA), GC C1 383 (Bâtiment GC), Station 18, CH-1015 Lausanne, Switzerland
* Correspondence: zaheerallam@gmail.com

Abstract: This perspective paper explores the rising impacts of the COVID-19 and the Russia–Ukraine war from different perspectives, with an emphasis on the role of climate financing in achieving equitable and just transition mechanisms and that of peace in expediting this pursuit and sustaining this drive. It is motivated by the realization that there is an urgent need for accelerating the decarbonisation agenda, as highlighted in pre-COP26 debates and in the resulting Glasgow Climate Pact, through the mitigation measures that can be unpacked at both cost and scale. This is further reiterated in the third instalment of Assessment Report 6 (AR6) the Intergovernmental Panel on Climate Change (IPCC) report, dwelling on Mitigation of Climate Change, underlining the required policy shifts and technology developmental needs. Green technology, however, comes at a green premium, being more expensive to implement in geographies that cannot absorb its cost in the immediate short term. This engenders an inequitable and unjust landscape, as those that require green technology are unable to have access to it but are most often on the frontlines of the impacts of climate change. While it is urgent to review this issue and to encourage more cooperation for technology development and transfer, the COVID-19 pandemic and the Russia–Ukraine war are posing mounting challenges for achieving these objectives. These two crises are causing an unprecedented rise in commodities and labour pricing, with further knock-on impacts on global supply chains for technology. This is in turn rendering green technology unattainable for developing and less developed countries and Small Island Developing States (SIDS).

Keywords: COVID-19 pandemic; Russia–Ukraine war; sustainability; resource management; energy transitions; climate justice; climate change; green premiums; supply chain

Citation: Allam, Z.; Bibri, S.E.; Sharpe, S.A. The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption. *Resources* **2022**, *11*, 99. https://doi.org/10.3390/resources11110099

Academic Editor: Eva Pongrácz

Received: 19 August 2022
Accepted: 25 October 2022
Published: 28 October 2022

1. Introduction

The impacts of climate change in this decade are becoming more apparent, especially in the frequency and intensity of diverse range of climate events and the cascading impacts of these events on socio-economic systems. As expressed in the latest IPCC report (Working Group III of the Sixth Assessment Report), events such as erratic and unpredictable weather are now more frequent [1]. The aftermath of these is a widespread consequence that includes irreversible losses of ecosystems, especially in coastal and low-lying regions and reduced food and water security [2] in many parts of the globe. This is due to issues such as increased desertification, acidification of soils and water [3] and the emergence of vector diseases. Climate change is also contributing to increasing adverse economic effects, resulting from losses in tourism activities, destruction of infrastructures and establishments

5.8 Paper 8 - Pandemic and Conflict Could Undermine Climate Action

5.8.1 Co-authorship form and contribution weightage

Title	Pandemic and Conflict Could Undermine Climate Action	
Journal	Frontiers in Climate	
Publisher	Frontiers	
Status	Published	
Cite as	Allam Z, Jones DS and Sharifi A (2022) Pandemic and Conflict Could Undermine Climate Action. Front. Clim. 4:918790. doi: 10.3389/fclim.2022.918790	
Contribution		
Name	**Share**	**Signature**
Zaheer Allam	75%	Production Note: Signature removed prior to publication.
David Sydney Jones	15%	Production Note: Signature removed prior to publication.
Ayyoob Sharifi	15%	Production Note: Signature removed prior to publication.

5.8.2 Abstract

In this opinion paper, we argue that two wars are currently raging in Ukraine and Russia: the COVID-19 pandemic and the ongoing conflict. The redirection of funding for resilience and preparedness towards the pandemic and the further redirection of financial flows from community resilience and climate action to military due to the conflict are leading to a lack of funding for sustainable development at national and local levels in Russia, Ukraine, and NATO members. We highlight that this will make it challenging for both Russia and Ukraine to achieve deep decarbonization and net-zero targets, leading to continued dependence on fossil fuels. Additionally, addressing sustainable policies will allow for more sensible longer-term prospects for developing sustainable cities. The paper concludes by calling for a global discourse on how funding flows need to be channeled to revitalize communities in- and post-conflict to fight the third war of climate change, which is currently being overlooked due to the ongoing conflicts in Ukraine and Russia.

5.8.3 Publication

Featured in Annex 8

frontiers | Frontiers in Climate

OPINION
published: 02 June 2022
doi: 10.3389/fclim.2022.918790

Pandemic and Conflict Could Undermine Climate Action

Zaheer Allam [1,2,3]*, *David S. Jones* [4,5] *and Ayyoob Sharifi* [6]

[1] *Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW, Australia,* [2] *Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, Paris, France,* [3] *Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC, Australia,* [4] *Wadawurrung Traditional Owners Aboriginal Corporation, Geelong, VIC, Australia,* [5] *Cities Research Institute, Griffith University, Nathan, QLD, Australia,* [6] *Graduate School of Humanities and Social Sciences and Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima, Japan*

Keywords: climate action, conflict, climate geopolitics, Ukraine-Russia conflict, sustainable transitions

OPEN ACCESS

Edited by:
Bao-Jie He,
Chongqing University, China

Reviewed by:
Junsong Wang,
South China University of Technology, China
Wei Wang,
Chongqing University, China

***Correspondence:**
Zaheer Allam
zaheerallam@gmail.com

Specialty section:
This article was submitted to Climate Adaptation, a section of the journal Frontiers in Climate

Received: *12 April 2022*
Accepted: *19 May 2022*
Published: *02 June 2022*

Citation:
Allam Z, Jones DS and Sharifi A (2022) Pandemic and Conflict Could Undermine Climate Action. Front. Clim. 4:918790. doi: 10.3389/fclim.2022.918790

Two wars are raging in Ukraine and Russia: the pandemic and the conflict. The former called for the necessary redirection of funding for resilience and preparedness, and the latter is leading to the further redirection of financial flows from community resilience and climate action to military. Combined, both wars lead to a lack of funding for sustainable development at national and local levels post-war in Russia and Ukraine, as well as NATO members. Additionally, current and future economic sanctions on Russia will impoverish communities and businesses, and reduce Russia's capacity to invest in internally sustainable transitions. Concurrently Ukraine (or the re-invented "Ukraine") will need to redirect further financing for re-building and economic development.

Such a landscape will make it near impossible for both Russia and Ukraine to realize their COP26 pledges to achieve deep decarbonization and net-zero targets (Duggal, 2021), leading to their continued high dependence upon the sustenance of fossil fuels for many years into the future. The increasingly vast and diverse imposed economic and business sanctions upon Russia will substantially delimit their future debt-funded infrastructures. A possible argument may be geared toward lifecycle extensions of fossil fuel power plants, as those offer lower upfront investment costs when compared to the erection of new renewable power plants and or nuclear complexes—even if they have faster Return on Investment (ROI) prospects (Castro, 2022). The need for funding can be bridged but will demand deeper commitments for green transitions, a re-structured societal system for more engaged citizen involvement, and renewed trading partnerships where the latter will unfortunately rely upon a sustenance of fossil resources trading. Ensuring sustainable, and long term stable infrastructure, will be particularly key for liveability of cities and communities, as ensuring the functioning of those territories not only ensures human processes, but power economic engines. On the climate side, addressing sustainable policies will allow for more sensible longer-term prospects for developing sustainable cities, and for accessing developmental funds provided for this effect.

On the Ukrainian side, a challenge of scale will present itself to its allies, particularly geared on how to distribute aid and climate financing. This includes tapping into the USD$100 billion climate fund pledged at COP26 (Ares and Loft, 2021) [or broken pledge (Timperley, 2021)], for urgent retrofits in essential infrastructures for both immediate liveability needs and post-war developments. The two avenues, however, must be structured in a way to avoid the reduction of financial flows to the Global South, Least Developing Countries (LDCs) and Small Islands Developing States [SIDS; (UN, 2022)], which are on the frontline of climate change. A global discourse will soon emerge on how funding flows need to be channeled, where, on one side, some

6. DISCUSSION

The exigency of climate action is now universally acknowledged, with the United Nations identifying it as an existential crisis requiring immediate and substantial attention. As outlined in previous sections, the interconnectedness of climate action with the Sustainable Development Goals (SDGs) underlines its centrality to global efforts in achieving a sustainable future. While global commitments to reducing carbon output and enhancing liveability are key, there is an equal need to work on localized policies, working both at regional, national and local levels. In this context, the Green New Deal emerges as a pivotal strategy, providing a framework for integrating climate mitigation efforts with socio-economic reforms.

The Green New Deal's adaptability to various geographies is fundamental. It provides a blueprint for localizing climate action, ensuring that policies are tailored to the specific socio-economic and environmental contexts of different regions. For instance, the European Union's alignment with the European Green Deal aims to render Europe climate-neutral by 2050, evidencing the global scalability of the Green New Deal's principles (European Commission, 2020).

The growing recognition of climate change and social inequality as urgent global challenges has spurred the development of Green New Deal (GND) models. These models aim to address the environmental crisis and promote equitable economic growth through the rapid deployment of clean energy, infrastructure investments, and social policies. However, current GND models often focus on sustainability transitions without adequately considering the importance of ecosystem accounting and conservation approaches. This paper introduces a novel dual framework that addresses this gap by integrating GND policies with ecosystem accounting and conservation strategies.

6.1 A dual framework of Green New Deals and Ecosystem Accounting and Conservation

The urgency of addressing climate change and inequality has led to the proliferation of Green New Deal (GND) models worldwide (Allam et al., 2021b). While these models have been successful in driving sustainable transitions, they often overlook the crucial role of ecosystem accounting and conservation approaches. This thesis proposes a novel dual framework, outlined in Figure 1 below, that combines GND policies with ecosystem accounting and conservation strategies, aiming to build sustainability, equity, and inclusivity at local, regional, and global scales. The framework is applied to extractive economies, transforming them into living economies, while also promoting the conservation of ecosystems critical to planetary balance.

By fostering equitable and inclusive living economies and preserving vital ecosystems, this dual framework holds promise for a more sustainable and just future.

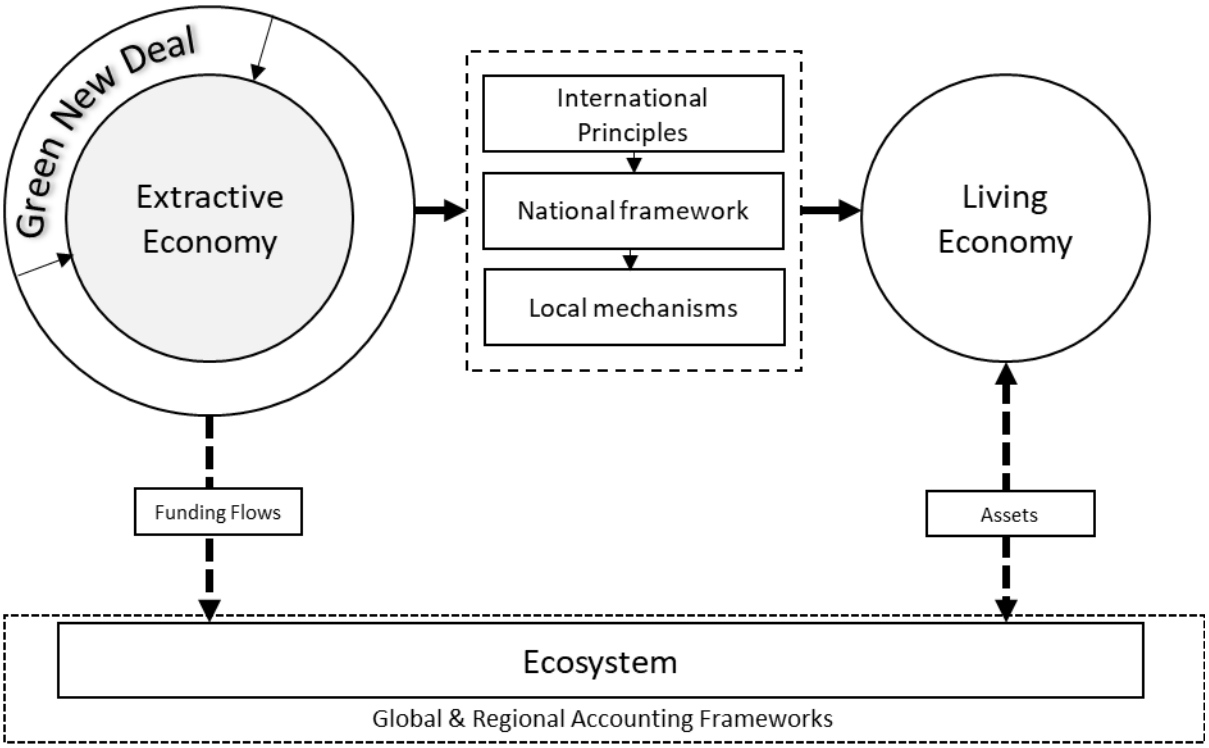

Figure 1. Proposed Green New Deal Framework, encompassing Ecosystem accounting & conservation principles. Source by Author.

The proposed dual framework is distinct from existing GND models in two significant ways. First, it incorporates both sustainability transitions through the application of GND policies and ecosystem accounting and conservation approaches. Second, it applies GND policies to extractive economies to facilitate their transformation into living economies, fostering more equitable and inclusive development.

The framework encompasses several key components. At the international level, it calibrates GND policies and ecosystem accounting principles to ensure a consistent narrative. This harmonization allows for better integration of national and local mechanisms, ultimately facilitating the implementation of sustainable and inclusive policies. Furthermore, the framework emphasizes the importance of global and regional accounting and conservation frameworks in understanding the role of specific ecosystem assets in their respective geographies.

6.1.1 Sustainability Transitions through Green New Deals

The application of GND policies to extractive economies is a pivotal aspect of the proposed framework. Extractive economies, often defined by their exploitation of natural resources and accompanying environmental degradation, are major contributors to greenhouse gas emissions. By implementing GND policies, these economies can embark on a transformative journey towards living economies, characterized by a prioritization of sustainability, equity, and inclusivity (Allam et al., 2022c). This transformation involves a multifaceted approach, including the adoption of clean energy technologies, the promotion of green jobs, investments in sustainable infrastructure, and the implementation of progressive social policies that address income inequality and social disparities (Barbier, 2010).

To ensure the success of these sustainability transitions, the framework advocates for aligning GND policies with international principles, while simultaneously allowing for flexibility to adapt to national and local contexts. This approach guarantees that GND policies are tailored to the unique needs and challenges of individual countries and regions, fostering more equitable and inclusive living economies. International collaboration and the sharing of best practices can facilitate this harmonization, encouraging the development of policies that address global climate goals and local socio-economic priorities. Moreover, the framework emphasizes the importance of integrating stakeholder participation, including governments, businesses, and civil society, in the design and implementation of GND policies. This inclusive process allows for the incorporation of diverse perspectives and fosters a sense of shared responsibility in transitioning towards a more sustainable and equitable future.

Capacity-building and targeted investments in education and skills development are also crucial components of this transition. By equipping workers with the skills needed to participate in the green economy, countries can ensure that the shift towards living economies is both just and inclusive (Pop et al., 2011). This focus on human capital development not only promotes economic growth but also contributes to social cohesion and resilience.

6.1.2 Ecosystem Accounting and Conservation Approaches

The dual framework not only facilitates sustainability transitions but also places significant emphasis on ecosystem accounting and conservation strategies. Extractive economies, often characterized by abundant financial resources, can play a crucial role in funding the conservation of critical ecosystems that underpin planetary balance. Traditional conservation approaches have been largely focused on geographical actors, limiting the scope and effectiveness of these

efforts (Wilson et al., 2006). In contrast, this thesis proposes an expansion of this scope to encompass global and regional accounting and conservation frameworks. By adopting global and regional accounting frameworks, stakeholders, including governments, businesses, and non-governmental organizations, can gain a more comprehensive understanding of the value and role of specific ecosystem assets within their broader geographies. This enhanced understanding enables the development of informed conservation strategies that prioritize the preservation of ecosystems essential to maintaining planetary balance and supporting biodiversity.

Furthermore, these conservation efforts can be bolstered by international cooperation and funding mechanisms. By pooling resources and expertise, countries can collectively address the challenge of conserving critical ecosystems that extend beyond their borders. This collaborative approach ensures that ecosystems are protected irrespective of their location, fostering a shared responsibility for environmental stewardship. Additionally, to conservation efforts, the dual framework encourages the integration of ecosystem accounting principles into economic planning and decision-making processes. By quantifying the value of ecosystem services, countries can better assess the trade-offs associated with different development paths and make more informed decisions that align with long-term sustainability goals (Costanza et al., 1997).

To operationalize this expanded approach to ecosystem accounting and conservation, capacity-building initiatives and the establishment of institutional frameworks at the regional and global levels are necessary (McGrath et al., 2008). This will enable the exchange of knowledge, best practices, and technical expertise, fostering a more effective and coordinated response to the challenges of ecosystem conservation and sustainable development.

6.1.3 Local Mechanisms and Global and Regional Frameworks

The dual framework underscores the significance of local mechanisms and global and regional frameworks in fostering sustainability, equity, and inclusivity. Local mechanisms, including community-based initiatives and locally tailored policies, are crucial for transforming extractive economies into living economies. Adapting GND policies to individual communities' specific needs and contexts promotes equitable and inclusive development.

Ecosystems, transcending national borders and impacting larger geographies, require global and regional frameworks for effective management and conservation (Allam et al., 2021a). The dual framework suggests that these frameworks should be developed alongside local mechanisms to

enhance the conservation of ecosystems critical to planetary balance. Aligning local efforts with global and regional strategies enables a comprehensive approach to preserving vital ecosystems.

To successfully implement this dual framework, cooperation and coordination among local, regional, and global stakeholders are essential. Sharing knowledge, best practices, and technical expertise, as well as developing joint programs addressing interconnected challenges of sustainability, equity, and ecosystem conservation, can facilitate this process. Empowering local communities is another crucial aspect of the dual framework, as their unique knowledge and perspectives are invaluable in sustainable development efforts. Involving communities in designing, implementing, and evaluating GND policies and conservation strategies fosters a sense of shared responsibility in achieving long-term sustainability goals.

7. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This thesis comprehensively explored the potential of Green New Deals (GNDs) in promoting equitable sustainability transitions across various geographies and economic contexts, while considering the challenges posed by the COVID-19 pandemic and geopolitical conflicts. By examining financial hurdles and prospects, technology adoption and transfer, and tailor-made strategies, the study has provided valuable insights into the role of GNDs in realizing sustainability objectives and fostering social and economic justice.

The eight publications forming this thesis by compilation have underscored the importance of crafting GNDs that cater to contextual needs and establish social protection frameworks. The research has highlighted the significant financial challenges and opportunities in global sustainability transitions and emphasized the critical role of various stakeholders, such as governments, industries, regulators, and communities, in addressing these challenges. Furthermore, the study has shed light on the potential of technology adoption, transfer, and innovation in hastening sustainability transitions and examined the impact of external factors, such as the COVID-19 pandemic and the Russia-Ukraine war, on technology advancement and access.

7.1 Limitations

In exploring the wide-ranging impacts of ecosystem accounting from a global standpoint, this thesis has strived to lay the groundwork for a comprehensive framework. While this lens has allowed to survey the overall landscape, it is crucial to recognize the inherent limitations. The foremost of these is the omission of specific regional challenges that are indispensable in shaping localized policies. Different corners of our world present a rich tapestry of ecological, economic, and socio-cultural variations that demand tailored accounting strategies. Another notable shortcoming lies in the complicated task of translating the immeasurable services of nature into financial metrics. Finally, in focusing on the broader spectrum, the thesis did not address potential roadblocks in the political and institutional arenas. The integration of ecosystem accounting into mainstream economic planning and policy decisions is often impeded by entrenched interests, the mismatch of short-term political agendas with long-term ecological realities, and the pressing need for capacity building to facilitate such a transformative change. It is however important to recognise that methodologies employed in ecosystem accounting continue to evolve and may represent a gap, particularly in respect to Green New Deal policies, committing significant resources. Finally, the thesis must acknowledge the disparities in data

quality and availability, which can lead to an underrepresentation of local and indigenous knowledge systems.

7.2 Recommendations

Given the findings and conclusions presented in this thesis, several recommendations for future research emerge. These recommendations aim to build on the insights gained from this study and contribute to a deeper understanding of the intricacies of GNDs and equitable sustainability transitions.

1. Develop context-specific GND policy instruments: Future research should explore the development of context-specific policy instruments that address the unique challenges and opportunities of different geographies and economies. This includes examining the role of local governance structures, community-based initiatives, and regional cooperation in implementing GNDs. Case studies focusing on specific regions or countries can provide valuable insights into the successes and challenges faced by these areas in adopting GND policies and can inform the development of best practices and lessons learned.

2. Investigate financing mechanisms for GND implementation: Given the significant financial challenges associated with sustainability transitions, future research should delve into innovative financing mechanisms that can support GND implementation. This includes exploring public and private financing options, blended finance, and the role of international financial institutions in mobilizing resources for GNDs. Additionally, research should examine the potential for fiscal policies, such as carbon pricing and subsidy reforms, to generate revenue for GND investments.

3. Evaluate the role of technology in GND implementation: The thesis has highlighted the potential of technology adoption, transfer, and innovation in accelerating sustainability transitions. Future research should further explore the role of technology in GND implementation, examining the barriers to technology transfer and the effectiveness of support mechanisms, such as research and development funding, capacity building, and technology sharing platforms.

4. Investigate the impact of external factors on GND implementation: Numerous papers in this thesis have demonstrated the detrimental effects of the COVID-19 pandemic and geopolitical conflicts on technology advancement and access. Future research should

continue to explore the impact of external factors on GND implementation, monitoring the evolving landscape of global challenges and identifying opportunities for resilience and adaptation in the face of uncertainty.

5. Examine the integration of ecosystem accounting and conservation strategies within GNDs: Building on the thesis's recommendation for a Global Planetary Ecosystem Accounting system, future research should explore the integration of ecosystem accounting and conservation strategies within GNDs. This includes examining the development of global and regional frameworks for ecosystem valuation, management, and conservation, as well as the establishment of monitoring and evaluation systems to assess the effectiveness of these strategies.

6. Assess the scalability and replicability of GND success stories: Future research should investigate the scalability and replicability of successful GND implementations in various contexts. By examining case studies and identifying the factors that contributed to their success, researchers can develop a better understanding of how GND policies can be adapted and scaled to different geographies and economies. This would also contribute to the development of best practices and guidelines that can facilitate the implementation of GNDs in diverse settings.

7. Foster interdisciplinary and transdisciplinary research on GNDs: Given the multifaceted nature of GNDs, future research should adopt interdisciplinary and transdisciplinary approaches that incorporate perspectives from various fields, such as economics, sociology, political science, and environmental sciences. By fostering cross-disciplinary collaboration, researchers can better understand the complex interactions between GND policies, social dynamics, and ecological systems, leading to more effective and holistic policy recommendations.

8. Engage with local communities and indigenous peoples in GND research: The thesis emphasises the importance of engaging with local communities and indigenous peoples in the development and implementation of GNDs. Future research should prioritize inclusive and participatory research methodologies that involve these stakeholders in the research process, ensuring that their unique knowledge and perspectives are incorporated into the analysis and policy recommendations.

9. Monitor and evaluate the long-term impacts of GND policies: To assess the effectiveness of GNDs in promoting equitable sustainability transitions, future research should focus

on the development of robust monitoring and evaluation frameworks that track the long-term social, economic, and environmental outcomes of GND policies. By measuring the impacts of GNDs over time, researchers can identify areas for improvement and ensure that policies evolve in response to emerging challenges and opportunities.

REFERENCES

ACUTO, M., PARNELL, S. & SETO, K. C. 2018. Building a global urban science. *Nature Sustainability,* 1**,** 2-4.

AFRICAN DEVELOPMENT BANK GROUP. 2022. *African Economic Outlook 2022* [Online]. African Development Bank. Available: https://www.afdb.org/en/documents/african-economic-outlook-2022 [Accessed 5th April 2023].

AGYEMAN, J. 2005. *Sustainable communities and the challenge of environmental justice*, NYU Press.

ALLAM, Z. 2020a. Chapter 7 - Vital COVID-19 Economic Stimulus Packages Pose a Challenge for Long-Term Environmental Sustainability. *In:* ALLAM, Z. (ed.) *Surveying the Covid-19 Pandemic and its Implications.* Elsevier.

ALLAM, Z. 2020b. Chapter 9 - Oil, Health Equipment, and Trade: Revisiting Political Economy and International Relations During the COVID-19 Pandemic. *In:* ALLAM, Z. (ed.) *Surveying the Covid-19 Pandemic and its Implications.* Elsevier.

ALLAM, Z. 2020c. *Cities and the Digital Revolution: Aligning technology and humanity*, Springer International Publishing.

ALLAM, Z. 2020d. *Surveying the Covid-19 Pandemic and Its Implications: Urban Health, Data Technology and Political Economy*, Elsevier Science.

ALLAM, Z., BIBRI, S. E. & SHARPE, S. A. 2022a. The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption. *Resources,* 11**,** 99.

ALLAM, Z., JONES, D. & SHARIFI, A. 2022b. Pandemic and Conflict could undermine Climate Action. *Frontiers in Climate,* 4.

ALLAM, Z., JONES, D. & THONDOO, M. 2020. Urban Resilience and Climate Change. *In:* ALLAM, Z., JONES, D. & THONDOO, M. (eds.) *Cities and Climate Change: Climate Policy, Economic Resilience and Urban Sustainability.* Cham: Springer International Publishing.

ALLAM, Z., JONES, D. S. & BIYIK, C. 2021a. Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires. *Humanities and Social Sciences Communications,* 8**,** 249.

ALLAM, Z., SHARIFI, A., GIURCO, D. & SHARPE, S. A. 2021b. On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals. *Sustainability,* 13**,** 12529.

ALLAM, Z., SHARIFI, A., GIURCO, D. & SHARPE, S. A. 2022c. Green new deals could be the answer to COP26's deep decarbonisation needs. *Sustainable Horizons,* 1**,** 100006.

AYE, G. C. & EDOJA, P. E. 2017. Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics & Finance,* 5**,** 1379239.

BARBIER, E. B. 2009. Rethinking the Economic Recovery: A Global Green New Deal. Wyoming: UNEP.

BARBIER, E. B. 2010. *A global green new deal: Rethinking the economic recovery*, Cambridge University Press.

BARBIER, E. B. 2020. Greening the post-pandemic recovery in the G20. *Environmental and Resource Economics,* 76**,** 685-703.

BARUA, S. 2020. Financing sustainable development goals: A review of challenges and mitigation strategies. *Business Strategy & Development,* 3**,** 277-293.

BAUMGARTNER, R., DAMERT, M., FRITZ, M. & SCHÖGGL, J. 2017. IP Sustainability in Global Supply Chains.

BEHNASSI, M. & EL HAIBA, M. 2022. Implications of the Russia–Ukraine war for global food security. *Nature Human Behaviour,* 6**,** 754-755.

BEN HASSEN, T. & EL BILALI, H. 2022. Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems? *Foods,* 11.

BIGG, M. M. 2023. *How Russia's war in Ukraine has unfolded month by month* [Online]. The New York Times. Available: https://www.nytimes.com/article/ukraine-russia-war-timeline.html [Accessed 5th April 2023 2023].

BIN-NASHWAN, S. A., HASSAN, M. K. & MUNEEZA, A. 2022. Russia–Ukraine conflict: 2030 Agenda for SDGs hangs in the balance. *International Journal of Ethics and Systems*.

BLOOMFIELD, J. & STEWARD, F. 2020a. The Politics of the Green New Deal. 91**,** 770-779.

BLOOMFIELD, J. & STEWARD, F. 2020b. The politics of the green new deal. *The Political Quarterly,* 91**,** 770-779.

BOUNGOU, W. & YATIÉ, A. 2022. The impact of the Ukraine–Russia war on world stock market returns. *Economics Letters,* 215**,** 110516.

BOYLE, A. D., LEGGAT, G., MORIKAWA, L., PAPPAS, Y. & STEPHENS, J. C. 2021. Green new deal proposals: Comparing emerging transformational climate policies at multiple scales. *Energy Research & Social Science,* 81**,** 102259.

BULKELEY, H. A., BROTO, V. C. & EDWARDS, G. A. 2014. *An urban politics of climate change: experimentation and the governing of socio-technical transitions*, Routledge.

CHA, J. M., STEVIS, D., VACHON, T. E., PRICE, V. & BRESCIA-WEILER, M. 2022. A Green New Deal for all: The centrality of a worker and community-led just transition in the US. *Political Geography,* 95**,** 102594.

CHEN, Y. & LI, A. 2021. Global green new deal: a global South perspective. *The Economic and Labour Relations Review,* 32**,** 170-189.

CHOHAN, U. W. 2019. A green new deal: Discursive review and appraisal. *Notes on the 21st Century (CBRI)*.

CONGRESS 2019. 116th Congress 1st Session: H. RES. 109. *In:* REPRESENTATIVE, H. O. (ed.). U.S: Congress.

CONTE, N. 2019. *Green New Deal* [Online]. WT North America. Available: https://wtpartnership.co/green-new-deal/ [Accessed 24th Feb 2021].

COSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R. V. & PARUELO, J. 1997. The value of the world's ecosystem services and natural capital. *nature,* 387**,** 253-260.

D'SOUZA, D. 2022. *Understanding the Green New Deal & What's in the Climate Proposal* [Online]. Investopedia. Available: https://www.investopedia.com/the-green-new-deal-explained-4588463 [Accessed 5th April 2023].

DAVIS, S. J., LIU, Z., DENG, Z., ZHU, B., KE, P., SUN, T., GUO, R., HONG, C., ZHENG, B., WANG, Y., BOUCHER, O., GENTINE, P. & CIAIS, P. 2022. Emissions rebound from the COVID-19 pandemic. *Nature Climate Change,* 12**,** 412-414.

DHUNNY, A. Z., ALLAM, Z., LOBINE, D. & LOLLCHUND, M. R. 2019. Sustainable renewable energy planning and wind farming optimization from a biodiversity perspective. *Energy,* 185**,** 1282-1297.

DOYLE, C. 2022. DOUGHNUT ECONOMICS: SEVEN WAYS TO THINK LIKE A 21ST CENTURY ECONOMIST. *A Development Education Review*.

EMENEKWE, C. C., OKEREKE, C., NNAMANI, U. A., EMODI, N. V., DIEMUODEKE, O. E. & ANIEZE, E. E. 2022. Macroeconomics of decarbonization strategies of selected global south countries: A systematic review. *Frontiers in Environmental Science,* 10.

EUROPEAN, C. 2021. *Financing the green transition: The European Green Deal Investment Plan and Just Transition Mechanism* [Online]. European Comission. Available: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17 [Accessed 30th Mar 2021].

EUROPEAN COMMISSION. 2019. *The European Green Deal: Questions & Answers* [Online]. European Commission. Available: https://ec.europa.eu/commission/presscorner/detail/en/QANDA_19_6690 [Accessed 23rd Feb 2021].

EUROPEAN COMMISSION. 2022. *Supply shock caused by Russian invasion of Ukraine puts strain on various EU agri-food sectors* [Online]. European Commission. Available: https://ec.europa.eu/info/news/supply-shock-caused-russian-invasion-ukraine-puts-strain-various-eu-agri-food-sectors-2022-apr-05_en [Accessed 21st April 2022].

EUROPEAN COMMISSION. 2023. *A European Green Deal* [Online]. European Commission. Available: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en [Accessed 5th April 2023].

EUROPEAN PARLIAMENT. 2020. *Inequality and the Green Deal* [Online]. Europe: European Parliament. Available: https://www.europarl.europa.eu/doceo/document/E-9-2020-000821_EN.html [Accessed 30th Mar 2021].

FANG, Y. & SHAO, Z. 2022. The Russia-Ukraine conflict and volatility risk of commodity markets. *Finance Research Letters,* 50**,** 103264.

FEOLA, G. 2020. Capitalism in sustainability transitions research: Time for a critical turn? *Environmental Innovation and Societal Transitions,* 35**,** 241-250.

FERROUKHI, R., GIELEN, D. & PRESS, E. 2020. *The post-COVID recovery: An agenda for resilience, development and equality*, International Renewable Energy Agency.

FILIPOVIĆ, S., LIOR, N. & RADOVANOVIĆ, M. 2022. The green deal–just transition and sustainable development goals Nexus. *Renewable and Sustainable Energy Reviews,* 168**,** 112759.

FISCHER, C. & JACOBSEN, G. D. 2021. The Green New Deal and the Future of Carbon Pricing 40**,** 988-995.

FRANKEL, J. A. 1999. *Greenhouse Gas Emissions* [Online]. Brookings. Available: https://www.brookings.edu/research/greenhouse-gas-emissions/ [Accessed 23rd Feb 2021].

GALVIN, R. & HEALY, N. 2020. The Green New Deal in the United States: What it is and how to pay for it. *Energy Research & Social Science,* 67**,** 101529.

GAUTAM, S. & HENS, L. 2020. COVID-19: Impact by and on the environment, health and economy. Springer.

GEELS, F. W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy,* 31**,** 1257-1274.

GEORGIEVA, K. 2021. *The Road Ahead for Africa—Fighting the Pandemic and Dealing with Debt* [Online]. International Monetary Fund. Available: https://www.imf.org/en/News/Articles/2021/06/23/sp062321-the-road-ahead-for-africa-fighting-the-pandemic-and-dealing-with-debt [Accessed 5th April 2023].

GORE, T. 2020. Confronting carbon inequality: Putting climate justice at the heart of the COVID-19 recovery.

GREEN, F. & HEALY, N. 2022. How inequality fuels climate change: The climate case for a Green New Deal. *One Earth*.

GURARA, D., KLYUEV, V., MWASE, N., PRESBITERO, A., XU, X. C. & BANNISTER, G. 2017. Trends and Challenges in Infrastructure Investment in Low-Income Developing Countries. International Monetary Fund.

HALL, S. 2022. *These charts show record renewable energy investment in 2022* [Online]. World Economic Forum. Available: https://www.weforum.org/agenda/2022/07/global-renewable-energy-investment-iea/ [Accessed 4th April 2023].

HANSEN, U. E., NYGAARD, I., ROMIJN, H., WIECZOREK, A., KAMP, L. M. & KLERKX, L. 2018. Sustainability transitions in developing countries: Stocktaking, new contributions and a research agenda. Elsevier.

HAWKINS, H., DUNLEA, M. & RYNN, J. 2020. *Whatever happened to the Green New Deal?* [Online]. Green Party US. Available: https://www.gp.org/whatever_happened_to_the_green_new_deal [Accessed 23rd Feb 2020].

HEPBURN, C., O'CALLAGHAN, B., STERN, N., STIGLITZ, J. & ZENGHELIS, D. 2020. Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxford Review of Economic Policy,* 36**,** S359-S381.

INTERNATIONAL LABOUR, O. 2021. *ILO Monitor: COVID-19 and the World of Work* [Online]. ILO. Available: https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/briefingnote/wcms_767028.pdf [Accessed 30th Mar 2021].

INTERNATIONAL LABOUR ORGANIZATION. 2022. *Global labour market to deteriorate further as Ukraine conflict and other crises continue* [Online]. ILO. Available: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_859191/lang--en/index.htm#:~:text=In%20addition%20to%20the%20terrible,%2C%20pre%2Dconflict%2C%20level. [Accessed 5th April 2023 2023].

INTERNATIONAL MONETARY, F. 2021. *IMF Financing and Debt Service Relief* [Online]. IMF. Available: https://www.imf.org/en/Topics/imf-and-covid19/COVID-Lending-Tracker [Accessed 30th Mar 2021].

IPCC 2014. Mitigation of climate change. *Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change,* 1454**,** 147.

JACOBSON, M. Z., DELUCCHI, M. A., CAMERON, M. A. & MATHIESEN, B. V. 2018. Matching demand with supply at low cost in 139 countries among 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes. *Renewable Energy,* 123**,** 236-248.

JAGANMOHAN, M. **2021**. *Solar PV - Statistics & Facts* [Online]. Statista. Available: https://www.statista.com/topics/993/solar-pv/ [Accessed 23rd Feb 2021].

JHA, S. 2023. *Will Russia sanctions dethrone 'King Dollar'?* [Online]. Aljazeera. Available: https://www.aljazeera.com/features/2023/3/7/will-russia-sanctions-dethrone-king-dollar [Accessed 5th April 2023 2023].

JORDANA, R. 2021. *False hopes for a Green New Deal* [Online]. Open Democracy. Available: https://www.opendemocracy.net/en/oureconomy/false-hopes-green-new-deal/ [Accessed 30th Mar 2021].

KATES, R. W. & PARRIS, T. M. 2003. Long-term trends and a sustainability transition. *Proceedings of the National Academy of Sciences,* 100**,** 8062-8067.

KILKIŞ, Ş. 2019. Benchmarking the sustainability of urban energy, water and environment systems and envisioning a cross-sectoral scenario for the future. *Renewable and Sustainable Energy Reviews,* 103**,** 529-545.

KIM, S., LEE, M., YU, I. & SON, J. 2022. Key initiatives for digital transformation, green new deal and recovery after COVID-19 within the construction industry in Korea. *Sustainability,* 14**,** 8726.

KLEIN, N. 2020. *On fire: The (burning) case for a green new deal*, Simon & Schuster.

KREIENKAMP, J., PEGRAM, T. & COEN, D. 2022. Explaining transformative change in EU climate policy: multilevel problems, policies, and politics. *Journal of European Integration,* 44**,** 731-748.

LEE, J.-H. & WOO, J. 2020. Green new deal policy of South Korea: Policy innovation for a sustainability transition. *Sustainability,* 12**,** 10191.

LOEWEN, B. 2022. Revitalizing varieties of capitalism for sustainability transitions research: Review, critique and way forward. *Renewable and Sustainable Energy Reviews,* 162**,** 112432.

LORIS, N. 2021. *The Green New Deal Would Cost Trillions and Make Not a Dime's Worth of Difference* [Online]. Heritage. Available: https://www.heritage.org/environment/commentary/the-green-new-deal-would-cost-trillions-and-make-not-dimes-worth-difference [Accessed 30th Mar 2021].

LUNDSGAARDE, E., DUPUY, K. & PERSSON, Å. 2018. *Coordination challenges in climate finance*, DIIS Working paper.

MALDONADO, C. 2018. *Trump Tax Cuts Helped Billionaires Pay Less Taxes Than The Working Class In 2018* [Online]. Forbes. Available: https://www.forbes.com/sites/camilomaldonado/2019/10/10/trump-tax-cuts-helped-billionaires-pay-less-taxes-than-the-working-class-in-2018/ [Accessed 30th Mar 2021].

MANDLER, C. 2022. *What's at stake with Ukraine's Zaporizhzhia nuclear power plant, and how does it compare to Chernobyl?* [Online]. CBS News. Available: https://www.cbsnews.com/news/ukraine-zaporizhzhia-nuclear-power-plant-risks-chernobyl-comparison/ [Accessed 6th May 2023].

MATTHEWS, D. 2019. *A very detailed walkthrough of Modern Monetary Theory, the big new left economic idea* [Online]. Vox. Available: https://www.vox.com/future-perfect/2019/4/16/18251646/modern-monetary-theory-new-moment-explained [Accessed 30th Mar 2021].

MCGRATH, D. G., CARDOSO, A., ALMEIDA, O. T. & PEZZUTI, J. 2008. Constructing a policy and institutional framework for an ecosystem-based approach to managing the Lower Amazon floodplain. *Environment, Development and Sustainability,* 10**,** 677-695.

MEADOWCROFT, J. 2011. Engaging with the politics of sustainability transitions. *Environmental innovation and societal transitions,* 1**,** 70-75.

NEWELL, P. & MULVANEY, D. 2013. The political economy of the 'just transition'. *The geographical journal,* 179**,** 132-140.

NPR 2021. Rep. Alexandria Ocasio-Cortez Interview About The Green New Deal : NPR. *In:* INSKEEP, S. (ed.) *Morning Edition.* NPR.

OECD. 2022. *Russia's war of aggression against Ukraine continues to create serious headwinds for global economy, OECD says* [Online]. OECD. Available: https://www.oecd.org/newsroom/russia-s-war-of-aggression-against-ukraine-continues-to-create-serious-headwinds-for-global-economy.htm [Accessed 5th April 2023].

ORGANIZATION, C. A. 2021. *2020 passenger totals drop 60 percent as COVID-19 assault on international mobility continues* [Online]. ICAO. Available: https://www.icao.int/Newsroom/Pages/2020-passenger-totals-drop-60-percent-as-COVID19-assault-on-international-mobility-continues.aspx [Accessed 30th Mar 2021].

PAK, A., ADEGBOYE, O. A., ADEKUNLE, A. I., RAHMAN, K. M., MCBRYDE, E. S. & EISEN, D. P. 2020. Economic Consequences of the COVID-19 Outbreak: the Need for Epidemic Preparedness. *Frontier Public Health,* 8.

PEREIRA, P., BAŠIĆ, F., BOGUNOVIC, I. & BARCELO, D. 2022. Russian-Ukrainian war impacts the total environment. *Science of The Total Environment,* 837**,** 155865.

PETTIFOR, A. 2020. *The case for the green new deal*, Verso Books.

POLLIN, R. 2019. Advancing a viable global climate stabilization project: Degrowth versus the green new deal. *Review of Radical Political Economics,* 51**,** 311-319.

POP, O., DINA, G. C. & MARTIN, C. 2011. Promoting the corporate social responsibility for a green economy and innovative jobs. *Procedia-Social and Behavioral Sciences,* 15**,** 1020-1023.

POPP, D. 2010. Innovation and climate policy. *Annu. Rev. Resour. Econ.,* 2**,** 275-298.

PUASCHUNDER, J. M. Monitoring and evaluation (M&E) of the green new deal (GND) and European Green Deal (EGD). Proceedings of the 21st International RAIS Conference on Social Sciences and Humanities, 2021. Scientia Moralitas Research Institute, 202-206.

RAHMANI, S., RANJBAR, M. S. & MAFI, V. 2022. Transition pathways, transition failure, and sustainable transition in developing countries: Insights from wind turbines in Iran. *Energy for Sustainable Development,* 70**,** 133-145.

RAZA, A. 2023. Russia's War on Ukraine-An Outcome of Everything but'Genuine Diplomacy'. *Available at SSRN 4350695*.

REAGAN, P. D. 1999. *Designing a new America: The origins of New Deal planning, 1890-1943*, University of Massachusetts Press Amherst.

REES, W. E. 1995. Achieving sustainability: reform or transformation? *Journal of planning literature,* 9**,** 343-361.

SCHLOSBERG, D. & COLLINS, L. B. 2014. From environmental to climate justice: climate change and the discourse of environmental justice. *Wiley Interdisciplinary Reviews: Climate Change,* 5**,** 359-374.

SCOONES, I., STIRLING, A., ABROL, D., ATELA, J., CHARLI-JOSEPH, L., EAKIN, H., ELY, A., OLSSON, P., PEREIRA, L. & PRIYA, R. 2020. Transformations to sustainability: combining structural, systemic and enabling approaches. *Current Opinion in Environmental Sustainability,* 42**,** 65-75.

SHEVCHENKO, H., PETRUSHENKO, M., BURKYNSKYI, B. & KHUMAROVA, N. 2021. SDGs and the ability to manage change within the European green deal: The case of Ukraine. *Problems and Perspectives in Management,* 19**,** 53.

SHUMILOVA, O., TOCKNER, K., SUKHODOLOV, A., KHILCHEVSKYI, V., DE MEESTER, L., STEPANENKO, S., TROKHYMENKO, G., HERNÁNDEZ-AGÜERO, J. A. & GLEICK, P. 2023. Impact of the Russia–Ukraine armed conflict on water resources and water infrastructure. *Nature Sustainability*.

SINGH, A. 2022. Impact of Russian-Ukrainian War on the Economy of South Asia. *International Research Journal of Modernization in Engineering Technology and Science,* 4**,** 239-249.

STEPMAN, J. 2019. *The Green New Deal Is a Trojan Horse for Socialism | Jarrett Stepman* [Online]. Fee Online. Available: https://fee.org/articles/the-green-new-deal-is-a-trojan-horse-for-socialism/ [Accessed 30th Mar 2021].

STIGLITZ, J. E., SEN, A. & FITOUSSI, J.-P. 2009. Report by the commission on the measurement of economic performance and social progress. Commission on the measurement of economic performance and social progress Paris.

UN-HABITAT 2021. Cities and Pandemics: Towards a More Just, Green and Healthy Future.

UNCTAD 2020. *The Least Developed Countries Report 2020: Productive Capacities for the New Decade*, UN.

UNITED NATIONS ECONOMIC AND SOCIAL COUNCIL. 2021. *Replacing Temporary COVID-19 Pandemic Responses with Lasting Social Protection Measures Key for Realizing Sustainable Development, Speakers Tell High-Level Political Forum* [Online]. United Nations. Available: https://press.un.org/en/2021/ecosoc7054.doc.htm [Accessed 5th April 2023].

UNITED NATIONS INDUSTRIAL DEVELOPMENT, O. 2020. *Global manufacturing production drops sharply due to economic disruptions caused by COVID-19 â" UNIDO report | UNIDO* [Online]. UN IDO. Available: https://www.unido.org/news/global-manufacturing-production-drops-sharply-due-economic-disruptions-caused-covid-19-unido-report [Accessed 30th Mar 2021].

UNITED NATIONS STATISTICS DIVISION. 2022. *End poverty in all its forms everywhere* [Online]. New York, NY: United Nations. Available: https://unstats.un.org/sdgs/report/2022/goal-01/ [Accessed 5th April 2023].

USMAN, B. A. 2022. Climate and Environmental Risk Action: A Call for Fresh Commitments to Adaptation and Resilience in West African Sub-Region. *Risk Management, Sustainability and Leadership.* IntechOpen.

WAISMAN, H., BATAILLE, C., WINKLER, H., JOTZO, F., SHUKLA, P., COLOMBIER, M., BUIRA, D., CRIQUI, P., FISCHEDICK, M. & KAINUMA, M. 2019. A pathway design framework for national low greenhouse gas emission development strategies. *Nature Climate Change,* 9**,** 261-268.

WILSON, K. A., MCBRIDE, M. F., BODE, M. & POSSINGHAM, H. P. 2006. Prioritizing global conservation efforts. *Nature,* 440**,** 337-340.

ZAK, D. 2019. *A Green New Deal ignites an old red scare* [Online]. Washington Post. Available: https://www.washingtonpost.com/lifestyle/style/a-green-new-deal-ignites-an-old-red-scare/2019/05/07/6f65be80-62df-11e9-9412-daf3d2e67c6d_story.html [Accessed 30th Mar 2021].

ANNEX – PUBLICATIONS INCLUDED AS PART OF THIS THESIS

frontiers | Frontiers in Climate

TYPE Review
PUBLISHED 28 October 2022
DOI 10.3389/fclim.2022.976427

OPEN ACCESS

EDITED BY
Bao-Jie He,
Chongqing University, China

REVIEWED BY
Shanshan Chen,
Humboldt University of Berlin, Germany
Jack Ngarambe,
Kyung Hee University, South Korea

*CORRESPONDENCE
Ayyoob Sharifi
sharifi@hiroshima-u.ac.jp

SPECIALTY SECTION
This article was submitted to Climate Adaptation, a section of the journal Frontiers in Climate

RECEIVED 23 June 2022
ACCEPTED 11 October 2022
PUBLISHED 28 October 2022

CITATION
Baninla Y, Sharifi A, Allam Z, Tume SJP, Gangtar NN and George N (2022) An overview of climate change adaptation and mitigation research in Africa. *Front. Clim.* 4:976427. doi: 10.3389/fclim.2022.976427

An overview of climate change adaptation and mitigation research in Africa

Yvette Baninla[1,2], Ayyoob Sharifi[2]*, Zaheer Allam[3], Suiven John Paul Tume[4], Ngeh Najibullah Gangtar[1] and Ngiamte George[5]

[1]Department of Geology, Mining and Environmental Science, University of Bamenda, Bamenda, Cameroon, [2]Graduate School of Humanities and Social Science and Network for Education and Research on Peace and Sustainability, Hiroshima University, Hiroshima, Japan, [3]Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW, Australia, [4]Department of Geogrpahy and Planning, University of Bamenda, Bamenda, Cameroon, [5]Pan-African University Life and Earth Science Institute (PAULESI), University of Ibanda, Ibadan, Nigeria

Research on climate change has increased significantly since the 1970s. There has also been a particular focus on Africa, given its vulnerability to climate change impacts and its urbanization trends that may have massive implications for climate change adaptation and mitigation. Despite the wealth of publications on climate change in Africa, there is a lack of review studies that highlight the overall research landscape. If this status of climate research is clarified, African countries can better deal with climate change. Hence, this paper aims to improve our understanding of the status and trends of research on climate change adaptation and mitigation in Africa. Our review, straddling from 1990 to late 2021, recognizes the foundations that underpin climate change adaptation and mitigation literature. Based on keywords associated with Africa's climate change adaptation and mitigation, we undertook bibliometric research by collecting 3,316 related SCI/SSCI articles. In addition, we provided a thematic evolution over three decades, compartmentalized into four sub-periods (1990–2007; 2008–2014; 2015–2019; 2020–2021). Priority research topics and themes have been dynamic over time, with some core concepts receiving more attention (vulnerability, food, water, and energy security). Although the number of published articles exhibited a rapidly growing trend, their distribution is extremely uneven. Articles were mainly published by institutions from certain parts of the continent, with the University of Cape Town, making the highest contribution. About 72% of the existing studies focused on climate change adaptation, while climate change mitigation was less represented with 22%. The results also showed that researchers have examined not all African countries. South Africa, Ethiopia, and Ghana are hot spots, while most countries are largely neglected. Africa and African countries need to improve their future research ability on climate change mitigation. Assessing climate change risks and measures in African countries should be prioritized.

KEYWORDS

climate change, adaptation, mitigation, Africa, bibliometric analysis, urbanization, vulnerability, risk

Introduction

Climate change is a threat to humanity. Global CO_2 emissions have increased considerably from 14.9 billion metric tons in 1970 to 36.4 billion metric tons in 2021[1]. Consequently, atmospheric concentration of CO_2 emissions has increased from 325 ppm to 414 ppm over the same period. Africa, like other continents, is vulnerable, and exposed to extreme climate events (Busby et al., 2014; Russo et al., 2016). Vulnerability is exacerbated by the continent's low adaptive capacity and its dependence on rain-fed agriculture (Dzoga et al., 2018; Apraku et al., 2021; Azadi et al., 2021).

Temperatures have been reported to be increasing in Africa. North Africa's temperature has been increasing between 0.2°C per decade and 0.4°C since the 1970s (Donat et al., 2014; Lelieveld et al., 2016). Meanwhile, in West Africa, temperatures have undergone positive trends of 0.28°C (Russo et al., 2016; Nikiema et al., 2017). Temperature intensity has increased from 0.25 to 1.8°C in the Sahel and West Africa (Vizy and Cook, 2012; Fotso-Nguemo et al., 2017; Iyakaremye et al., 2021). According to literature, South Africa has the highest projected increase (Engelbrecht et al., 2015; Moron et al., 2016; Hoegh-Guldberg et al., 2018). Frequent temperature increases affect arable land and reduce the production of many African crops (Berck et al., 2018; Mumo et al., 2018).

Annual rainfall in Africa has also varied between regions. North Africa has witnessed negative trends in precipitation (Tramblay et al., 2013; Hertig et al., 2014). Declining trends have also been observed in West Africa (Nicholson et al., 2018), but East and Southern Africa are experiencing high precipitation (Liebmann et al., 2014; Nicholson, 2017; Nikulin et al., 2018). The overall outcome is a negative trend in Africa's rainfall, which negatively impacts the environment, livelihoods, food, water, and energy security (Akinsanola et al., 2021). Approximately, US$ 1.4 billion annually on food crops across Africa has been lost (Sileshi and Gebeyehu, 2021). Aggregate annual production losses of 8.9% have been reported, translating to 2.3 million MT of wheat lost, affecting 48.2 million consumers across Africa (Sileshi and Gebeyehu, 2021). About 57% of arable land in Africa produces fewer crops, resulting in poverty, affecting about 40% of the population (Berck et al., 2018). About 25% reduction has been reported in East Africa's annual crop yields (Mumo et al., 2018). By 2023, $1.4trillion of Africa's GDP will be vulnerable to climate change, a significant 48% of the entire continent's GDP (Sileshi et al., 2019).

Economic growth and rapid urbanization have been evident in Africa. Some countries have recorded increasing economic growth, like Rwanda (8.7%), Ethiopia and Côte d'Ivoire (7.4%), Ghana (7.1%), Tanzania (6.8%), and Benin (6.7%) (Tenaw and Hawitibo, 2021). Africa's urbanization rate increased from 30.8 to 38.8% between 2000 and 2018, with a 2.2% economic growth (Nathaniel and Adeleye, 2021). Seventy-nine African cities are amongst the world's top 100 fast-growing cities and face extreme risks due to climate change (Weforum, 2021). An increase in economic growth and urbanization translates to high energy demand and GHG emissions. Africa is also characterized by its rapid demographic change. Countries like Tanzania, Nigeria, Ethiopia, and Angola have registered annual population growth rates of 4.8, 4.5, 4.3, and 3.7%, respectively (Weforum, 2021). Population explosion has increased CO_2 emission from 399,239Kw in 1990 to 823,424Kt in 2018 (Worldbank, 2022). In 2019, South Africa was the most polluting country, having emitted 479 billion metric tons of CO_2 emissions, followed by Egypt with 247 billion metric tons of CO_2 emissions (Saleh, 2021). Countries like Nigeria, Algeria, Libya, and Morocco are other large producers of CO_2 ($\geq$10 Mt/year) (Boden et al., 2017; Habimana Simbi et al., 2021). Rapid economic growth and population lead to the fast growth of CO_2 emissions and environmental degradation in many African countries. This showcases the role of Africa in global climate change during its socioeconomic transformation. Therefore, policymakers must focus more on adaptation and mitigation strategies to curtail the impacts of climate change on the continent.

There has been a rapidly increasing number of reviews on climate change in Africa. Akinyi et al., look at the trade-offs and synergies related to implementing climate adaptation strategies among farmers (Akinyi et al., 2021). There have been studies on the impacts of climate change on water resources (Nkhonjera, 2017; Leal Filho et al., 2022a), with a consensus that adaptation and mitigation measures are necessary to cut the impacts on water resources. A study by (Zinyengere et al., 2013) projects an 18% decline in maize yields and suggests adaptation could potentially moderate the negative impacts of climate change. Nyiwul (2021), examined if the needs of the poor somehow influence adaptation and mitigation policies and states. In addition to review studies, many research papers on climate change in Africa have been published (Steynor et al., 2020; North et al., 2022). This significant increase in publications makes it challenging for climate change researchers to maintain an up-to-date overview of the literature. Therefore, it is imperative to obtain a full overview of climate change mitigation and adaptation research in Africa for intellectual and political reasons.

Bibliometrics stands as one of the powerful quantitative methods that can be used to analyze the development of scientific literature in a research field like climate change (De Bakker et al., 2005; Hirsch, 2005; Sharifi et al., 2021). Bibliometric methods and tools can be used to trace the intellectual landscape of climate change across the globe (Li et al., 2011). Several bibliometric analyses of climate change studies have been conducted. For instance, a bibliometric analysis of climate change adaption has been done, and

1 Statistica.com

results show that the US ranks first in terms of publication output (Wang et al., 2018). Climate change vulnerability has been explored using quantitative analysis showing that food insecurity is one of the most frequently discussed areas in climate vulnerability research (Wang et al., 2014). In 2015, research hotspots and models in climate policy were reviewed using a bibliometric method (Wei et al., 2015). The interrelationship between resilience, adaptation, and vulnerability in the face of changing climate has been researched by Janssen et al. (2006). There have also been studies on the impacts of global warming on tea production using a bibliometric analysis (Marx et al., 2017). A study that has come so close to the present is the study of climate change in the belt and road initiative regions (Tan et al., 2021) where the authors elaborated on the status and trends of climate change research in the Belt and Road Initiative regions of Central Asia, Russia and Europe Other studies have focused on climate change mitigation, adaptation, and resilience (Einecker and Kirby, 2020), and mapped urban sustainability and its links to climate change mitigation and adaptation (Sharifi, 2021; Sharifi et al., 2021).

Thus, there are more than a few previous bibliometric studies with comprehensive analyses of climate change. However, to the best of our knowledge, there are rare, if not none, on climate change adaptation and mitigation in Africa. As Africa is highly vulnerable to climate change, a clearer picture of climate change adaptation and mitigation research is of practical significance to the intellectual community. Therefore, this study aims to review Africa's research status and trends on climate change adaptation and mitigation. This review addresses the following questions: What are the growth trends in research on climate change adaptation and mitigation in Africa? Which authors and documents in the literature on climate change adaptation and mitigation have had the greatest impact on citation in the past 30 years? What is the intellectual structure of the knowledge base on climate change adaptation and mitigation in Africa, and how has the research on this topic evolved? This overview is one of the first attempts to quantify the growth of climate change adaptation and mitigation science literature in the African continent. It should be noted that, unlike systematic reviews, this bibliometric review does not intend to provide details on different issues related to the study topic. Instead, it provides an overview of the state of the knowledge and highlights the related structures and trends.

The paper is organized as follows: Section Methodology describes the methodology, clearly explaining the parameters used in searching articles. Section Results and discussions outlines the results and discussions. Lastly, potential new areas that are likely to influence the field of climate change in Africa are investigated in the final section.

Methodology

Literature search and selection were conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA) (Moher et al., 2010). To retrieve documents related to two major themes, "Climate Change Adaptation" and "Climate Change Mitigation" a combination of keywords was used to build the search string (see the Supplementary material). The theme of climate change adaptation referred to keywords such as adaptation, resilience, risk, management, and reduction. In contrast, the theme of climate mitigation involved keywords such as decarbonization, mitigation, carbon, CO_2, and GHGs. Synonyms were taken into consideration. All countries in Africa were included in the search string. The search was further performed in the three fields of titles, abstracts, and keywords for a more comprehensive data retrieval. The start time of the search was 1990, and the end time was 2021. The search returned 3,958 documents in formats compatible with the VOSviewer software. The eligibility criteria included the following: (1) articles on adaptation and mitigation studies in Africa and or any African country; (2) Peer-reviewed empirical, primary research papers in academic journals, books or book chapters, or conference proceedings (3), papers pubished in English. The next step was the manual screening of the documents to exclude irrelevant ones. After exclusion, we retained 3,235 articles.

The following bibliometric databases were searched on November 15, 2021: Science Citation Index (SCI), Social Sciences Citation Index (SSCI), SCI-EXPANDED, Arts and Humanities Citation Index (A&HCI), and (Emerging Sources Science Citation Index (ESCI) in the Web of Science Core Collection of Clarivate Analytics, Canada. Vosviewer, which is a freely available Javan application, was used for data analysis (van Eck and Waltman, 2010) (VOSviewer at: https://www.vosviewer.com).

Text mining and bibliometric analysis

Bibliometric analysis was then conducted on related articles, and Vosviewer was used for data analysis. Among the different analyses used were the term co-occurrence analysis, bibliographic coupling, and co-citation analysis. For the term co-occurrence analysis, documents were set as the unit of analysis, while cited references, cited sources, and cited authors as units of analysis for co-citation analysis. Bibliometric coupling was also analyzed. This was done by using the full counting method, and organizations and countries were used as units of analysis.

To highlight major thematic areas, term co-occurrence analysis was used. This kind of analysis presents terms that have

co-occurred frequently and are strongly connected to each other. A thesaurus file was developed and added to the VOSviewer database prior to analysis. The reason is because some terms have different variants and can easily result in separate counting of synonyms; for example, Green House Gases and GHGs. The outputs of bibliometric analysis using VOSviewer are graphs (combination of nodes and links). The size of the nodes in the outputs is proportional to the occurrence frequency, and the width of the links connecting nodes is proportional to the strength of connections. Terms that co-occur more frequently form clusters that show different thematic areas. In addition to bibliometric analysis, content analysis of the abstracts was done to determine the studies' geographic focus (country level).

To map the thematic transition over time, we divided the study period into four subperiods (1990–2007, 2007–2014, 2015–2019, and after 2020). It should be noted that 2007 and 2014 were selected as milestones considering that releases of the IPCC reports in these years might have triggered climate change research in Africa. It was possible to include sub-periods before 1990, but, as can be seen from the results in section Results and discussions, less research was published until 1990, not warranting further sub-periods. To understand the thematic shift during each period, term co-occurrence analyses were conducted for each sub-period.

Results and discussions

The trends

The growth trends of climate change adaptation and mitigation literature were examined from the initial starting point of 1990. Figure 1 shows the total number of publications in the different time periods. It displays how climate change research in Africa has increased steadily across the three decades. The results show that the number of articles in this field has progressed through four stages: slow growth, rapid growth, explosive growth, and steady growth, with an average growth rate of 21%. During the first period (1990–2007), the number of articles was very small and growing slowly. More so, the publication volume within the years of this period was not very much different, indicating the very low volume of exploration. The second period corresponds to 2008–2014. In this period, an overall upward trend was observed, indicating an attraction of extensive attention from scholars worldwide, thus entering a period of expansion and promotion. In the third period (2015–2019), the number of articles significantly increased, especially after the publication of the fifth IPPC assessment report, indicating a highly productive period. The fourth and last period, 2020-2021, shows rapid growth, with 947 articles published in <2 years. The number of publications in the four study periods was 118, 684, 1,487, and 947, respectively. There is a significant increase in the growth of publications per year, with an annual average increase of 22.5%. It is evident that this is a young field as fewer papers were published from 1990 to 2007 compared to papers published from 2020 to November 2021. In fact, only 117 publications were made from 1990 to 2017, indicating the low relevance of the topic during this period compared to 947 publications for <2 years (2020–2021), indicating the current high relevance of the topic. The very slow growth in the first period was due to the limited theoretical understanding, while the significant increase in the subsequent periods could be attributed to general causes such as digital publication, the birth of new journals, and specific factors such as the release of the two IPCC assessment reports (fourth and fifth reports in 2007 and 2014, respectively). An implication is that climate change in Africa and its impacts are increasingly recognized together with the increasing significance of climate change adaptation and mitigation to curb these impacts.

Out of the 3,317 articles that were used in the analysis, the country focus was not uniform over Africa. There were 380 papers focused on South Africa alone. The second focus country was Ethiopia, with 301 (Figure 2). In West Africa, only Ghana has a high research focus with 242 articles, higher than Kenya and Tanzania. Surprisingly, the most populous nation, Nigeria, is not among the countries with a large number of publications. The high research focus on South Africa is likely because the universities in the country are among the leading organization in this field. For over three decades, African countries have received relatively low research focus. More research was done on Africa as a continent or on African regions than on specific countries. A total of 1,219 studies were focused on Africa and its sub-regions, excluding specific countries. Countries like Gabon, Libya, Eritrea, Chad, Central African Republic have so far had no research on climate change adaptation and mitigation (Figure 2). However, the ascending curve reveals, even if empirically, these numbers will continue to grow considerably, given the theme's relevance.

Looking at the thematic focus, 72% of the articles are on adaptation, 22% on mitigation, and 6% on both adaptation and mitigation. It, therefore, deserves attention that mitigation efforts are limited. We were also interested in knowing who the leading researchers in the continent were (in other words, authors that have published more papers on the topic). We noticed that researchers from the USA authored more publications ($N = 718$; 10%), followed by researchers from South Africa ($N = 660$; 9%), the United Kingdom ($N = 554$; 8%), Germany ($N = 420$; 6%), and Kenya ($N = 343$; 5%) (Figure 3). Researchers belonging to institutes based in Africa published 38.7%, while those from the West (America, Canada, Europe, and Australia) published 49%. The rest of the world (China, Indonesia, etc.) published 12.3%. Of the 54 African countries, 11% have not published anything on climate change adaptation and mitigation, 64% have carried out <100 case studies on their countries, while 9.2% have carried out above one hundred case studies in their countries. South Africa has the highest number

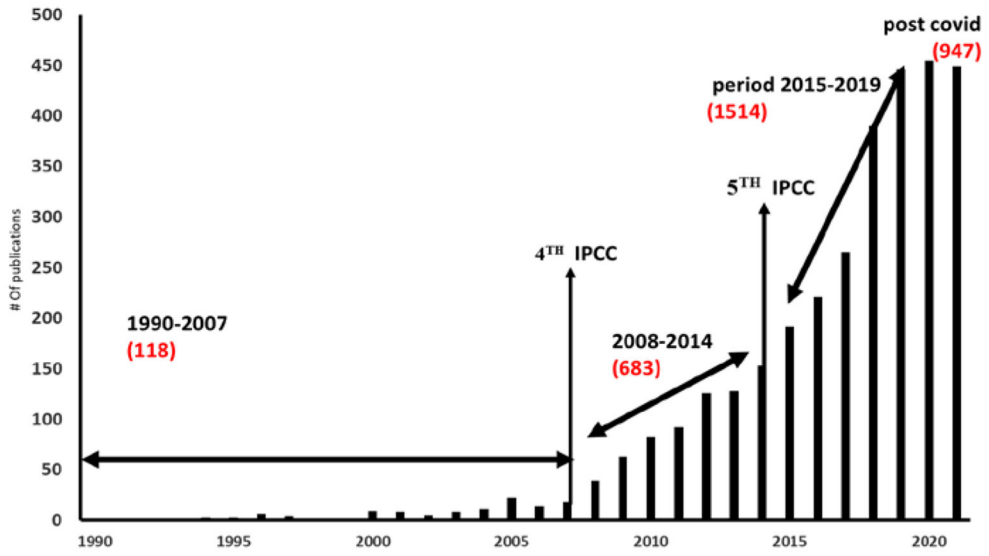

FIGURE 1
The number of articles published per year and the different periods considered in this research.

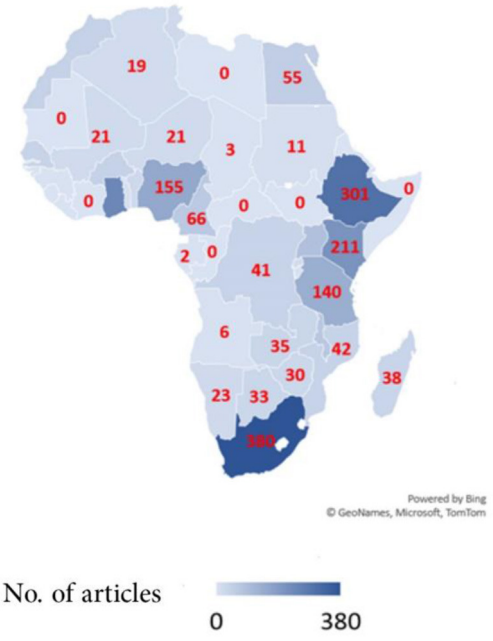

FIGURE 2
Geographical presentation of country focus.

of publications because of its well-developed science system that underpins climate change scenarios developed for South Africa. Authors based in England, South Africa, and Tanzania are those with the greatest focus on adaptation strategies. The works of Germany, the USA, and Kenya were mainly concentrated on food security, and those of Australia, Ethiopia, and China on carbon sequestration. However, a huge research gap exists on mitigation.

Regarding geographic focus, South Africa, Ethiopia and Ghana have received more attention (Figure 2). In contrast, less attention has been paid to Tanzania, Kenya, and Nigeria. Also, no case studies were found on the Central African Republic, Somalia, Gabon, Ivory Coast, Libya etc (Figure 2). Overall, it can be seen that climate change is poorly studied in the continent, and there is a gap in consideration of adaptation and mitigation policy designs.

Climate change is a global threat that can stress various sectors and deteriorate the sustainability of diverse sectors worldwide. Specifically, the vulnerability of the agricultural sector is globally concerning because of insufficient production and supplies. In effect, the global feeding patterns are challenged particularly in African countries where agriculture is an integral part of the economy. Therefore, mitigating the impacts of climate change is of great importance and requires global commitment.

The overall thematic focus of the literature on climate change adaptation and mitigation in africa

The overall thematic focus (1990–2021)

Based on the term co-occurrence analysis, there were four main clusters: blue, red, yellow, and green, each representing a different research focus. These clusters have been identified

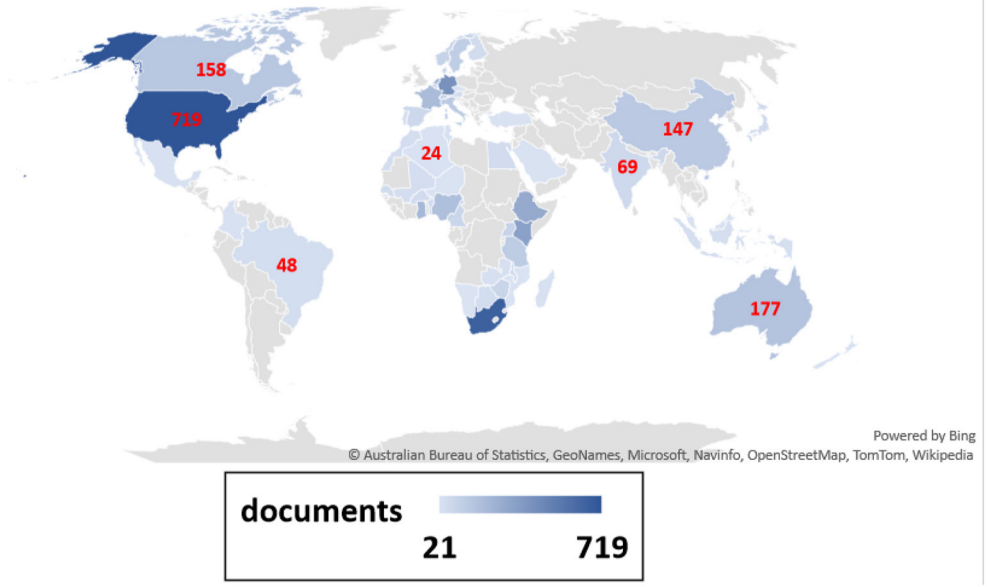

FIGURE 3
Global research on climate change adaptation and mitigation in Africa (Publications by countries).

by the software based on the co-occurrence frequenct and the strength of connection between terms.The size of each node reflects the frequency of appearance. A term with a larger node, is a research hotspot. The thicker the line, the more frequently the terms have co-occurred. The co-occurrence analysis showcases that there has been more attention on vulnerability (blue), agriculture (red), forest management and sequestration (green), and sustainability and energy-related climate mitigation (yellow). It should be mentioned that what is discussed in the following sections is not exhaustive. While there could be other important issues related to climate change adaptation and mitigation, we have mainly focused on those key topics that were highlighted in the outputs of the bibliometric analysis.

The adaptation/vulnerability cluster (blue)

The blue cluster highlights the vulnerability of households and farmers due to climate variability and the poverty it has inflicted on communities. The literature on this cluster is centered on the vulnerability of Africa to climate change impacts. From the blue cluster, it is visible that researchers are interested in studying adaptation from the gender, household, indigenous knowledge, and livelihood perspectives that are considered to be important factors for vulnerability (Jost et al., 2016; Flatø et al., 2017). The dominance of the terms climate variability, vulnerability, and resilience is not surprising, considering that a lot of research has been done on climate variability and the risks faced by farmers and smallholder farmers in Africa (Bryan et al., 2009; Müller et al., 2011; Adenle et al., 2017; Siderius et al., 2021). For instance, cocoyam farmers in Nigeria face challenges adapting to climate (Ifeanyi-Obi et al., 2017). Meanwhile, in Ghana, maize productivity has been affected by changes in climate (Aidoo et al., 2021). This has further warranted research on the vulnerability of households and how resilient they are to climate change. Gezimua (Gezimua, 2021) examined the prevalence of household food insecurity and vulnerability to climate change in East Africa and showed that households' adaptive capacity plays a significant role in reducing the prevalence of food insecurity (Gezimua, 2021). Researchers have preferred to study vulnerability and resilience from an adaptative perspective, as seen in Figure 4. Nyboer et al. (2019) presented a climate change vulnerability assessment of 85% of Africa's freshwater fishes. They concluded that vulnerable species are found in the African Rift Valley lakes, the Congo River drainage, and the coastal rivers of West Africa (Nyboer et al., 2019). A study on the degree of vulnerability and its impacts on human health in Central Africa showed that, the mean monthly household cooling energy demand is expected to significantly increase by 2,046, resulting in major energy security issues (Nematchoua et al., 2019). There have also been studies of vulnerability at different levels. Vulnerability has been more researched from the perspective of gender perception (Descheemaeker et al., 2016; Tesfaye et al., 2019). For instance, changes in temperature characteristics were highly perceived among female farmers in Ghana (Appiah and Guodaar, 2021). Another study done in Ghana found that there were gender-specific differences in the use of some adaptation practices

(Jamal et al., 2021). Another term that stands out is poverty, indicating how researchers are interested in knowing if poverty is contributing to vulnerability and if poorer households are prioritized for interventions that increase adaptive capacity (Williams et al., 2019).

From this cluster, we see how local and international scholars investigate how communities' efforts and changes in livelihood can display different degrees of resilience by employing different strategies. African communities are resilient to climate change through their attitudinal shifts and local technology innovations to better curb the impacts of climate change (Simpson et al., 2019). Communities build on their perceptions about past practices, skills, and knowledge to build adaptive capacity and resilience to suit their current life (Gandure et al., 2013; Perez et al., 2015; Elum et al., 2017; Talanow et al., 2021). Climate resilience is improved by incorporating gender perspectives (Perez et al., 2015; Adzawla et al., 2019a).

In addition, barriers hindering successful adaptation strategies were an area of consideration (Murkowski, 2000; Betsill and Bulkeley, 2007). Some of the barriers that have been hindering adaptation strategies are limited financial resources, government structures, and challenges with capacity development. An issue that needs to be noticed is that despite the increasing concerns about extreme heat and its impacts on human health, related terms did not emerge from the term co-occurrence analysis. This indicates the lack of research on this issue as also highlighted in other studies (Harrington and Otto, 2020; Ncongwane et al., 2021). More research on the adaptation to extreme heat in the context of Africa is, therefore, needed.

The food security cluster (red)

This cluster showcases the interest in understanding climate change's general impacts on food security. From Figure 4, most of the research is on the impacts of climate change on agriculture and its contribution to food security (Figure 4). The overwhelming concern of scientists is whether increased temperatures are impacting African agriculture and contributing to high levels of food insecurity (Sultan, 2012; Connolly-Boutin and Smit, 2016; Douxchamps et al., 2016). There have also been studies on the uncertainty of climate impacts and the extent of their impacts on food security (Ahmed, 2020; Mekonnen et al., 2021). The next concern from this cluster is the types of agricultural approaches used to increase food security. Conservation and smart agriculture are the main focus areas (Branca et al., 2021; Thierfelder and Mhlanga, 2022). Another thematic focus that has attracted publication is models and simulation. Researchers are keen to develop and use different climate change models to predict temperature and rainfall trends and yield productivity to better understand how to address climate change challenges (Jones et al., 2005; Araújo and Rahbek, 2006; Lobell and Burke, 2010; Semenov and Stratonovitch, 2010). Sub-Saharan Africa, particularly West and Southern Africa, have been the focused regions in this cluster (Brown et al., 2009; Müller et al., 2011; Shindell et al., 2012).

The forestry and sequestration cluster (green)

Cluster green is centered around the concept of climate change mitigation (Nyong et al., 2007; Syampungani et al., 2010; Tschora and Cherubini, 2020), which is focused on reducing GHGs emissions (Friedrich and Trois, 2011; Tongwane et al., 2016; Tongwane and Moeletsi, 2018). There have also been studies on how climate change impacts ecosystem services (Sintayehu, 2018). For instance, in Tanzania and Kenya, a key carbon sink, biomass has been reduced by 76% (Wilson et al., 2021). Tuli-Karoo transboundary aquifer in Southern Africa has been studied to understand the interaction between groundwater ecosystems and climate change (Majola et al., 2021). Furthermore, a considerable amount of mitigation research focuses on carbon sequestration (Adetoye et al., 2018; Gonzalez-Sanchez et al., 2019), soil organic carbon (Vågen et al., 2005; Swanepoel et al., 2016), REDD, and REDD+ (Rahlao et al., 2012; Soliev et al., 2021). The Congo Basin, Cameroon, Madagascar, and Zambia are often the focus areas of such research that generate knowledge regarding the role of forests in climate change mitigation (Somorin et al., 2012; Bele et al., 2015; Soazafy et al., 2021). Agricultural soils in Africa have been studied and found to generally have potential as a carbon sink (Vågen et al., 2005; Swanepoel et al., 2016). Different countries in Africa have demonstrated the different costs of carbon sequestration. For example, carbon sequestration cost in Botswana is $16.75 and in Congo DRC $16.77, the highest in the continent, while lower costs are reported in Nigeria at $7, and Mali at $8 (Adetoye et al., 2018). Policy implementation processes and institutional interactions have been examined in Cameroon and are known to shape Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Gakou-Kakeu et al., 2022). In Nigeria, it was noticed that the payment of monetary incentives does not necessarily motivate communities to participate in the REDD+ program (Isyaku, 2021). Here we see a link between mitigation and ecosystems services which is under-explored to the best of our knowledge. Research in this cluster improves governance of social-ecological systems at the local, regional and landscape levels.

Mitigation policy cluster (yellow)

This cluster is mainly focused on mitigation policies related to the energy sector and renewable energies. It shows how researchers are attracted to sustainability challenges faced by African countries (Beg et al., 2002; Ozturk, 2017). Researchers are also interested in the sustainable management of forests since they are the main absorbents of CO_2 (Teketay et al., 2010; Njana et al., 2021). The main link in this cluster is between institutions and policy. This is an indication that researchers are

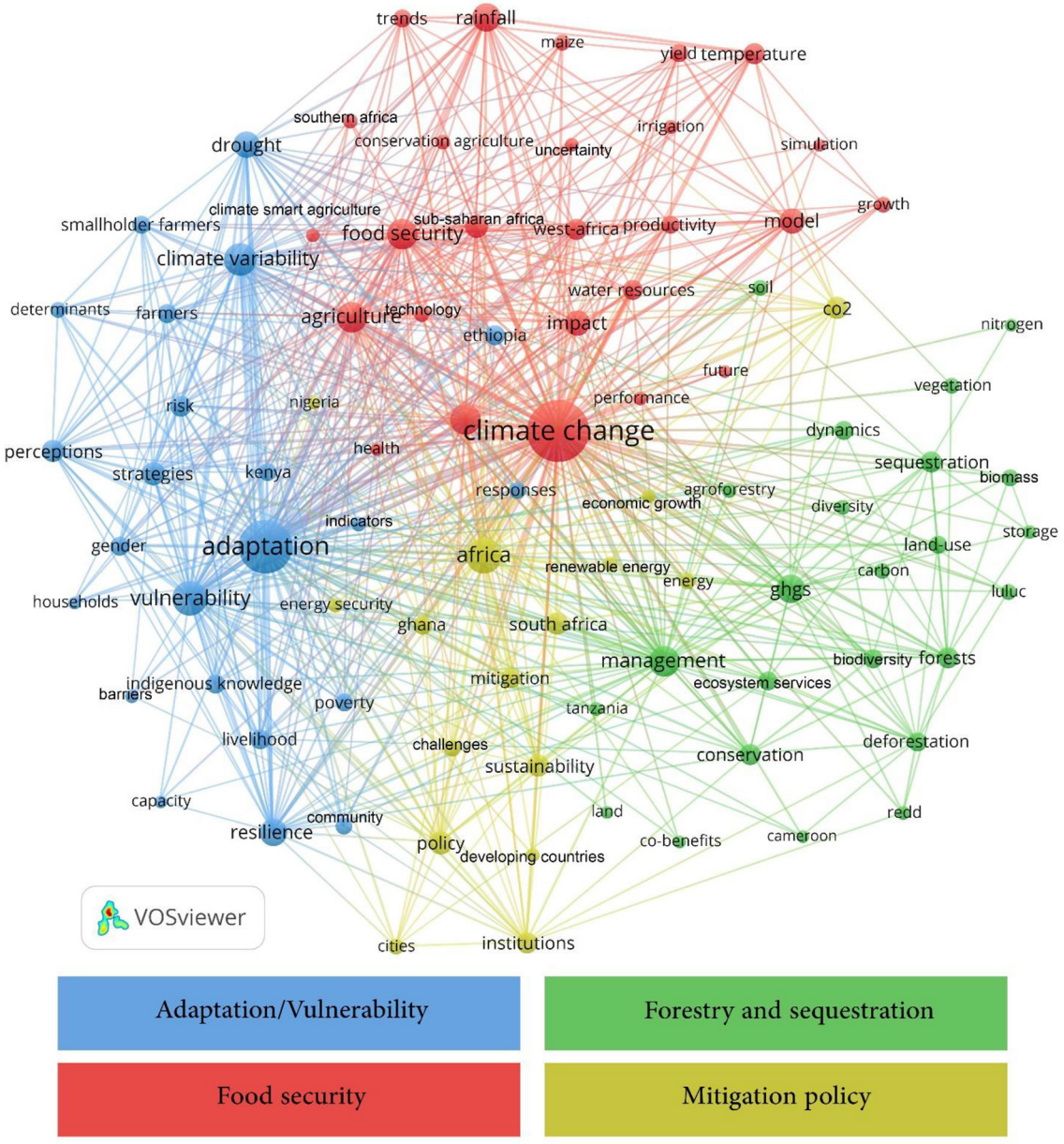

FIGURE 4
The output of the term co-occurrence analysis for the whole study period (1990–2021).

exploring climate policy designs and the institutions involved in policy making (Leal Filho et al., 2018; Epule et al., 2021), and the virtue of the importance of GHGs, mainly CO_2, in climate change policy. Despite the significance of mitigation policies, relatively limited research has been conducted on these issues. The Economic Community of West African States (ECOWAS) Renewable Energy Policy has shown a significant and positive impact on primary energy (Ali and Yu, 2021). In Nigeria, policies on ways to stimulate solar technology business are missing in the national solar energy policy document (Ozoegwu and Akpan, 2021). The results of Müller and colleagues agree with ours in that literature of renewable energy policies in African states are rare (Müller et al., 2020).

Thematic focus transitions over time

Four specific periods were investigated to see if some research topics have fluctuated, remained stable, or changed over time. Period one starts from 1990 to 2007, with 2007

corresponding to the release date of the fourth IPCC assessment report. Period two starts from 2008 to 2014, with 2014 corresponding to the publication of the fifth IPPC assessment report. Period three, from 2015 to 2019, and the fourth period from 2020, is referred to as the post-pandemic period in this study.

First period (1990–2007)

A total of 117 articles were published during this period. Although the concept of climate change can be noted as early as 1990, research focus on it was very low, as seen from the few occurrences of relevant terms (Figure 5). Adaptation has been the focus area since the first period, as seen in Figure 5. Concepts of vulnerability (blue), sustainability (red), and climate variability (green) have appeared during this period (Bohle et al., 1994; Schulze, 1997; Dixon, 2003; Ogunseitan, 2003). The blue cluster insinuates how agricultural practices had become vulnerable to climate change during this period. Therefore, more research had begun to be carried out on the impacts on agriculture. There was also the emergence of studies on the sensitivity of water resources to climate change. The centrality of water resources is relatively low during this period, showing less connection with other topics. Studies on policy formulation and implementation relating to climate change also gained attention. The green cluster is focused on CO_2 emissions and their related studies, which further triggered studies on carbon sequestration. During this period, CO_2 as the main greenhouse gas and its impacts on biodiversity were among the major priority research topics (Olivier et al., 1999; Blignaut et al., 2005).

There were also studies specifically focused on modeling the optimal mitigation of the potential impact of climate change (Jenkins et al., 2002). For example, in 2000, Zheng and Neelin used the atmosphere–land–vegetation model to explore vegetation–climate interactions in African savanna (Zeng and Neelin, 2000). It is evident that studies were more on forestry, and its absorbing nature was seen as a mitigating measure. For instance, in 1992, sources and sinks of carbon dioxide and methane exchanges were studied in the Mayombe forest, which was proven to be a net sink of atmospheric methane (Delmas et al., 1992). In this period, main research themes are not closely linked and are weakly related to external topics. This period coincided with the increasing prevalence of the term sustainability, which will be seen in subsequent analysis to dominate the thematic focus of climate change research in Africa. The importance of climate change was further recognized with the signing of the Kyoto Protocol (1992)[2], which gradually accelerated academic discussion of climate change in the continent as well as the meetings of COP 1 in 1995 to COP 13 in 2007. The release of the IPPC fourth assessment report in 2007 was also a game changer as will be seen in the next period.

Second period (2007–2014)

This period witnessed a rapid growth of publications in the red, green, and blue clusters. This rapid growth might have been triggered by the publication of the fourth IPPC assessment report in 2007. The red cluster had seemingly gained more attention this time. Interestingly research on food security emerges. This is a keyword that was absent in the first period. During this period, it is noticed that there is more research on the climate-stressed water resources presenting a challenge for protecting food security. In the previous period, research was focused on the sensitivity of water resources to climate change, while in this period, water resources and food security are closely linked (Yang et al., 2003; Ngigi, 2009; Sheffield et al., 2014). Studies on food security have attracted further research on the impacts of climate change on soil. A study on Ethiopian soils showed soil losses were 35.4 t ha^{-1} yr^{-1} under changing climate conditions (Lanckriet et al., 2012). There are also other studies focused on soil. For instance, a study was carried out on ferrasols of coastal West Africa to examine soil fertility under global warming (Amouzou et al., 2013). This period sees a shift from carbon sequestration models to models that detect the sensitivity of various alimentary crops. For instance, in Benin, high-resolution regional climate models were used to detect the sensitivity of alimentary crops to changing climate conditions (Paeth et al., 2008). A robust model application to several African crops showed that, except for cassava, there is a 95% probability that climate change damages to crops exceed 7% (Schlenker and Lobell, 2010). Scientists are, therefore, interested in simulating the impacts of climate variability on changing crop yield (Kurukulasuriya and Mendelsohn, 2008; Knox et al., 2012; Ahmed et al., 2015). There is also a shift in research from water resources-from the adaptative perspective- to the food security perspective, which has gained more prominence compared with the previous period. Urama and Ozor carried out a study on the impact of climate change on water resources from the adaptative perspective and found that rising temperatures of 1.5–2°C affects fisheries in West African lakes (Urama and Ozor, 2010). It was suggested by Ngoran et al., that looking beyond command and control policy will be a better regulatory measure to mitigate climate change on water resources (Ngoran et al., 2015).

There is robust information in the blue cluster to understand climate variability and trends, a requirement to draw a context-specific climate change adaptation intervention. For instance, in 2010, Tshiala and Olwoch studied the relationship between tomato production and climate variability and found a positive trend (Tshiala and Olwoch, 2010). While some keywords continue to be dominant and prominent, like sustainability, climate variability, and vulnerability, several new keywords

2 https://unfccc.int/kyoto_protocol?gclid=CjwKCAjw-rOaBhA9EiwAUkLV4lwCd7zjxPdYULehR8k0wOCej_nVq5gL4YMU0B1-lIol5qgiRceuLxoCfn0QAvD_BwE

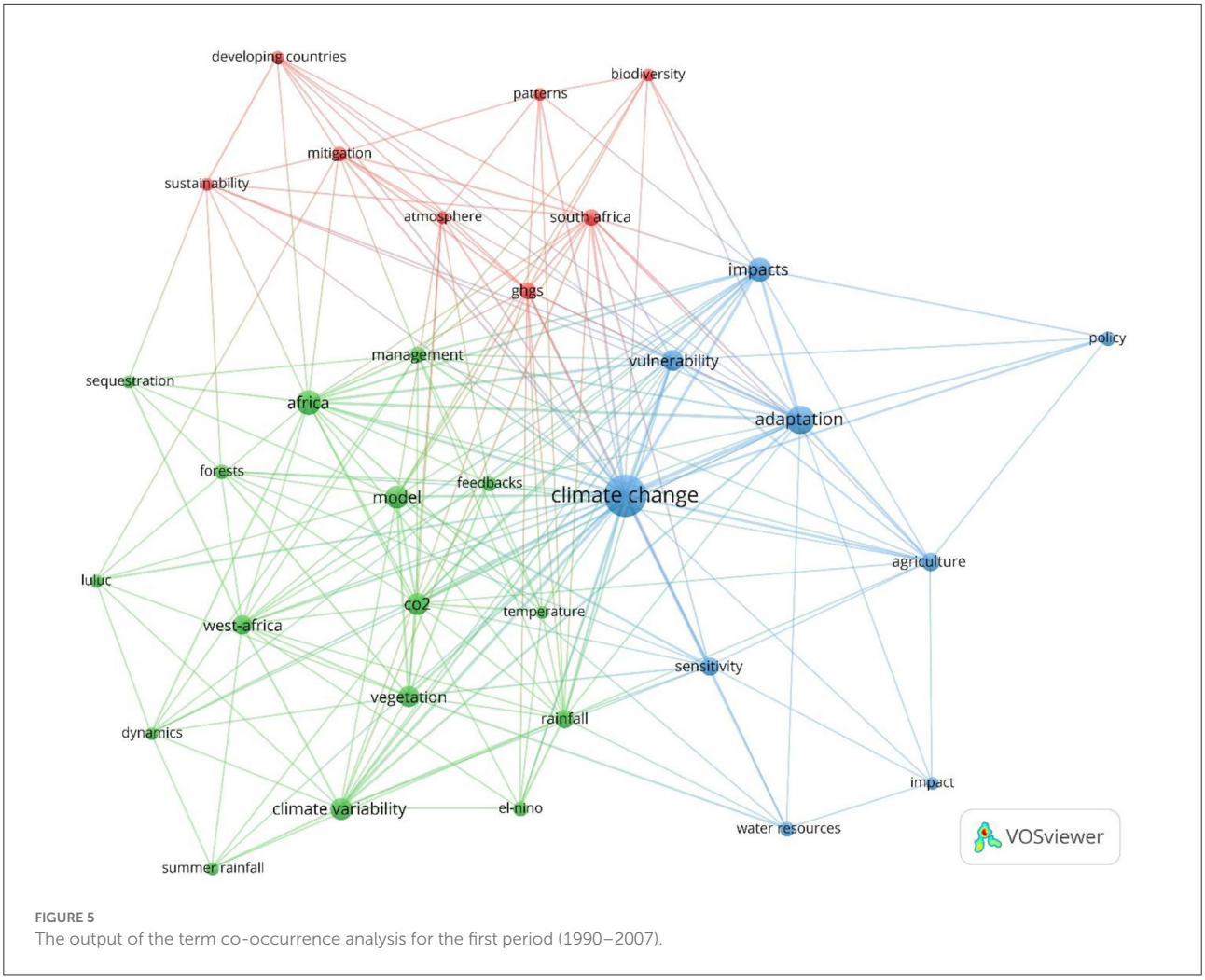

FIGURE 5
The output of the term co-occurrence analysis for the first period (1990–2007).

emerge: energy security, ecosystem services, bioenergy, biomass, productivity, deforestation, conservation, resilience, etc. The emergence of these keywords shows how much attention has been given to the study of climate change. Some or most of these keywords will gain greater momentum in the subsequent periods, as will be discussed in the following sections. There is a drive toward studies on bioenergy (green cluster) that is considered to be an innovative approach in global climate mitigation efforts. There is mainly a new drive toward studies that primarily encompass biofuels produced from forest resources with simple and indigenous technologies (Adedayo et al., 2010; Langat et al., 2016). Bio-energy is very potent in reducing atmospheric methane emissions (Weiland, 2006). There is also the emergence of studies on policies to offset climate change impacts on ecosystem services. In South Africa, two key policies emerged: National Climate Change Response White Paper and South Africa's Second National Communication (Ziervogel et al., 2014). In Ethiopia, providing farmers with farming equipment is a policy tool to facilitate farmers' adaptation to climate change (Bryan et al., 2009). As seen in Figure 6, it is evident that a significant increase has occurred in research on local perceptions about environmental awareness, attitudes, beliefs, and risk perception. Studies on the green cluster have maintained steady growth while the red cluster has bulged. Almost all themes are closely linked and strongly related to the external topics with more attention and influence compared with the first period. The research intensity during this period changed with an increase in the development and maturity of themes.

Third period (2015–2019)

The third period has witnessed explosive growth with the birth of a new cluster (Figure 7). The new yellow cluster focuses on renewable energy, showing a shift from conventional energy consumption to more renewables. The specific renewable

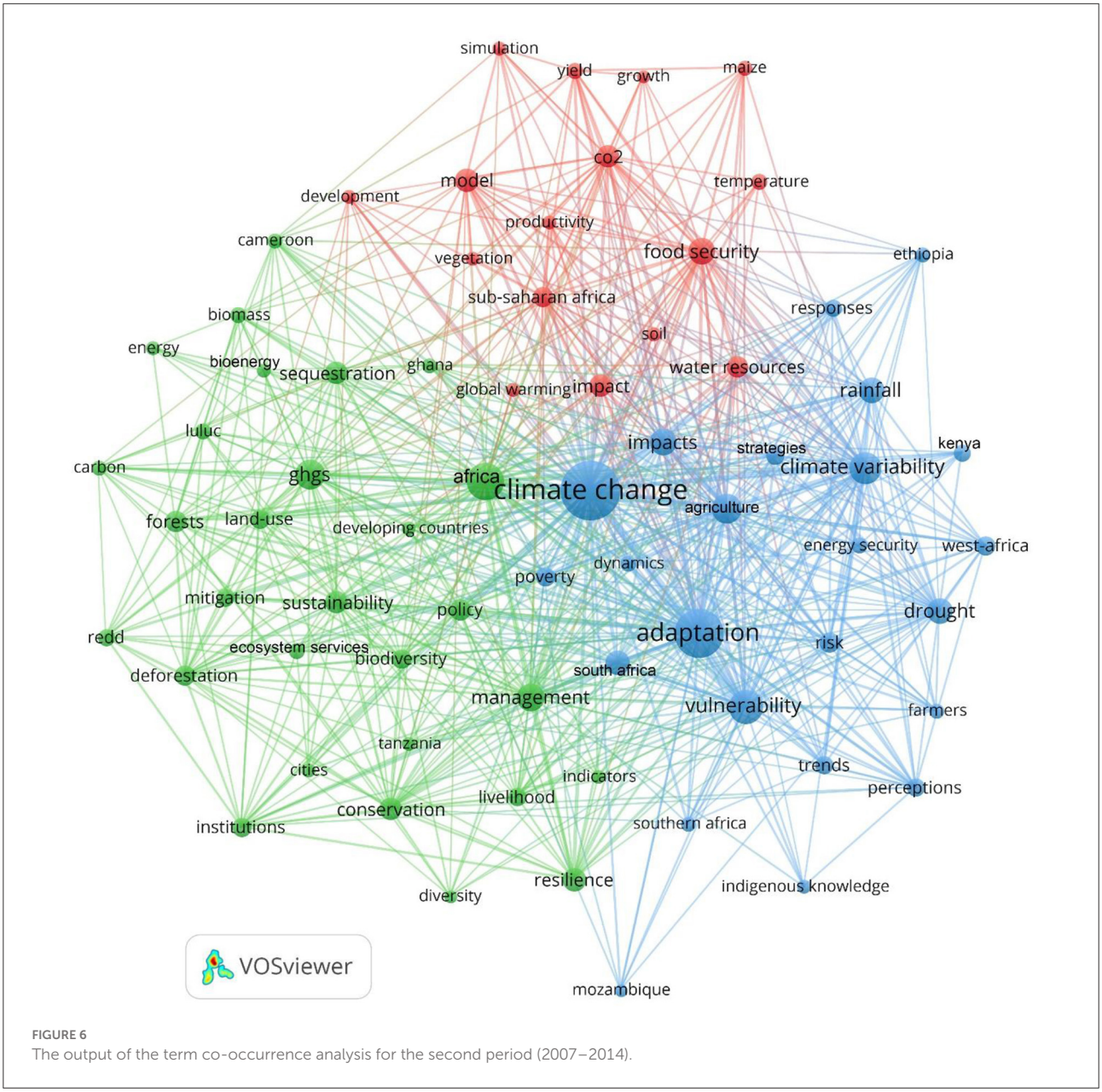

FIGURE 6
The output of the term co-occurrence analysis for the second period (2007–2014).

energies used in Africa are solar, wind, and hydropower. Nigeria, Angola, DRC, Sudan, and Zambia are leading countries in hydropower, with Angola and DRC generating a net capacity of 2,763 and 2,750 MW, respectively (Frangoul, 2019). Meanwhile, solar and wind energy South Africa, Morocco, Ethiopia, Mozambique, and Egypt are leading states, with South Africa having the highest maximum net capacity of 6,065 MW followed by Egypt with 4,813 and Ethiopia with 4,351 (Frangoul, 2019). The period sees the addition of some new keywords. Among the new keywords are agroforestry, economic growth, smallholder farmers, and conservation agriculture.

Multiple studies have explored the link between climate change and economic growth (Abidoye and Odusola, 2015; Alagidede et al., 2016; Adzawla et al., 2019b). A study in 2015 shows that climate change has a negative impact on economic growth in Africa, such that a 1°C increase in temperature reduces GDP growth by 0.67% (Abidoye and Odusola, 2015). Arndt et al. note that climate change impacts from 2007 to 2050 will lead to a loss of USD 610 million in Malawi (Arndt et al., 2014). According to Radhouane in 2013, a 1°C rise in temperatures in the Northern African countries in a given year reduces economic growth by 1.1 points (Radhouane, 2013). The intensification of studies related to renewable energy is a shift from conventional exhaustible energy resources. Conventional sources raise serious environmental concerns while hampering sustainable economic growth. In Mozambique, there have been

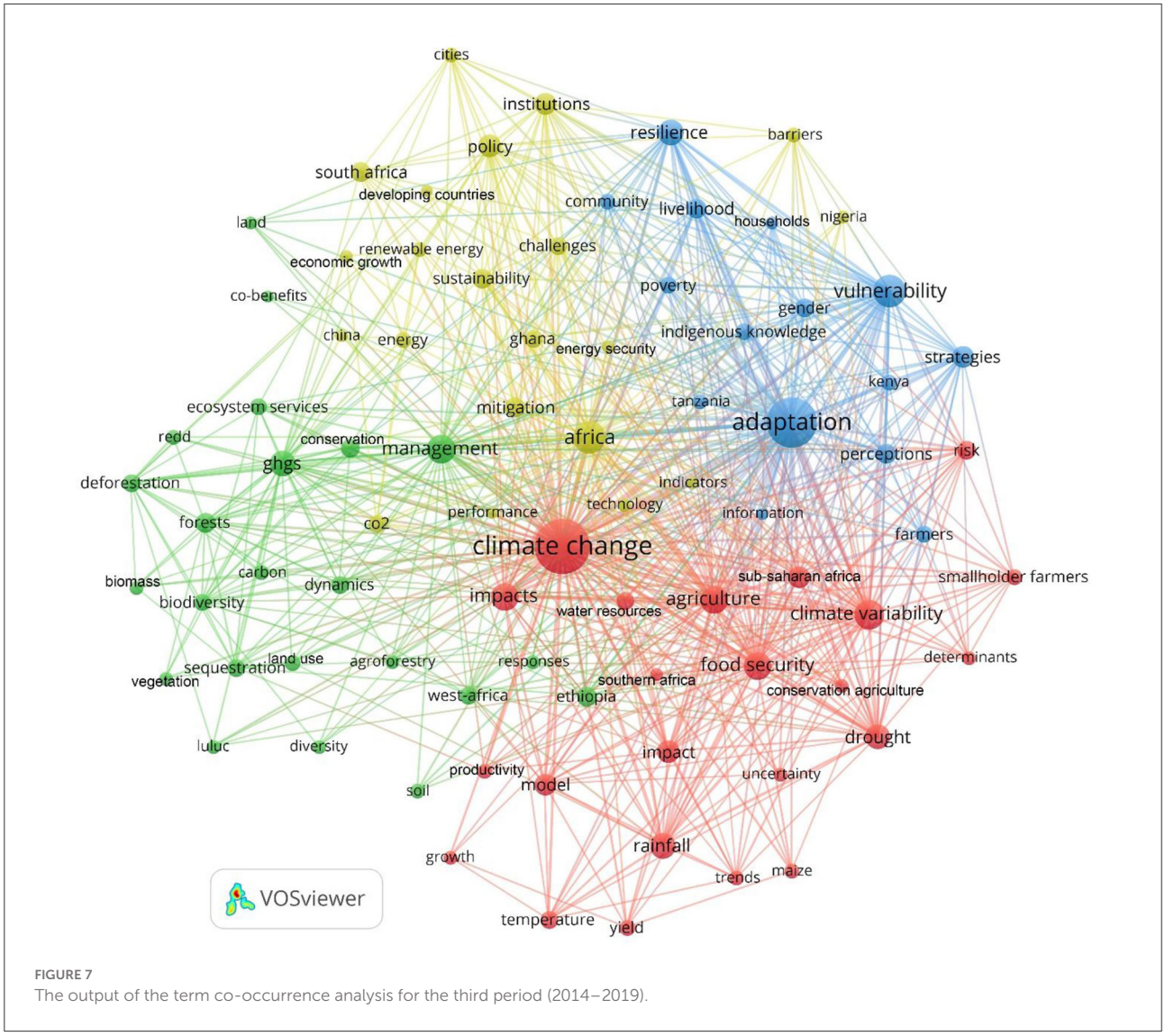

FIGURE 7
The output of the term co-occurrence analysis for the third period (2014–2019).

advancements toward using renewable energy for irrigation in the agriculture sector (Chilundo et al., 2019; Mahumane and Mulder, 2019). Renewable energy policies in Ghana have also been reviewed, and a lack of policy implementation was one of the reasons for a slow transition toward sustainable electrification (Sakah et al., 2017). Another stream of research in the energy discourse mainly focuses on the relationship between renewable energy consumption and economic growth. Arguments on this particular theme emphasize how renewable energy consumption will increase renewable energy production as a measure of environmental sustainability and how this will impact economic growth in Africa (Alper and Oguz, 2016; Bhattacharya et al., 2016). Aly et al., investigated the techno-economic feasibility of solar power in Tanzania and found that the net capital cost for an optimized plant in 2025 will be 4680 $/kW at 7% interest rate (Aly et al., 2019).

During this period, there has been a clear focus on adaptation strategies used to deal with climate change and adaptation capacities employed by communities (blue cluster). The main adaptation link occurs with risks and strategies. This observation suggests the propensity to design strategies for climate change adaptation and their interests in how to thwart or be prepared for the likely risks this entails. For instance, developing cultivars is one of the adaptation strategies applied in Northern Cameroon, which shortens the time of cotton maturity and causes a shift in the rainy season without affecting cotton yield (Gérardeaux et al., 2018). The word perception is also associated with risk perception. This indicates the increasing number of studies on indigenous knowledge and how farmers perceive risks where their activities are undertaken (Leal Filho et al., 2022b). Ayanlade and colleagues studied farmers' perceptions in Nigeria and confirmed that 67% of farmers had

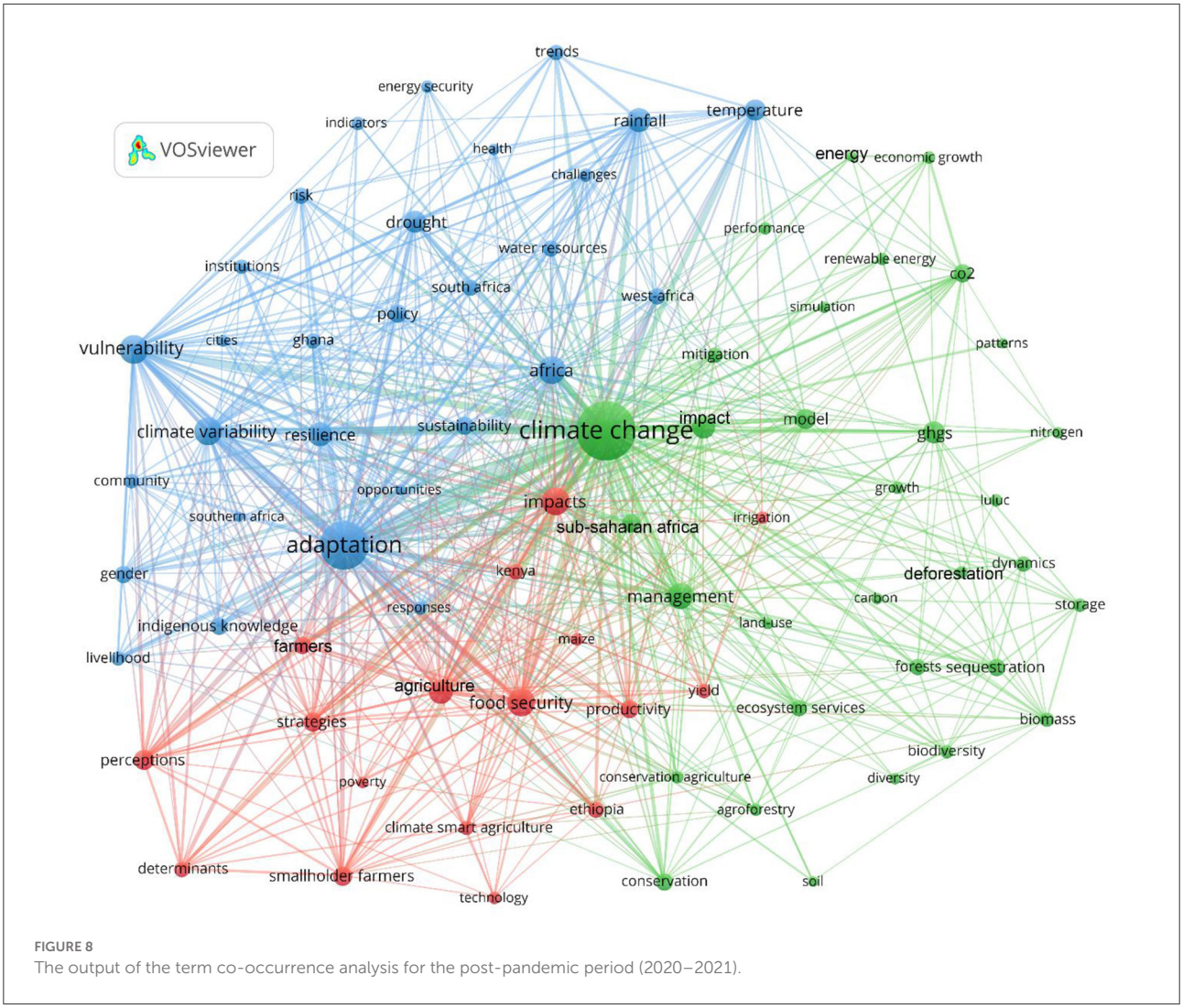

FIGURE 8
The output of the term co-occurrence analysis for the post-pandemic period (2020–2021).

noticed fluctuations in early and late growing seasons (Ayanlade et al., 2017). In South Africa, 77.3% of potato farmers and 66.7% of cabbage farmers experienced extreme temperatures, which led to a fall in their farm productivity. Potato farmers turned to integrate pest management to deal with climate risk, while cabbage farmers turned to planting drought-tolerant varieties (Elum et al., 2017). More studies have adopted a holistic approach to climate change by considering stakeholders' perceptions. For instance, a heat management policy was advocated when mining workers in Ghana suffered heat-related illnesses after a stakeholder consultation meeting (Nunfam et al., 2019). During this period, researchers appear to prefer studying climate change resilience from the adaptation perspective under full consideration of vulnerability. The overwhelming concern of researchers is the socio-environmental impacts on agriculture from extreme events like floods leading to food security issues under different climate variability scenarios. The next most frequent concern in dealing with food security is a shift in focus from agriculture to conservation agriculture. Overall, adaptation-related (blue cluster) studies shrunk while research on food security (red cluster) bulged and research on green cluster maintained a steady growth. The release of the fifth IPCC assessment report, with its scientific information, and technical and socio-economic relevance, triggered a good number of articles based on scientific research about adaptation and mitigation strategies. Thus, in this period, climate change studies have been increasing and becoming more diverse in Africa. These studies incorporated new concepts that allow the topic to be addressed from a range of different disciplines. The fifth IPPC assessment report in 2014 was a critical scientific contribution that led to the successful agreement on the Paris Climate Change accord, producing more research impetus.

Post pandemic period (2020–2021)

During this period, the green cluster and its related sequestration studies continue to attract more relevance (Figure 8). Compared with the previous period, the blue cluster

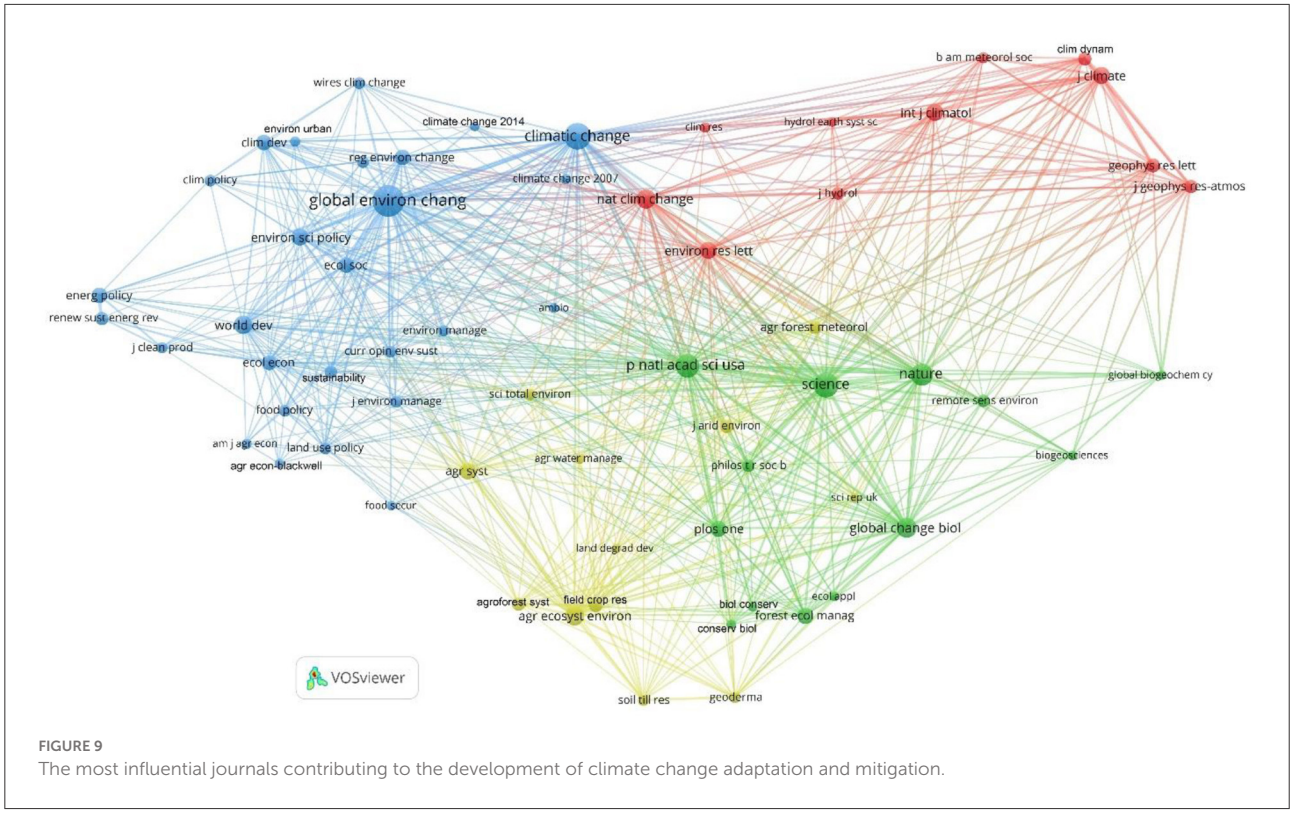

FIGURE 9
The most influential journals contributing to the development of climate change adaptation and mitigation.

has expanded, while studies on the red cluster begin to receive less relevance. Publications on sustainability, vulnerability, and resilience continued to increase from an adaptation perspective. As seen from the green cluster, ecosystem services and conservation agriculture were studied more closely. Climate-smart agriculture (CSA) is a new area of research receiving more relevance and is widely studied under the red cluster. Among the climate-smart agricultural practices adopted by African farmers are diversification of crops, change of planting time, and crop rotation/mixed cropping (Nyang'au et al., 2021). Climate-smart agricultural practices are recognized as one of the best adaptative strategies because they boost agricultural productivity, increase resilience, and reduce greenhouse gases that cause climate change (Anuga et al., 2020). The yellow cluster that was found in the previous period now merges with the mitigation cluster, and studies on renewable energy continue to rise. Mukoro et al.'s (2021) work predict that by 2040, renewable energy capacity in Africa is expected to reach 169.4 GW from 48.5 GW in 2019. Specifically, in South Africa, as of 2021, a total of 6,422 MW of power has been acquired across 112 renewable energy Independent Power Producers (Ayamolowo et al., 2022). The inevitability of more frequent and more extensive floods, displaying the inherent variability of climate, continued to be studied under the blue cluster (Ficchi et al., 2021; Petrova, 2022). Ethiopia's location indicates it is more worried about climate effects on food security (red cluster). At the same time, South Africa and Ghana are also concerned about vulnerability issues (blue cluster). But the main concern of Sub-Saharan Africa is mitigation issues (green cluster).

The outset of the pandemic positively impacted climate change research as researchers were able to develop new ideas seen from the rise in publications in <2 years. Unfortunately, the unending lockdowns have drawn attention away from climate change policy nationally and internationally. Environmentalists wonder why there has not been a pandemic preparedness for climate change as it has been for the COVID pandemic (Phillips et al., 2020). Pandemic recovery measures could be one of the solutions to climate change in Africa and the world. A complementary strategy is to use opportunities and lessons provided by the pandemic to accelerate the decline of carbon-intensive industries, technologies, and practices (Rosenbloom and Markard, 2020). Amid the pandemic, agricultural innovation and technologies have been promoted in Africa. The African Development Bank has helped increase the uptake and use of proven high-yielding climate-smart maize technologies by smallholder farmers in Sub-Saharan Africa (Fernando, 2020).

Influential sources

The co-citation analysis was used to find out which journals have contributed the most to the development of the field. Here, the size of the nodes is proportional to the number of citations,

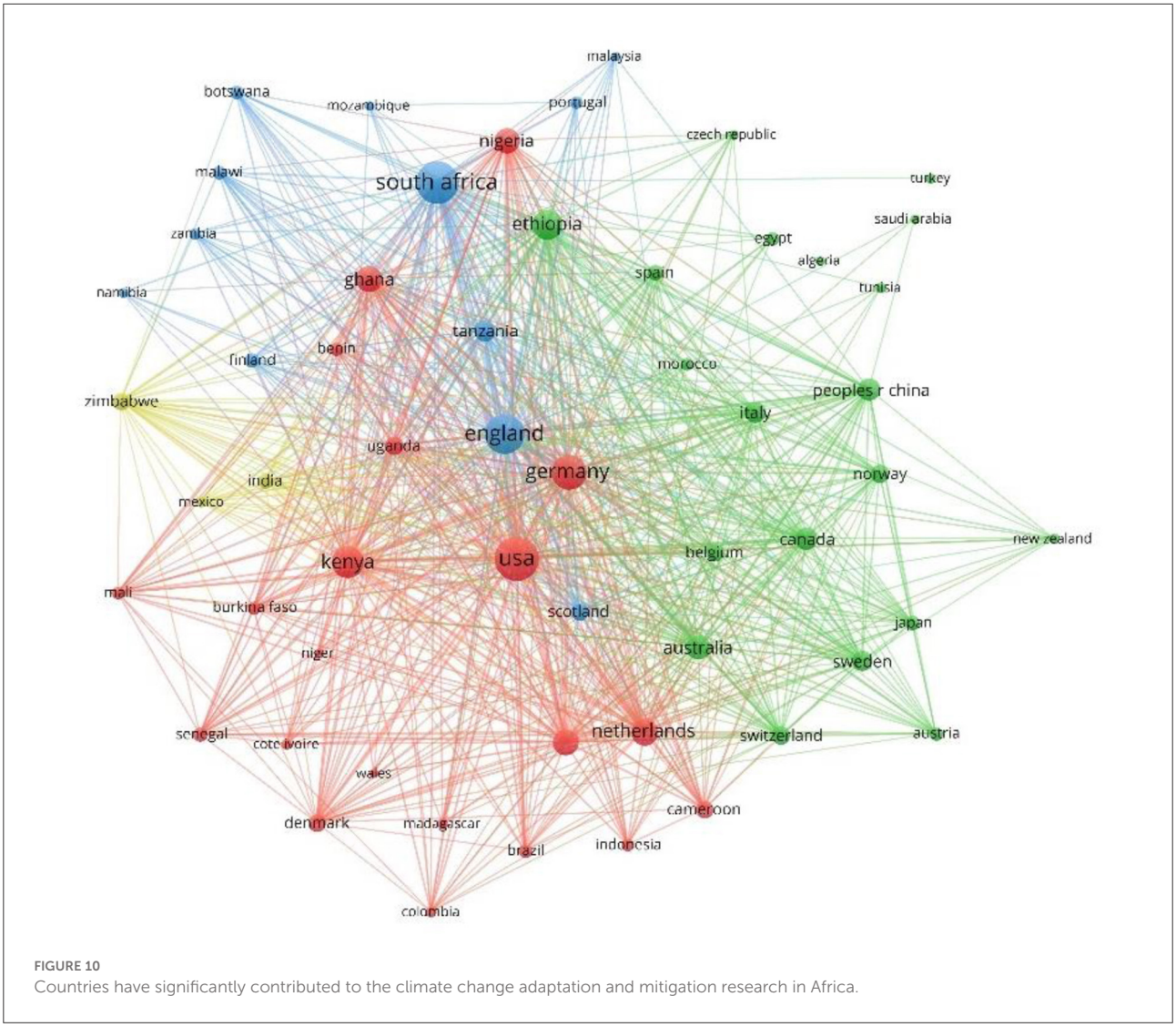

FIGURE 10
Countries have significantly contributed to the climate change adaptation and mitigation research in Africa.

and link width is proportional to the strength of the connection between two nodes. Four major clusters can be identified from the results of the co-citation analysis (Figure 9). The colors of these clusters are consistent with those reported for the term co-occurrence analysis. The largest cluster (blue) includes journals that are mainly focused on adaptation and vulnerability aspects. As expected, journals with a key focus on climate change and environmental issues have played a significant role in advancing Africa's knowledge of climate change adaptation. The most prominent journals in this cluster are Climatic Change, Global Environmental Change (GEC), Environmental Science Policy, and World Development. The results show that mitigation (green cluster) has mainly been addressed by journals such as PNAS, Science, Nature, and Forest Ecology and Management. The yellow cluster is dominated by influential journals like Agriculture, Ecosystem and Environment journal, Agricultural Systems, Field Crop Research, and Science of the Total Environment. The red cluster is dominated by journals like Nature Climate Change, Environmental Research Letters, and the Journal of Climatology.

Overall, the journals that have contributed the most to this literature include Global Environmental Change, PNAS, Climatic Change, Science, Agriculture, Ecosystem and Environment, Energy policy, Environmental Research Letters, Forest Ecology and Management, and Climate while the journals with the most documents are Climate and Development and Sustainability with totals of 131 and 121 documents, respectively.

An interesting observation here is the multidisciplinary nature of this field of knowledge. As seen in Figure 9, all articles are distributed and disseminated through 66 journals, which involve different fields of application, with emphasis on food security, climate change adaptation, and mitigation studies. This requires that future studies/efforts actively involve the

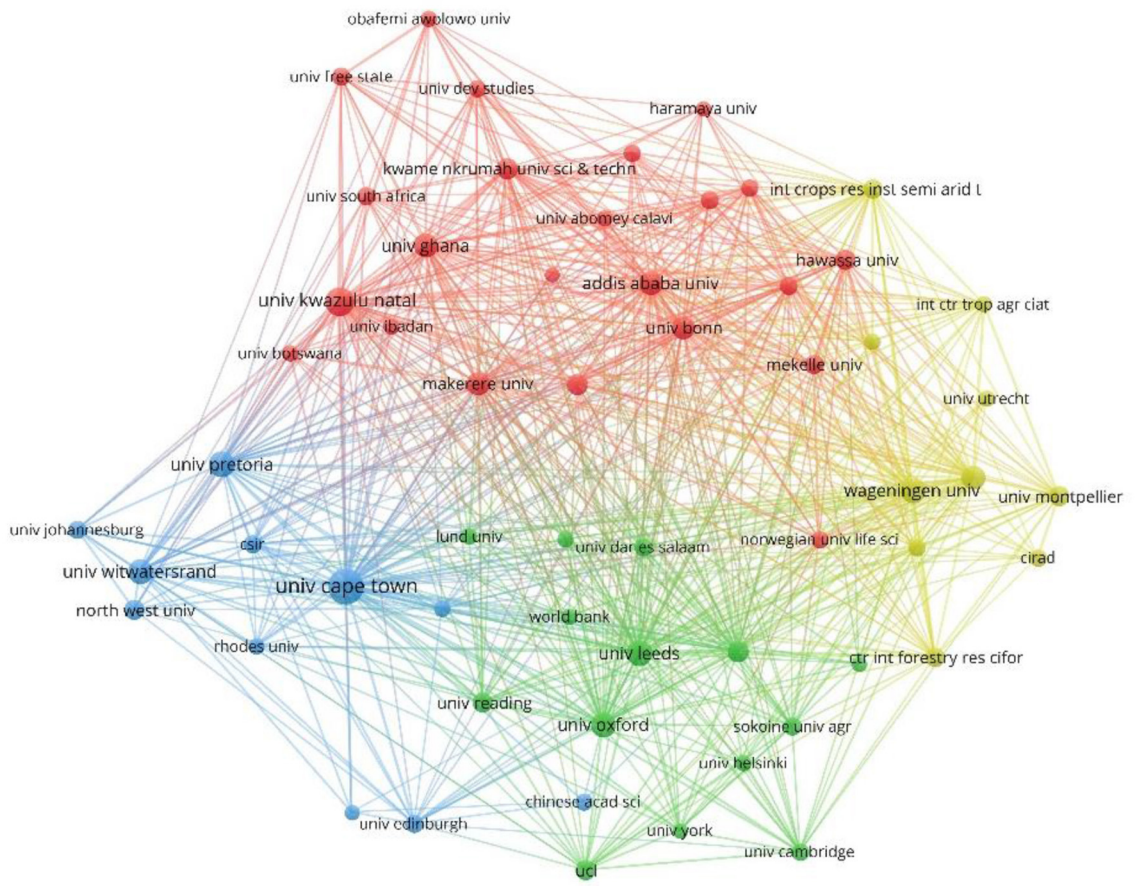

FIGURE 11
Organizations that have made significant contributions to the advancement of the field.

participation of several professionals to add learning in such a complex decision environment.

Major contributing countries and institutions

To recognize the most prominent countries that have contributed to the field, a bibliographic coupling analysis was conducted (Figure 10). The list of the top 20 most prominent countries with the number of documents, number of citations, and total link strength is presented in the Supplementary Table S1. It is noted that countries like the USA, South Africa, England, Germany, Kenya, and Ethiopia have published more on this topic (Figure 10). The USA, the UK, and South Africa ranked highest in terms of the total number of citations. Interestingly, while developed countries have contributed more, several African countries have also been highlighted. South Africa, Botswana, and Tanzania are some of the African countries with a close collaboration on adaptation, while Kenya, Cameroon, Ghana, and Nigeria have some research interests in food security. Ethiopia, Morocco, Egypt, Tunisia, and Algeria are interested in mitigation research, and Zimbabwe in the energy issues (Figure 10). The first 10 publishing African universities are shown in the Supplementary material with universities from South Africa taking the lead (Supplementary Table S2). Universities in South Africa are ahead of other African universities. An overwhelming number of African universities have not yet contributed to this literature.

International organizations like the World Bank, the Center for International Forest Research, World Agroforestry, etc. (Supplementary Table S3) made significant contributions, while international universities from Europe and the USA were prominent contributors (Supplementary Table S4). The focus of most African universities was on food security and adaptation, while that of some international organizations was on mitigation (Figure 11).

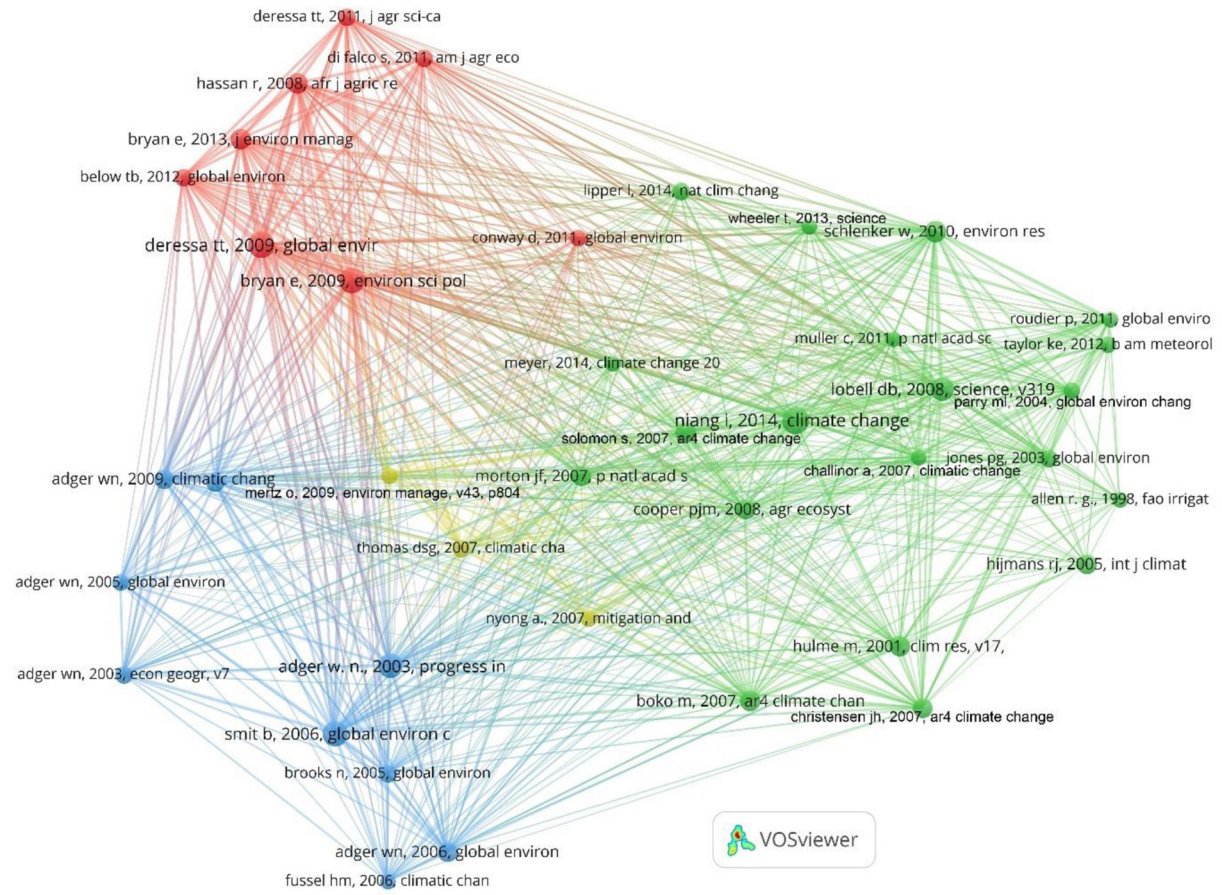

FIGURE 12
The most influential documents contributing to the development of the field.

Influential documents

The blue and yellow clusters include studies that were mostly done from 1990 to 2007 (Figure 12). Obviously, their focus on fundamental adaptation concepts has played an important role in guiding adaptation and vulnerability research. The red and green clusters include studies that were mostly done in the second period (2008–2014). The works of Roudier et al. (2011) stand out in the green cluster. This work predicted 11% yield loss in West Africa due to climate changes, with a higher yield loss of 18% in Northern West Africa (Roudier et al., 2011). Still, in the green cluster, the study by Lobell et al. (2008), concluded that there is a 95% chance that climate change will harm Southern Africa's maize and wheat, which are seen as the most important crops in need of adaptation. In the red cluster, the work of Deressa et al. (2009) is influential. They assessed the barriers to adaptation in Ethiopia. The result showed that the main barrier to adaptation was a lack of information and finance (Deressa et al., 2009). The work of Brooks et al. (2005) provided a robust assessment of vulnerability to climate-related mortality. They noted that the most vulnerable nations are those situated in sub-Saharan Africa experiencing conflict (Brooks et al., 2005).

Influential authors

The most published authors were Neil Adger, Philip Thornton, Temesgen Deressa, David Lobell, Elizabeth Basauri Bryan, Mike Hulme, Lal Rattan, and Barry Smit (Figure 13). The works of Adger are mostly on the vulnerability of communities and ecosystems to unforeseen climatic changes, causes and consequences of these vulnerabilities, and adaptation strategies (Adger and Barnett, 2009; Adger et al., 2009). Thornton, is interested in the impacts of climate change on livestock and livestock systems in developing countries and also curious to know how some African crops respond to climate change (Thornton et al., 2009a,b). These results are in line with Nalau and Verrall (2021), where Adger is also seen as the most prominent author in climate change adaptation research. Our

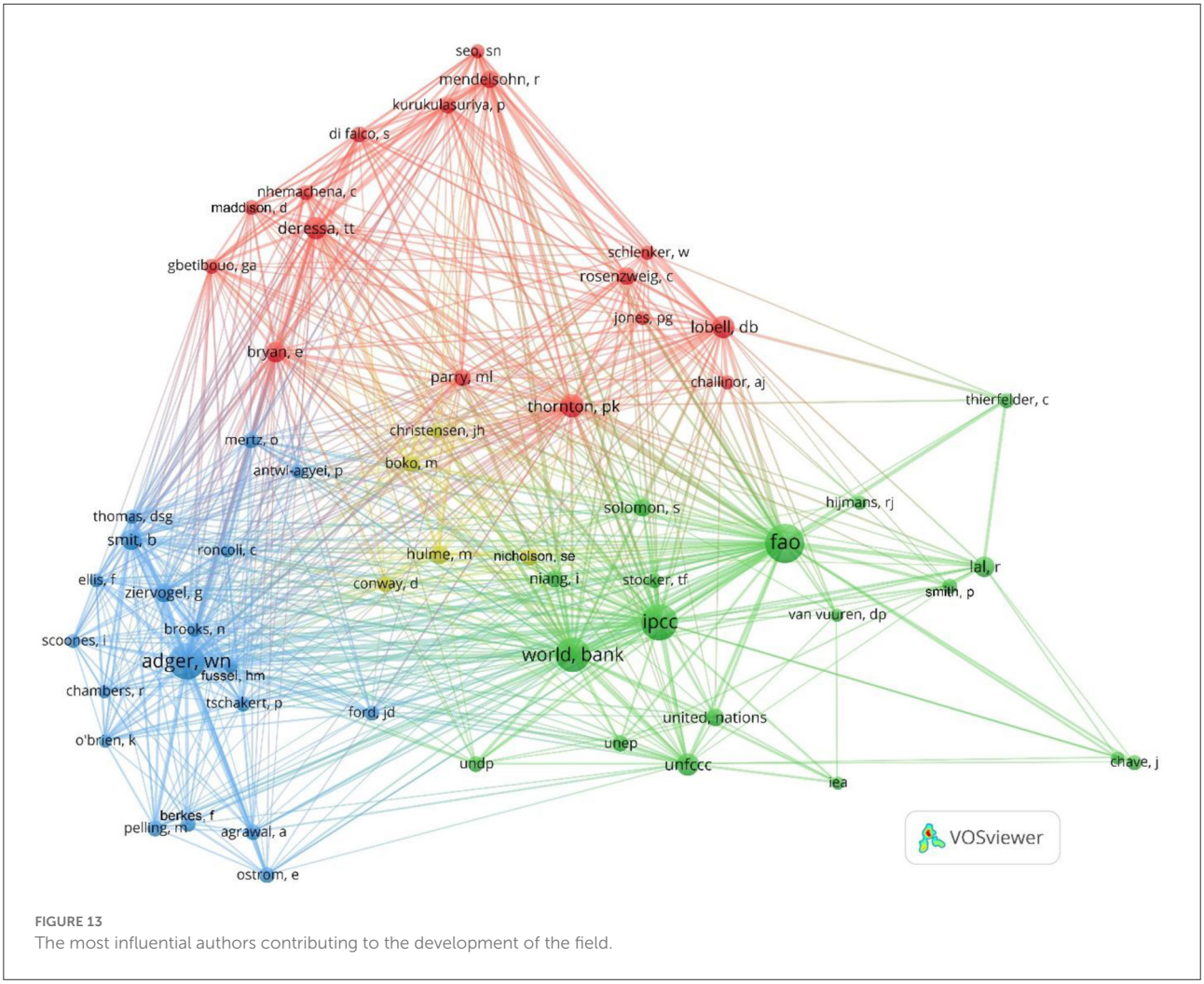

FIGURE 13
The most influential authors contributing to the development of the field.

results are consistent with the authors' publication record. For instance, Adger is a famous author in climate change adaptation, Lobell is noted for his writings on climate change mitigation, while Deressa and Bryan are noticeable for their publications on the impacts of climate change on food security.

Conclusion

This overview analysis echos a clear penchant to study and understand local adaptation capacities in Africa in the face of extreme events given that the impacts of climate change are irreversible. The most common unbiased objective in the documents is to determine how people cope with climate change based on their location. Clustering results of the literature suggest that studies on climate change adaptation mainly focused on agriculture and agroforestry, forestry, food, water and energy security. The focus is mainly on climate change adaptation in the agricultural sector. In contrast, less attention is paid to mitigation. Therefore, more research on this topic would be needed.

Woefully, most African institutions lack adequate research, which hampers efforts to address climate change in the continent. Adaptation and mitigation policies need to be developed based on regional and local characteristics, and the promotion and funding of research in this domain led by local experts for the building of a green Africa. African institutions should improve their ability to conduct research on climate change adaptation and mitigation, enter corresponding climate adaptation and mitigation cooperation, and ensure research in this field is relevant and fruitful. Africa, with the highest population and urban population growth rates globally, is likely to have major implications for climate change. However, it did not emerge from our analysis.

The more that is known about climate change adaptation and mitigation in the African continent, the greater the understanding and support will be to make feasible decisions. There will also be more motivation to engage in local climate

change adaptation and mitigation actions. Local knowledge and cultural practices should be recognized because they can complement scientific information in the design of adequate and effective adaptation and mitigation policies. Knowledge and technology gaps in African countries should be overcome to promote climate change mitigation research, whose progress is still due to inadequate analytical infrastructure to conduct the required measurements to assess the impacts of climate change which act as a prerequisite for adaptation planning. African countries need to enhance their research ability in the field of climate change mitigation through international cooperation and other extensive methods. This will bring more focus on African problems and, therefore, find solutions suitable to African characteristics. There is a need for a closing window of opportunity to avoid worse case scenarios in the continent. Collaboration, determination and trust across countries and amongst stakeholder groups will one way in meeting the challenge.

This study conducted statistical analysis on the data of SCI/SSCI published from 1990 to November 2021 through keyword retrieval. The study found that the publication volume of climate change adaptation and mitigation research in Africa has risen rapidly in recent years. Despite this rapid increase, some countries have contributed less to the publication volume. It is necessary to implement regional cooperation on climate change adaptation and mitigation in the region and improve the research capabilities of African countries in this field. Research on climate change adaptation and mitigation in African countries is of great concern and future research should pay more attention to African countries that have contributed less to the publication volume. In the end, it should be noted that this bibliometric review had some limitations. Using only English papers and sourcing data from the web of science database means that other potentially relevant studies published in local journals not indexed in the web of science could have been missed. Examining such sources would allow gaining a more comprehensive understanding of the structure and trend of the literatyre. Apart from articles published in local journals, the exclusion of gray literature was due to quality concerns and also because such studies are not indexed in formats compatible with the bibliometric analysis software tools. However, since our aim was to understand the overall structure and we already have a large number of articles in the database, we argue that the impacts of these limitations on the results are minimal.

Author contributions

Conceptualization, methodology, and software: AS. Formal analysis: AS and YB. Writing—original draft preparation: YB, AS, ST, NNG, and NG. Writing—review and editing: AS and ZA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.976427/full#supplementary-material

References

Abidoye, B. O., and Odusola, A. F. (2015). Climate change and economic growth in Africa: an econometric analysis. *J. Afr. Econ.* 24, 277–301. doi: 10.1093/jae/eju033

Adedayo, A., Oyun, M., and Kadeba, O. (2010). Access of rural women to forest resources and its impact on rural household welfare in North Central Nigeria. *For. Policy Econ.* 12, 439–450. doi: 10.1016/j.forpol.2010.04.001

Adenle, A. A., Ford, J. D., Morton, J., Twomlow, S., Alverson, K., Cattaneo, A., et al. (2017). Managing climate change risks in Africa-A global perspective. *Ecol. Econ.* 141, 190–201. doi: 10.1016/j.ecolecon.2017.06.004

Adetoye, A. M., Okojie, L. O., and Akerele, D. (2018). Forest carbon sequestration supply function for African countries: an econometric modelling approach. *For. Policy Econ*. 90, 59–66. doi: 10.1016/j.forpol.2018.01.007

Adger, W. N., and Barnett, J. (2009). Four reasons for concern about adaptation to climate change, *Environ. Plann. A* 41, 2800–2805. doi: 10.1068/a42244

Adger, W. N., Eakin, H., and Winkels, A. (2009). Nested and teleconnected vulnerabilities to environmental change. *Front. Ecol. Environ.* 7, 150–157. doi: 10.1890/070148

Adzawla, W., Azumah, S. B., Anani, P. Y., and Donkoh, S. A. (2019a). Gender perspectives of climate change adaptation in two selected districts of Ghana. *Heliyon* 5, e02854. doi: 10.1016/j.heliyon.2019.e02854

Adzawla, W., Sawaneh, M., and Yusuf, A. M. (2019b). Greenhouse gasses emission and economic growth nexus of sub-Saharan Africa. *Sci. Afr.* 3, *e*00065. doi: 10.1016/j.sciaf.2019.e00065

Ahmed, K. F., Wang, G., Yu, M., Koo, J., and You, L. (2015). Potential impact of climate change on cereal crop yield in West Africa. *Clim. Change* 133, 321–334. doi: 10.1007/s10584-015-1462-7

Ahmed, S. M. (2020). Impacts of drought, food security policy and climate change on performance of irrigation schemes in Sub-saharan Africa: the case of Sudan. *Agric. Water Manage.* 232, 106064. doi: 10.1016/j.agwat.2020.106064

Aidoo, D. C., Boateng, S. D., Freeman, C. K., and Anaglo, J. N. (2021). The effect of smallholder maize farmers' perceptions of climate change on their adaptation strategies: the case of two agro-ecological zones in Ghana. *Heliyon* 7, *e*08307. doi: 10.1016/j.heliyon.2021.e08307

Akinsanola, A. A., Ongoma, V., and Kooperman, G. J. (2021). Evaluation of CMIP6 models in simulating the statistics of extreme precipitation over Eastern Africa. *Atmosp. Res.* 254, 105509. doi: 10.1016/j.atmosres.2021.105509

Akinyi, D. P., Karanja Ng'ang'a, S., E.H. Girvetz. (2021). Trade-offs and synergies of climate change adaptation strategies among smallholder farmers in sub-Saharan Africa: a systematic review. *Reg. Sustain.* 2, 130–143. doi: 10.1016/j.regsus.2021.05.002

Alagidede, P., Adu, G., and Frimpong, P. B. (2016). The effect of climate change on economic growth: evidence from Sub-Saharan Africa. *Environ. Econ. Policy Stud.* 18, 417–436. doi: 10.1007/s10018-015-0116-3

Ali, M. M. M., and Yu, Q. (2021). Assessment of the impact of renewable energy policy on sustainable energy for all in West Africa. *Renew. Energy* 180, 544–551. doi: 10.1016/j.renene.2021.08.084

Alper, A., and Oguz, O. (2016). The role of renewable energy consumption in economic growth: evidence from asymmetric causality. *Renew. Sustain. Energy Rev.* 60, 953–959. doi: 10.1016/j.rser.2016.01.123

Aly, A., Bernardos, A., Fernandez-Peruchena, C. M., Jensen, S. S., and Pedersen, A. B. (2019). Is Concentrated Solar Power (CSP) a feasible option for Sub-Saharan Africa?: Investigating the techno-economic feasibility of CSP in Tanzania. *Renew. Energy* 135, 1224–1240. doi: 10.1016/j.renene.2018.09.065

Amouzou, K. A., Ezui, K. S., and Sogbedji, J. M. (2013). Impacts of climate variability and soil fertility management strategies on maize grain yield on ferrralsols in Coastal Western Africa. *J. Renew. Agric.* 1, 44–52. doi: 10.12966/jra.06.04.2013

Anuga, S. W., Chirinda, N., Nukpezah, D., Ahenkan, A., Andrieu, N., Gordon, C., et al. (2020). Towards low carbon agriculture: Systematic-narratives of climate-smart agriculture mitigation potential in Africa. *Curr. Res. Environ. Sustain.* 2, 100015. doi: 10.1016/j.crsust.2020.100015

Appiah, D. O., and Guodaar, L. (2021). Smallholder farmers' perceptions and knowledge on climate variability and perceived effects in vulnerable rural communities in the Offinso Municipality, Ghana. *Environ. Dev.* (2021) 42, 100691. doi: 10.1016/j.envdev.2021.100691

Apraku, A., Morton, J. F., and Apraku-Gyampoh, B. (2021). Climate change and small-scale agriculture in Africa: does indigenous knowledge matter? Insights from Kenya and South Africa. *Sci. Afr.* 12, e00821. doi: 10.1016/j.sciaf.2021.e00821

Araújo, M. B., and Rahbek, C. (2006). How does climate change affect biodiversity?, *Science* 313, 1396–1397. doi: 10.1126/science.1131758

Arndt, C., Schlosser, A., Strzepek, K., and Thurlow, J. (2014). Climate change and economic growth prospects for Malawi: An uncertainty approach. *J. Afr. Econ.* 23, ii83–ii107. doi: 10.1093/jae/eju013

Ayamolowo, O. J., Manditereza, P., and Kusakana, K. (2022). South Africa power reforms: The Path to a dominant renewable energy-sourced grid. *Energy Rep.* 8, 1208–1215. doi: 10.1016/j.egyr.2021.11.100

Ayanlade, A., Radeny, M., and Morton, J. F. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: a case study from southwestern Nigeria. *Weather Clim. Extr.* 15, 24–33. doi: 10.1016/j.wace.2016.12.001

Azadi, H., Moghaddam, S. M., Burkart, S., Mahmoudi, H., Van Passel, S., Kurban, A., et al. (2021). Rethinking resilient agriculture: from climate-smart agriculture to vulnerable-smart agriculture. *J. Clean. Prod.* 319, 128602. doi: 10.1016/j.jclepro.2021.128602

Beg, N., Morlot, J. C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Denton, F., et al. (2002). Linkages between climate change and sustainable development. *Clim. Pol.* 2, 129–144. doi: 10.3763/cpol.2002.0216

Bele, M. Y., Sonwa, D. J., and Tiani, A-. M. (2015). Adapting the Congo Basin forests management to climate change: Linkages among biodiversity, forest loss, and human well-being. *For. Policy Econ.* 50, 1–10. doi: 10.1016/j.forpol.2014.05.010

Berck, P., Berck, C. S., and Jacobson, T. N. (2018). *A Changing Climate in a Changing Land, Agricultural Adaptation to Climate Change in Africa*. London, UK: Routledge.

Betsill, M., and Bulkeley, H. (2007). Looking back and thinking ahead: a decade of cities and climate change research. *Local Environ.* 12, 447–456. doi: 10.1080/13549830701659683

Bhattacharya, M., Paramati, S. R., Ozturk, I., and Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy* 162, 733–741. doi: 10.1016/j.apenergy.2015.10.104

Blignaut, J. N., Chitiga-Mabugu, M., and Mabugu, R. (2005). Constructing a Greenhouse Gas Emissions Inventory Using Energy Balances: The Case of South Africa for 1998 *J. Energy South. Afr.* 16, 21–32.

Boden, T., Andres, R., and Marland, G. (2017). *Global, Regional, and National Fossil-Fuel CO2 Emissions (1751-2014)(v. 2017). Environ. System Science Data Infrastructure for a Virtual Ecosystem*.

Bohle, H. G., Downing, T. E., and Watts, M. J. (1994). Climate change and social vulnerability: toward a sociology and geography of food insecurity. *Glob. Environ. Change* 4, 37–48. doi: 10.1016/0959-3780(94)90020-5

Branca, G., Arslan, A., Paolantonio, A., Grewer, U., Cattaneo, A., Cavatassi, R., et al. (2021). Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: a case study in Southern Africa. *J. Clean. Prod.* 285, 125161. doi: 10.1016/j.jclepro.2020.125161

Brooks, N., Adger, W. N., and Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Glob. Environ. Change* 15, 151–163. doi: 10.1016/j.gloenvcha.2004.12.006

Brown, M. E., Hintermann, B., and Higgins, N. (2009). *Markets, Climate Change, and Food Security in West* Africa. Washington, D.C.: ACS Publications.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environ. Sci. policy* 12, 413–426. doi: 10.1016/j.envsci.2008.11.002

Busby, J. W., Smith, T. G., and Krishnan, N. (2014). Climate security vulnerability in Africa mapping 3.01. *Pol. Geogr.* 43, 51–67. doi: 10.1016/j.polgeo.2014.10.005

Chilundo, R. J., Neves, D., and Mahanjane, U. S. (2019). Photovoltaic water pumping systems for horticultural crops irrigation: Advancements and opportunities towards a green energy strategy for Mozambique. *Sustain. Energy Technol. Assess.* 33, 61–68. doi: 10.1016/j.seta.2019.03.004

Connolly-Boutin, L., and Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. *Reg. Environ. Change* 16, 385–399. doi: 10.1007/s10113-015-0761-x

De Bakker, F. G., Groenewegen, P., and Den Hond, F.. (2005). A bibliometric analysis of 30 years of research and theory on corporate social responsibility and corporate social performance. *Bus. Soc.* 44, 283–317. doi: 10.1177/0007650305278086

Delmas, R., Servant, J., Tathy, J., Cros, B., and Labat, M. (1992). Sources and sinks of methane and carbon dioxide exchanges in mountain forest in equatorial Africa. *J. Geophy. Res. Atmosp.* 97, 6169–6179. doi: 10.1029/90JD02575

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Change* 19, 248–255. doi: 10.1016/j.gloenvcha.2009.01.002

Descheemaeker, K., Oosting, S. J., Tui, S. H-. K., Masikati, P., Falconnier, G. N., Giller, K. E., et al. (2016). Climate change adaptation and mitigation in smallholder crop–livestock systems in sub-Saharan Africa: a call for integrated impact assessments. *Reg. Environ. Change* 16, 2331–2343. doi: 10.1007/s10113-016-0957-8

Dixon, R. K., Smith, J., and Guill, S. (2003). Life on the edge: Vulnerability and adaptation of african ecosystems to global climate change. *Mitigat. Adapt. Strateg. Glob. Chang.* 8, 93–113. doi: 10.1023/A:1026001626076

Donat, M., Peterson, T., Brunet, M., King, A., Almazroui, M., Kolli, R., et al. (2014). Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO. *Int. J. Climatol.* 34, 581–592. doi: 10.1002/joc.3707

Douxchamps, S., Van Wijk, M. T., Silvestri, S., Moussa, A. S., Quiros, C., Ndour, N. Y. B., et al. (2016). Linking agricultural adaptation strategies, food security and vulnerability: evidence from West Africa. *Reg. Environ. Change* 16, 1305–1317. doi: 10.1007/s10113-015-0838-6

Dzoga, M., Simatele, D., and Munga, C. (2018). Assessment of ecological vulnerability to climate variability on coastal fishing communities: a study of Ungwana Bay and Lower Tana Estuary, Kenya. *Ocean Coast. Manage.* 163, 437–444. doi: 10.1016/j.ocecoaman.2018.07.015

Einecker, R., and Kirby, A. (2020). Climate change: a bibliometric study of adaptation, mitigation and resilience. *Sustainability* 12, 6935. doi: 10.3390/su12176935

Elum, Z. A., Modise, D. M., and Marr, A. (2017). Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Clim. Risk Manage.* 16, 246–257. doi: 10.1016/j.crm.2016.11.001

Engelbrecht, F., Adegoke, J., Bopape, M-. J., Naidoo, M., Garland, R., Thatcher, M., et al. (2015). Projections of rapidly rising surface temperatures over Africa under low mitigation. *Environ. Res. Lett.* 10, 085004. doi: 10.1088/1748-9326/10/8/085004

Epule, T. E., Chehbouni, A., Dhiba, D., Moto, M. W., and Peng, C. (2021). African climate change policy performance index. *Environ. Sustain. Indicat.* 12, 100163. doi: 10.1016/j.indic.2021.100163

Fernando, A. J. (2020). How Africa is promoting agricultural innovations and technologies amidst the COVID-19 pandemic. *Mol. Plant* 13, 1345–1346. doi: 10.1016/j.molp.2020.08.003

Ficchi, A., Cloke, H., Neves, C., Woolnough, S., de Perez, E. C., Zsoter, E., et al. (2021). Beyond El Niño: unsung climate modes drive African floods. *Weather Clim. Extr.* 33, 100345. doi: 10.1016/j.wace.2021.100345

Flatø, M., Muttarak, R., and Pelser, A. (2017). Women, weather, and woes: The triangular dynamics of female-headed households, economic vulnerability, and climate variability in South Africa. *World Dev.* 90, 41–62. doi: 10.1016/j.worlddev.2016.08.015

Fotso-Nguemo, T. C., Vondou, D. A., Pokam, W. M., Djomou, Z. Y., Diallo, I., Haensler, A., et al. (2017). On the added value of the regional climate model REMO in the assessment of climate change signal over Central Africa. *Clim. Dyn.* 49, 3813–3838. doi: 10.1007/s00382-017-3547-7

Frangoul (2019). *From Angola to Zambia, Here are Africa's Leaders in Green Energy*. Available online at: https://www.cnbc.com/2019/06/10/from-angola-to-zambia-here-are-africas-leaders-in-green-energy.html (accessed on 2022, 2019).

Friedrich, E., and Trois, C. (2011). Quantification of greenhouse gas emissions from waste management processes for municipalities–A comparative review focusing on Africa. *Waste Manage.* 31, 1585–1596. doi: 10.1016/j.wasman.2011.02.028

Gakou-Kakeu, J., Gregorio, M. D. i., Paavola, J., and Sonwa, D. J. (2022). REDD+ policy implementation and institutional interplay: Evidence from three pilot projects in Cameroon. *For. Pol. Econ.* 135, 102642. doi: 10.1016/j.forpol.2021.102642

Gandure, S., Walker, S., and Botha, J. (2013). Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environ. Dev.* 5, 39–53. doi: 10.1016/j.envdev.2012.11.004

Gérardeaux, E., Loison, R., Palaï, O., and Sultan, B. (2018). Adaptation strategies to climate change using cotton (Gossypium hirsutum L.) ideotypes in rainfed tropical cropping systems in Sub-Saharan Africa. A modeling approach. *Field Crops Res.* 226, 38–47. doi: 10.1016/j.fcr.2018.07.007

Gezimua, G. (2021). Prevalence of Household Food Insecurity in East Africa: Linking Food Access with Climate Vulnerability. *Clim. Risk Manage.* 33, 100333. doi: 10.1016/j.crm.2021.100333

Gonzalez-Sanchez, E. J., Veroz-Gonzalez, O., Conway, G., Moreno-Garcia, M., Kassam, A., Mkomwa, S., et al. (2019). Meta-analysis on carbon sequestration through Conservation Agriculture in Africa. *Soil Tillage Res.* 190, 22–30. doi: 10.1016/j.still.2019.02.020

Habimana Simbi, C., Lin, J., Yang, D., Ndayishimiye, J. C., Liu, Y., Li, H., et al. (2021). *Decomposition and Decoupling Analysis of Carbon Dioxide Emissions in African Countries During* 1984–2014.

Harrington, L. J., and Otto, F. E. L. (2020). Reconciling theory with the reality of African heatwaves. *Nat. Clim. Change* 10, 796–798. doi: 10.1038/s41558-020-0851-8

Hertig, E., Seubert, S., Paxian, A., Vogt, G., Paeth, H., Jacobeit, J., et al. (2014). Statistical modelling of extreme precipitation indices for the Mediterranean area under future climate change. *Int. J. Climatol.* 34, 1132–1156. doi: 10.1002/joc.3751

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proc. Natl. Acad. Sci.* 102, 16569–16572. doi: 10.1073/pnas.0507655102

Hoegh-Guldberg, O., Jacob, D., Bindi, M., Brown, S., Camilloni, I., Diedhiou, A., et al. (2018). *Impacts of 1, 5. C Global Warming on Natural and Human Systems, Global warming of 1.5 C. An IPCC Special Report*.

Ifeanyi-Obi, C., Togun, A., Lamboll, R., Adesope, O., and Arokoyu, S. (2017). Challenges faced by cocoyam farmers in adapting to climate change in Southeast Nigeria. *Clim. Risk Manage.* 17, 155–164. doi: 10.1016/j.crm.2017.04.002

Isyaku, U. (2021). What motivates communities to participate in forest conservation? A study of REDD+ pilot sites in Cross River, Nigeria. *For. Pol. Econ.* 133, 102598. doi: 10.1016/j.forpol.2021.102598

Iyakaremye, V., Zeng, G., Yang, X., Zhang, G., Ullah, I., Gahigi, A., et al. (2021). Increased high-temperature extremes and associated population exposure in Africa by the mid-21st century. *Sci. Total Environ.* 790, 148162. doi: 10.1016/j.scitotenv.2021.148162

Jamal, A. M., Antwi-Agyei, P., Baffour-Ata, F., Nkiaka, E., Antwi, K., Gbordzor, A., et al. (2021). Gendered perceptions and adaptation practices of smallholder cocoa farmers to climate variability in the Central Region of Ghana. *Environ. Challenges* 5, 100293. doi: 10.1016/j.envc.2021.100293

Janssen, M. A., Schoon, M. L., Ke, W., and Börner, K. (2006). Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Glob. Environ. Change* 16, 240–252. doi: 10.1016/j.gloenvcha.2006.04.001

Jenkins, G. S., Adamou, G., and Fongang, S. (2002). The challenges of modeling climate variability and change in West Africa. *Clim.Change* 52, 263–286. doi: 10.1023/A:1013741803144

Jones, C., McConnell, C., Coleman, K., Cox, P., Falloon, P., Jenkinson, D., et al. (2005). Global climate change and soil carbon stocks; predictions from two contrasting models for the turnover of organic carbon in soil. *Global Change Biol.* 11, 154–166. doi: 10.1111/j.1365-2486.2004.00885.x

Jost, C., Kyazze, F., Naab, J., Neelormi, S., Kinyangi, J., Zougmore, R., et al. (2016). Understanding gender dimensions of agriculture and climate change in smallholder farming communities. *Clim. Dev.* 8, 133–144. doi: 10.1080/17565529.2015.1050978

Knox, J., Hess, T., Daccache, A., and Wheeler, T. (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environ. Res. Lett.* 7, 034032. doi: 10.1088/1748-9326/7/3/034032

Kurukulasuriya, P., and Mendelsohn, R. (2008). Crop switching as a strategy for adapting to climate change. *Afr. J. Agric. Resour. Econ.* 2, 105–126. doi: 10.22004/ag.econ.56970

Lanckriet, S., Araya, T., Cornelis, W., Verfaillie, E., Poesen, J., Govaerts, B., et al. (2012). Impact of conservation agriculture on catchment runoff and soil loss under changing climate conditions in May Zeg-zeg (Ethiopia). *J. Hydrol.* 475, 336–349. doi: 10.1016/j.jhydrol.2012.10.011

Langat, D., Maranga, E., Aboud, A., and Cheboiwo, J. (2016). Role of forest resources to local livelihoods: The case of East Mau forest ecosystem, Kenya. *Int. J. For. Res.* 2016. doi: 10.1155/2016/4537354

Leal Filho, W., Balogun, A-. L., Ayal, D. Y., Bethurem, E. M., Murambadoro, M., Mambo, J., et al. (2018). Strengthening climate change adaptation capacity in Africa-case studies from six major African cities and policy implications. *Environ. Sci. Policy* 86, 29–37. doi: 10.1016/j.envsci.2018.05.004

Leal Filho, W., Barbir, J., Gwenzi, J., Ayal, D., Simpson, N. P., Adeleke, L., et al. (2022a). The role of indigenous knowledge in climate change adaptation in Africa. *Environ. Sci. Policy* 136, 250–260. doi: 10.1016/j.envsci.2022.06.004

Leal Filho, W., Totin, E., Franke, J. A., Andrew, S. M., Abubakar, I. R., Azadi, H., et al. (2022b). Understanding responses to climate-related water scarcity in Africa. *Sci. Total Environ.* 806, 150420. doi: 10.1016/j.scitotenv.2021.150420

Lelieveld, J., Proestos, Y., Hadjinicolaou, P., Tanarhte, M., Tyrlis, E., Zittis, G., et al. (2016). Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. *Clim. Change* 137, 245–260. doi: 10.1007/s10584-016-1665-6

Li, J., Wang, M-. H., and Ho, Y-. S. (2011). Trends in research on global climate change: a science citation index expanded-based analysis. *Global Planet. Change* 77, 13–20. doi: 10.1016/j.gloplacha.2011.02.005

Liebmann, B., Hoerling, M. P., Funk, C., Bladé, I., Dole, R. M., Allured, D., et al. (2014). Understanding recent eastern Horn of Africa rainfall variability and change. *J. Climate* 27, 8630–8645. doi: 10.1175/JCLI-D-13-00714.1

Lobell, D. B., and Burke, M. B. (2010). On the use of statistical models to predict crop yield responses to climate change. *Agric. For. Meteorol.* 150, 1443–1452. doi: 10.1016/j.agrformet.2010.07.008

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., Naylor, R. L., et al. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science* 319, 607–610. doi: 10.1126/science.1152339

Mahumane, G., and Mulder, P. (2019). Expanding versus greening? Long-term energy and emission transitions in Mozambique. *Energy Policy* 126, 145–156. doi: 10.1016/j.enpol.2018.10.056

Majola, K., Xu, Y., and Kanyerere, T. (2021). *Assessment of climate change impacts on groundwater-dependent ecosystems in transboundary aquifer settings with reference to the Tuli-Karoo transboundary* aquifer. *Ecohydrol. Hydrobiol.* 22, 126–140. doi: 10.1016/j.ecohyd.2021.08.013

Marx, W., Haunschild, R., and Bornmann, L. (2017). Global warming and tea production—the bibliometric view on a newly emerging research topic. *Climate* 5, 46. doi: 10.3390/cli5030046

Mekonnen, A., Tessema, A., Ganewo, Z., and Haile, A. (2021). Climate change impacts on household food security and farmers adaptation strategies. *J. Agric. Food Res.* 6, 100197. doi: 10.1016/j.jafr.2021.100197

Moher, D., Liberati, A., Tetzlaff, J., and Altman, D. G. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int. J. Surg.* 8, 336–341. doi: 10.1016/j.ijsu.2010.02.007

Moron, V., Oueslati, B., Pohl, B., Rome, S., and Janicot, S. (2016). Trends of mean temperatures and warm extremes in northern tropical Africa (1961–2014) from observed and PPCA-reconstructed time series. *J. Geophys. Res. Atmos.* 121, 5298–5319. doi: 10.1002/2015JD024303

Mukoro, V., Gallego-Schmid, A., and Sharmina, M. (2021). Life cycle assessment of renewable energy in Africa. *Sustain. Prod. Consump.* 28, 1314–1332. doi: 10.1016/j.spc.2021.08.006

Müller, C., Cramer, W., Hare, W. L., and Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proc. Natl. Acad. Sci.* 108, 4313–4315. doi: 10.1073/pnas.1015078108

Müller, F., Claar, S., Neumann, M., and Elsner, C. (2020). Is green a Pan-African colour? Mapping African renewable energy policies and transitions in 34 countries. *Energy Res. Soc. Sci.* 68, 101551. doi: 10.1016/j.erss.2020.101551

Mumo, L., Yu, J., and Fang, K. (2018). Assessing impacts of seasonal climate variability on maize yield in Kenya. *Int. J. Plant Prod.* 12, 297–307. doi: 10.1007/s42106-018-0027-x

Murkowski, F. H. (2000). The Kyoto protocol in not the answer to climate change. *Harv. J. Legis.* 37, 345. Available online at: https://heinonline.org/HOL/LandingPage?handle=hein.journals/hjl37&div=20&id=&page=

Nalau, J., and Verrall, B. (2021). Mapping the evolution and current trends in climate change adaptation science. *Clim. Risk Manag.* 32, 100290. doi: 10.1016/j.crm.2021.100290

Nathaniel, S. P., and Adeleye, N. (2021). Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected African countries: implication for sustainability. *J. Clean. Prod.* 285, 125409. doi: 10.1016/j.jclepro.2020.125409

Ncongwane, K. P., Botai, J. O., Sivakumar, V., Botai, C. M. (2021). A literature review of the impacts of heat stress on human health across Africa. *Sustainability* 13, 5312. doi: 10.3390/su13095312

Nematchoua, M. K., Orosa, J. A., and Reiter, S. (2019). Climate change: Variabilities, vulnerabilities and adaptation analysis-A case of seven cities located in seven countries of Central Africa. *Urban Clim.* 29, 100486. doi: 10.1016/j.uclim.2019.100486

Ngigi, S. N. (2009). *Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in sub-Saharan Africa*. New York, NY: The Earth Institute at Columbia University.

Ngoran, S. D., Dogah, K. E., and Xue, X. (2015). Assessing the impacts of climate change on water resources: The Sub-Saharan Africa perspective. *J. Econ. Sustain. Dev.* 6, 185–193. Available online at; https://www.researchgate.net/profile/Suinyuy-Derrick-Ngoran/publication/288181618_Assessing_the_Impacts_of_Climate_Change_on_Water_Resources_The_Sub-Saharan_Africa_Perspective/links/567ec98c08aebccc4e05de5d/Assessing-the-Impacts-of-Climate-Change-on-Water-Resources-The-Sub-Saharan-Africa-Perspective.pdf

Nicholson, S. E. (2017). Climate and climatic variability of rainfall over eastern Africa. *Rev. Geophy.* 55, 590–635. doi: 10.1002/2016RG000544

Nicholson, S. E., Funk, C., and Fink, A. H. (2018). Rainfall over the African continent from the 19th through the 21st century. *Global Planet. Change* 165, 114–127. doi: 10.1016/j.gloplacha.2017.12.014

Nikiema, P. M., Sylla, M. B., Ogunjobi, K., Kebe, I., Gibba, P., Giorgi, F., et al. (2017). Multi-model CMIP5 and CORDEX simulations of historical summer temperature and precipitation variabilities over West Africa. *Int. J. Climatol.* 37, 2438–2450. doi: 10.1002/joc.4856

Nikulin, G., Lennard, C., Dosio, A., Kjellström, E., Chen, Y., Hänsler, A., et al. (2018). The effects of 1.5 and 2 degrees of global warming on Africa in the CORDEX ensemble. *Environ. Res. Lett.* 13, 065003. doi: 10.1088/1748-9326/aab1b1

Njana, M. A., Mbilinyi, B., and Eliakimu, Z. (2021). The role of forests in the mitigation of global climate change: Emprical evidence from Tanzania. *Environ. Challenges* 100170. doi: 10.1016/j.envc.2021.100170

Nkhonjera, G. K. (2017). Understanding the impact of climate change on the dwindling water resources of South Africa, focusing mainly on Olifants River basin: a review. *Environ. Sci. Policy* 71, 19–29. doi: 10.1016/j.envsci.2017.02.004

North, M. A., Hastie, W. W., Craig, M. H., and Slotow, R. (2022). Tracing primary sources of funding for, and patterns of authorship in, climate change research in Africa. *Environ. Sci. Policy* 127, 196–208. doi: 10.1016/j.envsci.2021.10.023

Nunfam, V. F., Van Etten, E. J., Oosthuizen, J., Adusei-Asante, K., and Frimpong, K. (2019). Climate change and occupational heat stress risks and adaptation strategies of mining workers: Perspectives of supervisors and other stakeholders in Ghana. *Environ. Res.* 169, 147–155. doi: 10.1016/j.envres.2018.11.004

Nyang'au, J. O., Mohamed, J. H., Mango, N., Makate, C., and Wangeci, A. N. (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon* 7, e06789. doi: 10.1016/j.heliyon.2021.e06789

Nyboer, E. A., Liang, C., and Chapman, L. J. (2019). Assessing the vulnerability of Africa's freshwater fishes to climate change: a continent-wide trait-based analysis. *Biol. Conserv.* 236, 505–520. doi: 10.1016/j.biocon.2019.05.003

Nyiwul, L. (2021). Innovation and adaptation to climate change: Evidence from the water sector in Africa. *J. Clean. Prod.* 298, 126859. doi: 10.1016/j.jclepro.2021.126859

Nyong, A., Adesina, F., and Elasha, B. O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation Adap. Strat. Global Change* 12, 787–797. doi: 10.1007/s11027-007-9099-0

Ogunseitan, O. (2003). Framing environmental change in Africa: cross-scale institutional constraints on progressing from rhetoric to action against vulnerability. *Glob. Environ. Change* 13, 101–111. doi: 10.1016/S0959-3780(03)00004-9

Olivier, J., Bouwman, A., Berdowski, J., Veldt, C., Bloos, J., Visschedijk, A., et al. (1999). Sectoral emission inventories of greenhouse gases for 1990 on a per country basis as well as on 1× 1. *Environ. Sci. Policy* 2, 241–263. doi: 10.1016/S1462-9011(99)00027-1

Ozoegwu, C. G., and Akpan, P. U. (2021). A review and appraisal of Nigeria's solar energy policy objectives and strategies against the backdrop of the renewable energy policy of the Economic Community of West African States. *Renew. Sustain. Energy Rev.* 143, 110887. doi: 10.1016/j.rser.2021.110887

Ozturk, I. (2017). The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected Sub-Saharan African Countries. *Energy Policy* 107, 289–299. doi: 10.1016/j.enpol.2017.04.048

Paeth, H., Capo-Chichi, A., and Endlicher, W. (2008). Climate change and food security in tropical West Africa—a dynamic-statistical modelling approach. *Erdkunde*. 62, 101–115. doi: 10.3112/erdkunde.2008.02.01

Perez, C., Jones, E., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., et al. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environ. Change* 34, 95–107. doi: 10.1016/j.gloenvcha.2015.06.003

Petrova, K. (2022). Floods, communal conflict and the role of local state institutions in Sub-Saharan Africa. *Pol. Geogr.* 92, 102511. doi: 10.1016/j.polgeo.2021.102511

Phillips, C. A., Caldas, A., Cleetus, R., Dahl, K. A., Declet-Barreto, J., Licker, R., et al. (2020). Compound climate risks in the COVID-19 pandemic. *Nat. Clim. Change* 10, 586–588. doi: 10.1038/s41558-020-0804-2

Radhouane, L. (2013). Climate change impacts on North African countries and on some Tunisian economic sectors. *J. Agric. Environ. Int. Dev.* (JAEID) 107, 101–113. doi: 10.12895/jaeid.20131.123

Rahlao, S., Mantlana, B., Winkler, H., and Knowles, T. (2012). South Africa's national REDD+ initiative: assessing the potential of the forestry sector on climate change mitigation. *Environ. Sci. Policy* 17, 24–32. doi: 10.1016/j.envsci.2011.11.013

Rosenbloom, D., and Markard, J. (2020). A COVID-19 recovery for climate. *Am. Assoc. Adv. Sci.* 368, 447–447. doi: 10.1126/science.abc4887

Roudier, P., Sultan, B., Quirion, P., and Berg, A. (2011). The impact of future climate change on West African crop yields: what does the recent literature say?. *Glob. Environ. Change* 21, 1073–1083. doi: 10.1016/j.gloenvcha.2011.04.007

Russo, S., Marchese, A. F., Sillmann, J., and Immé, G. (2016). When will unusual heat waves become normal in a warming Africa?. *Environ. Res. Lett.* 11, 054016. doi: 10.1088/1748-9326/11/5/054016

Sakah, M., Diawuo, F. A., Katzenbach, R., and Gyamfi, S. (2017). Towards a sustainable electrification in Ghana: a review of renewable energy deployment policies. *Renew. Sustain. Energy Rev.* 79, 544–557. doi: 10.1016/j.rser.2017.05.090

Saleh, M. (2021). Production-Based Carbon Dioxide (CO2) Emissions in Africa in 2020, by Country. Available online at: https://www.statista.com/statistics/1268395/production-based-co2-emissions-in-africa-by-country/ (accessed January 17, 2022).

Schlenker, W., and Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environ. Res. Lett.* 5, 014010. doi: 10.1088/1748-9326/5/1/014010

Schulze, R. (1997). Impacts of global climate change in a hydrologically vulnerable region: challenges to South African hydrologists. *Progr. Phys. Geogr.* 21, 113–136. doi: 10.1177/030913339702100107

Semenov, M. A., and Stratonovitch, P. (2010). Use of multi-model ensembles from global climate models for assessment of climate change impacts. *Clim. Res.* 41, 1–14. doi: 10.3354/cr00836

Sharifi, A. (2021). Urban sustainability assessment: An overview and bibliometric analysis. *Ecol. Indicat.* 121, 107102. doi: 10.1016/j.ecolind.2020.107102

Sharifi, A., Allam, Z., Feizizadeh, B., and Ghamari, H. (2021). Three decades of research on smart cities: mapping knowledge structure and trends. *Sustainability* 13, 7140. doi: 10.3390/su13137140

Sheffield, J., Wood, E. F., Chaney, N., Guan, K., Sadri, S., Yuan, X., et al. (2014). A drought monitoring and forecasting system for sub-Sahara African water resources and food security. *Bull. Am. Meteorol. Soc.* 95, 861–882. doi: 10.1175/BAMS-D-12-00124.1

Shindell, D., Kuylenstierna, J. C., Vignati, E., van Dingenen, R., Amann, M., Klimont, Z., et al. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science* 335, 183–189. doi: 10.1126/science.1210026

Siderius, C., Kolusu, S. R., Todd, M. C., Bhave, A., Dougill, A. J., Reason, C. J., et al. (2021). Climate variability affects water-energy-food infrastructure performance in East Africa. *One Earth* 4, 397–410. doi: 10.1016/j.oneear.2021.02.009

Sileshi, G. W., and Gebeyehu, S. (2021). Emerging infectious diseases threatening food security and economies in Africa. *Global Food Secur* 28, 100479. doi: 10.1016/j.gfs.2020.100479

Sileshi, G. W., Gebeyehu, S., and Mafongoya, P. L. (2019). The threat of alien invasive insect and mite species to food security in Africa and the need for a continent-wide response. *Food Secur.* 11, 763–775. doi: 10.1007/s12571-019-00930-1

Simpson, N. P., Shearing, C. D., and Dupont, B. (2019). Climate gating: a case study of emerging responses to Anthropocene Risks. *Clim. Risk Manage.* 26, 100196. doi: 10.1016/j.crm.2019.100196

Sintayehu, D. W. (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. *Ecosyst. Health Sustain.* 4, 225–239. doi: 10.1080/20964129.2018.1530054

Soazafy, M. R., Osen, K., Wurz, A., Raveloaritiana, E., Martin, D. A., Ranarijaona, H. L. T., et al. (2021). Aboveground carbon stocks in Madagascar's vanilla production landscape—exploring rehabilitation through agroforestry in the light of land-use history. *Glob. Ecol. Conserv.* 31, *e*01853. doi: 10.1016/j.gecco.2021.e01853

Soliev, I., Theesfeld, I., Abert, E., and Schramm, W. (2021). Benefit sharing and conflict transformation: Insights for and from REDD+ forest governance in sub-Saharan Africa. *For. Pol. Econ.* 133, 102623. doi: 10.1016/j.forpol.2021.102623

Somorin, O. A., Brown, H. C. P., Visseren-Hamakers, I. J., Sonwa, D. J., Arts, B., Nkem, J., et al. (2012). The Congo Basin forests in a changing climate: policy discourses on adaptation and mitigation (REDD+). *Glob. Environ. Change* 22, 288–298. doi: 10.1016/j.gloenvcha.2011.08.001

Steynor, A., Leighton, M., Kavonic, J., Abrahams, W., Magole, L., Kaunda, S., et al. (2020). Learning from climate change perceptions in southern African cities. *Clim. Risk Manage.* 27, 100202. doi: 10.1016/j.crm.2019.100202

Sultan, B. (2012). Global warming threatens agricultural productivity in Africa and South Asia. *Environ. Res. Lett.* 7, 041001. doi: 10.1088/1748-9326/7/4/041001

Swanepoel, C., Van der Laan, M., Weepener, H., Du Preez, C., and Annandale, J. G. (2016). Review and meta-analysis of organic matter in cultivated soils in southern Africa. *Nutr. Cycl. Agroecosyst.* 104, 107–123. doi: 10.1007/s10705-016-9763-4

Syampungani, S., Chirwa, P., Akinnifesi, F., and Ajayi, O. (2010). The potential of using agroforestry as a win-win solution to climate change mitigation and adaptation and meeting food security challenges in Southern Africa. *Agric. J.* 5, 80–88. doi: 10.3923/aj.2010.80.88

Talanow, K., Topp, E. N., Loos, J., and Martín-López, B. (2021). Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape. *J. Rural Stud.* 81, 203–219. doi: 10.1016/j.jrurstud.2020.10.026

Tan, X-. C., Zhu, K-. W., Sun, Y-. L., Zhao, W-. Y., and Chen, F. (2021). Bibliometric research on the *Dev.* of climate change in the BRI regions. *Adv. Clim. Change Res.* 12, 254–262. doi: 10.1016/j.accre.2021.03.010

Teketay, D., Lemenih, M., Bekele, T., Yemshaw, Y., Feleke, S., Tadesse, W., et al. (2010). *Forest Resources and Challenges of Sustainable Forest Management and Conservation in Ethiopia, Degraded Forests in Eastern Africa.* London, UK: Routledge, 31–75.

Tenaw, D., and Hawitibo, A. L. (2021). Carbon decoupling and economic growth in Africa: Evidence from production and consumption-based carbon emissions. *Resour. Environ. Sustain.* 6, 100040. doi: 10.1016/j.resenv.2021.100040

Tesfaye, A., Hansen, J., Kassie, G. T., Radeny, M., and Solomon, D. (2019). Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: a choice experiment approach. *Ecol. Econ.* 162, 157–168. doi: 10.1016/j.ecolecon.2019.04.019

Thierfelder, C., and Mhlanga, B. (2022). Short-term yield gains or long-term sustainability?–a synthesis of Conservation Agriculture long-term experiments in Southern Africa. *Agric. Ecosyst. Environ.* 326, 107812. doi: 10.1016/j.agee.2021.107812

Thornton, P. K., Jones, P. G., Alagarswamy, G., and Andresen, J. (2009a). Spatial variation of crop yield response to climate change in East Africa. *Glob. Environ. Change* 19, 54–65. doi: 10.1016/j.gloenvcha.2008.08.005

Thornton, P. K., van de Steeg, J., Notenbaert, A., and Herrero, M. (2009b). The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. *Agric. Syst.* 101, 113–127. doi: 10.1016/j.agsy.2009.05.002

Tongwane, M., Mdlambuzi, T., Moeletsi, M., Tsubo, M., Mliswa, V., Grootboom, L., et al. (2016). Greenhouse gas emissions from different crop production and management practices in South Africa. *Environ. Dev.* 19, 23–35. doi: 10.1016/j.envdev.2016.06.004

Tongwane, M. I., and Moeletsi, M. E. (2018). A review of greenhouse gas emissions from the agriculture sector in Africa. *Agric. Syst.* 166, 124–134. doi: 10.1016/j.agsy.2018.08.011

Tramblay, Y., El Adlouni, S., and Servat, E. (2013). Trends and variability in extreme precipitation indices over Maghreb countries. *Nat Haz Earth Syst Sci.* 13, 3235–3248. doi: 10.5194/nhess-13-3235-2013

Tschora, H., and Cherubini, F. (2020). Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. *Global Ecol. Conserv.* 22, *e*00919. doi: 10.1016/j.gecco.2020.e00919

Tshiala, M., and Olwoch, J. M. (2010). Impact of climate variability on tomato production in Limpopo Province, South Africa. *Afr. J. Agric. Res.* 5, 2945–2951. Available online at: https://repository.up.ac.za/bitstream/handle/2263/16115/Tshiala_Impact%282010%29.pdf?sequence=1&isAllowed=y

Urama, K. C., and Ozor, N. (2010). Impacts of climate change on water resources in Africa: the role of adaptation. *Afr. Technol. Policy Stud. Netw.* 29, 1–29. Availabloe online at: https://www.researchgate.net/profile/Nicholas-Ozor/publication/267218899_Impacts_of_climate_change_on_water_resources_in_Africa_the_role_of_adaptation/links/552e5ed20cf2acd38cb92f1a/Impacts-of-climate-change-on-water-resources-in-Africa-the-role-of-adaptation.pdf

Vågen, T. G., Lal, R., and Singh, B. (2005). Soil carbon sequestration in sub-Saharan Africa: a review. *Land degrad. Dev.* 16, 53–71. doi: 10.1002/ldr.644

van Eck, N. J., and Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84, 523–538. doi: 10.1007/s11192-009-0146-3

Vizy, E. K., and Cook, K. H. (2012). Mid-twenty-first-century changes in extreme events over northern and tropical Africa. *J. Climate* 25, 5748–5767. doi: 10.1175/JCLI-D-11-00693.1

Wang, B., Pan, S-. Y., Ke, R-. Y., Wang, K., and Wei, Y-. M. (2014). An overview of climate change vulnerability: a bibliometric analysis based on Web of Science database. *Nat. Haz.* 74, 1649–1666. doi: 10.1007/s11069-014-1260-y

Wang, Z., Zhao, Y., and Wang, B. (2018). A bibliometric analysis of climate change adaptation based on massive research literature data. *J. cleaner Prod.* 199, 1072–1082. doi: 10.1016/j.jclepro.2018.06.183

Weforum (2021). *Africa's Fastest-Growing Cities are the Most Vulnerable to Climate Change Globally*. Cologny, Switzerland: World Economic Forum (weforum.org) (accessed on December 28, 2021).

Wei, Y-. M., Mi, Z-. F., and Huang, Z. (2015). Climate policy modeling: an online SCI-E and SSCI based literature review. *Omega* 57, 70–84. doi: 10.1016/j.omega.2014.10.011

Weiland, P. (2006). State of the art of solid-state digestion–recent developments, solid-state digestion–state of the art and further randD requirements. *Gulzower Fachgespräche* 24, 22–38.

Williams, P. A., Crespo, O., and Abu, M. (2019). Adapting to changing climate through improving adaptive capacity at the local level–The case of smallholder horticultural producers in Ghana. *Clim. Risk Manage.* 23, 124–135. doi: 10.1016/j.crm.2018.12.004

Wilson, R. J., Sailley, S. F., Jacobs, Z. L., Kamau, J., Mgeleka, S., Okemwa, G. M., et al. (2021). Large projected reductions in marine fish biomass for Kenya and

Tanzania in the absence of climate mitigation. *Ocean Coast. Manage.* 215, 105921. doi: 10.1016/j.ocecoaman.2021.105921

Worldbank (2022). *CO2 Emissions (kt) - Sub-Saharan Africa | Data*. Available online at: worldbank.org (accessed on January 17, 2022).

Yang, H., Reichert, P., Abbaspour, K. C., and Zehnder, A. J. (2003). *A Water Resources Threshold and its Implications for Food Security*, Washington, D.C.: ACS Publications.

Zeng, N., and Neelin, J. D. (2000). The role of vegetation–climate interaction and interannual variability in shaping the African savanna. *J. Climate* 13, 2665–2670. doi: 10.1175/1520-0442(2000)013<2665:TROVCI>2.0.CO;2

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., et al. (2014). Climate change impacts and adaptation in South Africa. *Wiley Interdiscip. Rev. Clim. Change* 5, 605–620. doi: 10.1002/wcc.295

Zinyengere, N., Crespo, O., and Hachigonta, S. (2013). Crop response to climate change in southern Africa: a comprehensive review. *Global Planet. Change* 111, 118–126. doi: 10.1016/j.gloplacha.2013.08.010

sustainability

MDPI

Article

Emerging Trends and Knowledge Structures of Smart Urban Governance

Zaheer Allam [1,2,3,*], Ayyoob Sharifi [4,5], Simon Elias Bibri [6,7] and Didier Chabaud [1]

1 Chaire Entrepreneuriat Territoire Innovation (ETI), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France; chabaud.iae@univ-paris1.fr
2 Live + Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia
3 Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW 2007, Australia
4 Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan; sharifi@hiroshima-u.ac.jp
5 Center for Peaceful and Sustainable Futures (CEPEAS), IDEC Institute, Hiroshima University, Hiroshima 739-8529, Japan
6 Department of Computer Science, Norwegian University of Science and Technology, Sem Saelands Veie 9, NO-7491 Trondheim, Norway; simoe@ntnu.no
7 Department of Architecture and Planning, Norwegian University of Science and Technology, Alfred Getz Vei 3, Sentralbygg 1, 5th Floor, NO-7491 Trondheim, Norway
* Correspondence: zaheerallam@gmail.com

Abstract: The concept of smart cities peaked in 2015, bringing an increased influx of 'smart' devices in the form of the Internet of Things (IoT) and sensors in cities. As a result, interest in smart urban governance has become more prevalent in administrative, organisational, and political circles. This is sustained by both local and global demands for an increased contribution to the goals of sustainability through urban governance processes in response to climate change urgencies. Cities generate up to 70% of global emissions, and in light of societal pressures for more inclusivity and democratic processes, the need for sound urban governance is merited. Further knowledge on the theme of smart urban governance is required to better understand the trends and knowledge structures and better assist policy design. Therefore, this study was undertaken to understand and map the evolution of the concept of smart urban governance through a bibliometric analysis and science mapping techniques using VOSviewer. In total, 1897 articles were retrieved from the Web of Science database over 5 decades, from 1968 to 2021, and divided into three subperiods, namely 1978 to 2015, 2016 to 2019, and 2020 to early 2022. Results indicate that the overall emerging themes across the three periods highlight the need for citizen participation in urban policies, especially in relation to smart cities, and for sustained innovation for e-participation, e-governance, and policy frameworks. The results of this study can aid both researchers exploring the concept of urban governance and policy makers rendering more inclusive urban policies, especially those hosting technological and digital domains.

Keywords: smart cities; urban governance; smart governance; ICT; IoT; big data analytics; inclusivity; citizen participation; innovation; institutions; democracy

check for updates

Citation: Allam, Z.; Sharifi, A.; Bibri, S.E.; Chabaud, D. Emerging Trends and Knowledge Structures of Smart Urban Governance. *Sustainability* **2022**, *14*, 5275. https://doi.org/10.3390/su14095275

Academic Editor: Wann-Ming Wey

Received: 25 March 2022
Accepted: 22 April 2022
Published: 27 April 2022

1. Introduction

Cities across the globe have been confronted by several challenges in the past century, including climate change, rapid population growth, and exponential urbanization, amongst others. After the end of World War Two (WW2), it was reported that the economic welfare of many global residents started to grow, especially in urban areas, courtesy of sound urban governance approaches that were adopted [1]. This was prompted by an increase in opportunities for economic growth, education, socialization, and recreation in cities, thereby attracting a sizeable number of people, businesses, and government operations.

This prompted further growth of cities in terms of population, size, and Gross Domestic Products (GDP), as well as opening opportunities for the emergence of new urban areas [2]. Currently, as a result of increased activities in cities, they are home to more than 55% of the global population; by the year 2050, it is projected that they will host more than 68% of the global population [3]. Furthermore, their contribution to the global economy is expected to continue as more frontiers and opportunities continue to emerge, especially prompted by the adoption of new technologies. Additionally, the commitment of those governing cities would be very critical in spurring more growth by ensuring they seal loopholes and leakages prompted by the endemic urban challenges. Currently, cities have been argued to contribute approximately 70% of the global GDP, and this is expected to grow to more than 80% by 2050 [4]. However, it has been observed that cities also prompt numerous governance challenges at varying scales, both at local and national levels (see Bibri [5] for a detailed account and discussion).

Such challenges include provision of services, investments in capital infrastructures, collection of revenues, and financing of different projects and initiatives, among others. The adoption of technology in cities has been observed to help ease many challenges, especially with an increase in efficiency and performance of cities [6,7]. This has been made possible by the emergence of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Cloud computing, and others that have increased the potential to render various aspects of cities 'smart', a concept that cements the decades-long appeal of technology use in urban areas [8–10]. In this strand of smart urbanism, governance denotes the capacity of employing technology and innovation as a set of intelligent and adaptive acts for facilitating decision making, implementing policies and tracking their effects, developing advanced organisational structures, and dealing with substantive challenges. Smart urban governance is about utilising and harnessing the innovative potential and significant role of advanced Information and Communication Technology (ICT) in the functioning of smart cities (e.g., [5,11–14]) in terms of their planning and management. Its emergence has made local governments in many cities rethink their functions in regard to the use of smart technologies in upgrading administrative systems, improving institutional structures, and optimising organisational processes. This involves streamlining urban operations by seamlessly integrating them into manageable networks instead of maintaining disjointed systems, enhancing stakeholders' collaboration capabilities, increasing the capacity to handle urban challenges, and enhancing decision making based on evidence-based approaches. This has become possible due to the flowing-torrent of data produced from different urban frontiers, coupled with its analytical power. This in turn aids in extracting deep insights for a wide range of uses pertaining to urban management and urban policy.

While the adoption of smart technologies in urban governance is not ultimately perfect, as there have been pitfalls and risks reported in different cities in relation to a variety of areas, it nevertheless has numerous advantages and benefits that are accrued. For instance, it was recorded that smart urban governance has the potential to help save each urban resident approximately 100 h per year, which when monetized, could translate to approximately $1377 per person per year in America, or £904 in the United Kingdom [15]. This, however, is much less significant than other direct benefits such as improved liveability status [16–18], improved emergency preparedness and response [19], and improved infrastructural development [20] thanks to emerging technologies. Smart urban governance is further seen to be instrumental in the achievement of urban sustainable agendas, as captured in the Sustainable Development Goal 11 [21]. Regarding this, Tomor et al. [22] note that different smart technologies have made it possible for local governments to partner with citizens in finding solutions to endemic environmental challenges. This includes participation in making housing projects smarter, adoption of smart grids, smart parking, responsive waste management, regeneration of urban green spaces, and others.

With the diverse potential that smart urban governance has unlocked, many cities across the globe are now turning toward the adoption of different technologies to enhance various urban dimensions. However, this has opened a plethora of issues relating to

privacy [23–26], data security [24,27], data ownership [28], and personal security [24], amongst others. From a wide range of data, those concerns are legitimate and have capacities to influence the success of smart technologies' deployment in cities.

In light of the above information, this study seeks to explore, through a bibliometric analysis, the various publications that have been made concerning adoption of smart technologies, especially in the governance of cities. While several bibliometric studies touching on smart cities exist, only one [29] has been identified that directly touches on the subject matter of urban governance, being key in the smart city discourse [30–32]; hence, this study seeks to increase the knowledge on this topic by incorporating works that arose immediately after and during the height of COVID-19. The rationale is that it is possible that the number of publications continues to increase as more attention is focused on adoption of smart technologies in cities, and specifically to the need to further ponder and include societal factors [16,33]. Furthermore, with concerns such as monetization of data by third party corporations and start-ups contracted by local governments to manage the massive data being generated in cities, it becomes paramount to analyse the research interests and terminologies that are emerging. This way, the analysis will help guide researchers and other stakeholders seeking to understand the dynamics in the academic realm concerning the emergence and widespread acceptability and appeal of the smart city concept in respect to urban governance. This can ultimately lead to better-informed decisions and enhanced urban policies. In addition, there is still a lack of research on the knowledge structure and trends of smart urban governance over different time periods. The performance of this analysis is the main novelty of this study, and provides interested stakeholders with a better understanding of the evolution of this field. Therefore, the main objectives of this study were to:

- Understand the major thematic focus areas of smart urban governance;
- Discuss how they have evolved over time; and
- Highlight authors, sources, and publications that have been notably influential.

Throughout the course of addressing the objectives set in this study, several observations were made on:

- The time periods in which research on smart urban governance gained maximum attention and the possible reasons as to why;
- How the field of smart urban governance evolved thematically over time; and
- Some of the contributing factors to the growth of this field.

In order to respond to the above objectives, this article is structured as follows. Section 1 covers the Introduction and background information. It is followed by Section 3, which entails a detailed Materials and Methodology section that comprehensively highlights all the approaches, materials, tools, and steps that were adopted to attain observations satisfying the objectives. Section 3 subsequently covers the literature review related to this study. The methodology section is followed by a detailed *Result* section (Section 4) that captures and presents all the results obtained after running the available data in VOSviewers software. The results are presented in the form of graphs, tables, and relationship diagrams. The analysis of the results and their implications is presented in the Discussion section, which is succeeded by a Conclusion section.

2. Background

Smart city governance is a new approach to urban policy, planning, and management that is able to solve the emerging challenges of urban areas while ensuring sustainability. It has emerged as a result of the innovative potential and growing role of advanced ICT in the functioning of smart cities (e.g., [10,32–35]). Several literature reviews have been carried out on the topic of smart urban governance, approaching the subject from a variety of perspectives. In one of the early literature reviews conducted on the topic, Meijer and Bolívar [34] attempted to fill the gap pertaining to the conceptual understanding of smart urban governance. Accordingly, the authors explored the concept of smart urban

governance both theoretically and empirically to build a research model. Inductively, they identified various categories within the key dimensions of smart urban governance: defining elements, aspired outcomes, and implementation strategies. The categories were then refined based on an empirical investigation on the dominant perceptions of practitioners of these dimensions. Using a slightly different approach to the topic to fill the gap of a rather systematic understanding of the different components of smart urban governance and their measurement metrics, envisaged outcomes, and influencing contextual factors, Ruhlandt [36] proposed conceptual insights and generated a research scheme, and then used this for an extensive discussion of the literature instead. The author revealed substantial variances in contextual factors, measurement techniques, and outcomes among the concepts of smart city governance, in addition to the differences in its definitions. To expand their previous work, Meijer and Bolívar [34] offered another review on the topic. In this light, the authors endeavoured to bring some structure to the debate by analysing a corpus of 51 publications and mapping their variation. The authors demonstrate key differences in the emphasis of these publications with respect to the key dimensions addressed in their previous paper, namely (1) smart technology, smart people, or smart collaboration; (2) better outcomes or a more open process as the legitimacy claim for smart city governance; and (3) a transformative or incremental perspective on changes in urban governance. They provide several arguments, highlights, suggestions, and contributions involving conceptual, practical, research, and policy implications. The two studies by the same authors complete each other in terms of analysis and findings with the aim to enhance the conceptual and practical foundations of smart urban governance.

The literature review performed by Pereira et al. [31] focuses on smart governance as an emerging domain of study and provides further insights into the definition and conceptualisation of smart governance and its relationships with e-government. The authors show that smart government can be a basis for developing smart governance using ICT for governing purposes to improve decision-making through better collaboration among different stakeholders. They also highlight the role of ICT-based tools in increasing citizen engagement and participation and supporting the development of new governance models for smart government, among others. Expanding on this work, Tomor et al. [22] provide a systematic review on smart governance as technology-enabled collaboration between citizens and local governments to advance sustainable development. The authors focus on the relationships between ICT-enabled citizen–government collaboration and sustainable urban development and how contextual circumstances influence these related elements. The latter connects well with the review conducted by Ruhlandt [36], but from a smart governing perspective. However, the authors show that empirical evidence for the alleged sustainability benefits is sparse, and the emerging picture is ambiguous, as it reports both positive and negative effects as it regards the social sustainability achievements of smart governance. This review is part of a large research project that assesses the value of ICT for engaging citizens in the governance of sustainable cities. One of the conclusions drawn in this review is that smart governance, in the sense of ICT-enabled government–citizen collaboration to advance urban sustainability, is still rare. Despite the increasing variety of collaboration-based digital instruments, a one-way information supply in citizen–government interactions tends to dominate. Moreover, although governments promote online and offline citizen engagement and civic empowerment, in practice they do not encourage deliberation or any broad-based public–civil interactions. Therefore, ICT-supported government–citizen cooperation for collectively shaping public matters seldom occurs. Rather, as concluded in a review carried out by Bibri [12] on smart sustainable cities, what smart governance entails and the way it functions raises several critical questions, including whether the policy and governance of smart sustainable cities of the future will become too technocentric and technocratic, respectively, and also with regard to other aspects of social and environmental sustainability. In their recent review paper, however, Przeybilovicz and Cunha [37] put an emphasis on government characteristics to achieve smart urban governance from internal to external transformation. Therefore,

the authors provide a systematic literature review based on 36 publications and merge this with the existing e-government literature on critical success factors for adopting IT in the public sector. In contrast to the two previous reviews, the authors shed light on the key organizational attributes that can pave the way for the transition from government to smart urban governance. They identify three main characteristics: (1) local governance related to the nature of the relationship among key stakeholders; (2) government assets as to funding, technology, and human capital; and (3) local government management and strategy and local public administration positioning. As a conclusion, unlike e-government, which focuses on transforming the social organization internally, smart governance focuses on transforming the social organisation internally and externally.

Overall, while new ICT-based solutions are constantly emerging to help city governments improve their institutional and organisational structures, processes, and practices, these solutions are largely associated with smart cities and their strategies and objectives. Moreover, review studies tend to address either conceptual or practical issues while espousing different approaches to the topic of smart urban governance. However, there is a lack of the theoretical basis and empirical evidence required to holistically evaluate the potential effects of the transformative processes within smart governance in connection with the practices, operations, and institutions of smart cities. Furthermore, the topic of sustainability is still underexplored, both theoretically and empirically, with regard to its social and environment dimensions, as well as to the integration of these with the economic dimension of sustainability. Notably, existing literature reviews on smart urban governance are associated with some limitations in terms of exploring and analysing only a limited number of publications on the topic. This bibliometric analysis involves large volumes of scientific data and allows us to unpack the evolutionary nuances of the field of smart urban governance in regard to its emergence, insertion, functioning, and evolvement as a discourse facilitated by politics. These aspects, the driving forces behind the expansion and prevalence of smart urban governance, and other nuances are missing from the previously overviewed review papers. In addition, this bibliometric analysis sheds light on the emerging areas in the domain of smart governance beyond its own. More explicitly, it fills the gap pertaining to the knowledge structure and trends of smart urban governance over different periods in order to enhance the understanding of the evolution of the field.

3. Materials and Methods

This research was conducted in two major steps. The first step involved scope definition (development of search string) and literature search and selection. The second step was conducting bibliometric analysis using VOSviewer and interpreting the outputs of the bibliometric analysis. These are shown in Figure 1 and will be further explained below.

Input data for bibliometric analysis are the bibliographic details of academic publications that were obtained from the Web of Science (WoS) [38,39]. Among different databases that archive academic research (e.g., Scopus [40,41] and Dimensions [39,42]), WoS was selected due to its reputation for indexing quality research related to the topic of this study and since it provides detailed bibliographic information necessary for accurate analysis using the bibliometric software (i.e., VOSviewer [43–45]). We acknowledge that this is a limitation of this study, as a more comprehensive analysis would require including literature from other databases as well as grey literature. However, as we have analysed a large number of articles, we believe the results are sufficiently reasonable and representative. We designed a broad-based search string to include as many articles as possible relevant to smart urban governance in the analysis. The search string (see the Appendix A) is a combination of different terms related to smartness, governance, and cities. We searched for the relevant articles in all citation indexes of the WoS (i.e., A&HCI, ESCI, SCI-EXPANDED, SSCI) on 15 January 2022. The search period was unlimited (i.e., all research published until 15 January 2022), but we only searched for articles, review articles, proceeding papers, book chapters, editorial materials, and data papers. This literature search returned 2001 articles. After screening titles and abstracts of these documents, 1897 articles that were related to

smart urban governance were selected and their associated data (i.e., 'Full Record and Cited References') were downloaded for bibliometric analysis.

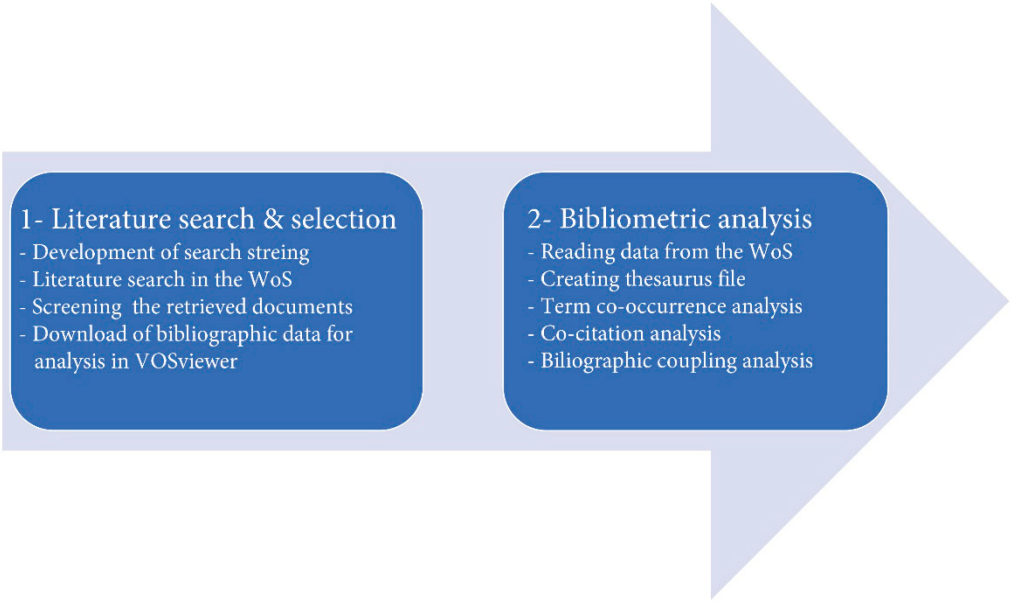

Figure 1. Major steps taken for the purpose of this study.

Over the past two decades, several software tools for bibliometric analysis have been developed [44]. These include VOSviewer, SciMAT, and CiteSpace. Despite their differences, all these tools provide means to understand the overall structure of a research field and the complex interactions between different variables related to academic papers (e.g., keywords, references, authors, journals, etc.). Here we used VOSviewer, as its interface is more user friendly and its graphic outputs are more suitable for interpretation [45–48]. VOSviewer is a freely available Java application (https://www.vosviewer.com, (accessed on the 1 December 2021)). Free access to user manuals and demo projects is provided by the developers and interested readers are referred to the tool manual for step-by-step description of the different steps for analysis. We used VOSviewer to conduct term co-occurrence analysis (using the 'full counting' counting method and setting 'all keywords' as the unit of analysis), citation (setting 'documents' as the unit of analysis), co-citation (using the 'full counting' counting method, and setting 'cited references', 'cited sources', and 'cited authors' as units of analysis), and bibliographic coupling (using the 'full counting' counting method, and setting 'organizations' and 'countries' as units of analysis) [28]. It should be noted that 'fractional counting' can also be used to create the maps using VOSviewer. We have used 'full counting', as its outputs are easier to interpret [48]. We suggest that a similar analysis using fractional counting could also be done in the future to compare the outputs. The term co-occurrence analysis was used to identify the most dominant terms and understand how they are linked to other terms related to smart urban governance. Also, terms that co-occur frequently provide information about major thematic research clusters. It should be mentioned that, as different variants of a term may exist (e.g., Information and Communication Technologies and ICT), before conducting the term co-occurrence analysis, a thesaurus file was created and added to the VOSviewer database to avoid separate counting of synonyms.

In Section 4, outputs of the analyses are shown in a graph format. In each case, the node size is proportional to the frequency and link width is proportional to the strength of connection between two nodes. For instance, in the case of term co-occurrence analysis, the node size is proportional to the number of times a term has co-occurred with other terms and the link width indicates the strength of connection between two terms. The frequently co-occurred terms establish clusters that represent different thematic research areas.

As one of the objectives of this study was to find out how the field has evolved thematically over time, we divided the study period into three sub-periods. This was based on important milestones that could have influenced the evolution of the field. As different international policy frameworks related to cities (e.g., Agenda 2030 and the New Urban Agenda) were adopted in 2015, it was selected as one of the milestones. Additionally, given the significant impacts of the COVID-19 pandemic on cities and its effects on the acceleration of digitalization, the post-pandemic period was considered as a separate sub-period. More sub-periods could have been considered before 2015; however, as can be seen in Section 3, the pace of publications was slow until then, not warranting further sub-periods. Accordingly, the following sub-periods were considered: until 2015, 2016 to 2019, and 2020 until now. Term co-occurrence analyses were conducted for each sub-period to understand their thematic research focus and see how it has evolved over time.

To find out what authors, journals, and references have made more contribution to the development of the field, we used co-citation analysis. Co-citation refers to the link between two documents that are both simultaneously cited by another document [28]. Based on this definition, cited references of the selected articles are also considered in the co-citation analysis. Bibliographic coupling is another analysis that can be used to understand countries and institutions that have made more contributions to the development of the field. "A bibliographic coupling link is a link between two items that both cite the same document" [47].

4. Results

This section presents the results obtained after running the data in VosViewer. The results are ordered in different thematic areas, including publication trends, most influential journals and authors, and the overall thematic focus for each of the three periods under which the publication years were categorized.

4.1. Publications Trends

From the literature, the quest to transform cities with the use of data came into light since the 1970s, when Los Angeles (first data used in 1974) became the first urban centre to experiment with this [49]. However, it was not until the emergence of the fourth industrial revolution that the concept started to attract substantial attention. This is confirmed in Figure 2 below, showcasing that between 1978 and 2015, only 220 publications touching on smart urban governance had been published. Even during this first phase of publications, it is evident that researchers' attention to smart technologies in cities was drawn as from 2004 and grew steadily until 2015, when substantial interest was clearly noticed. The drive to investigate, research, and publish on smart urban governance during the 2000s was being influenced by activities by large IT corporations such as Cisco and IBM, which were the main pioneers in concentrating on the usage of information technology in cities [30]. For instance, in 2005, Cisco became the first corporation to invest in research and development (R&D), committing $25 million [50]. In 2009, IBM committed $50 million to the Smarter Cities campaign, aimed at influencing cities to embrace technology in their planning to increase urban efficiency and performance [51]. By 2015, the concept had become almost mainstream in most countries, with cities slowly embracing different aspects of smart cities.

Between 2015 and 2019, the number of publications increased substantially, and this could be attributed to the increased acceptance of the smart city concept in different urban fabrics. Furthermore, during this period, many technologies such as AI, IoT, Machine Learning, and others started to gain traction in cities, as smart components such as sensors, cameras, smart mobile devices (smartphones), wearables, and others continued to increase globally, thereby prompting an increase in data generation and its subsequent analysis [32]. With the diversification of smart components, numerous terminologies, areas of research interest, and demand for publications on this topic increased, prompting an increase in research works published.

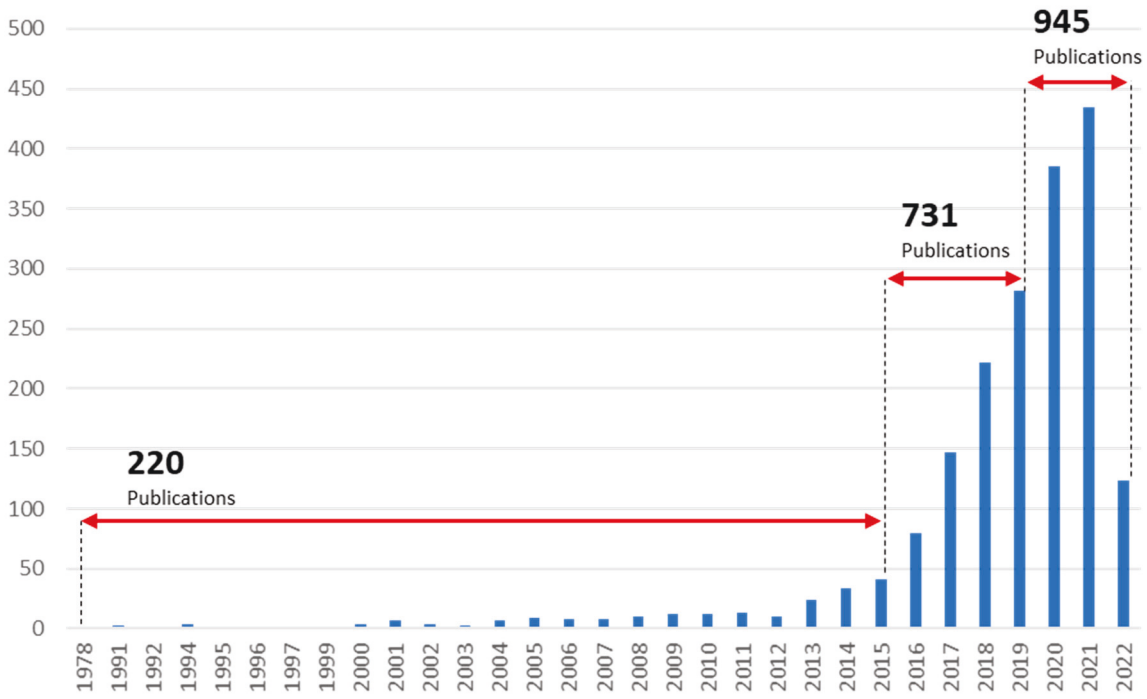

Figure 2. Number of publications on 'Smart Urban Governance' between 1978 and early 2022.

Between 2020 and 2022, despite the outbreak of COVID-19 that brought about an unprecedented change in normal activities globally, the number of publications increased even further. This could be attributed to the role technology played in helping urban residents, governments, and stakeholders in the health sector to identify the coronavirus and craft strategies to combat its spread. During this period, despite the lockdowns, controlled movement of people, and other health measures instituted, people continued to undertake some activities, especially through the work-from-home clarion. Such influence of technology may have prompted even more interest among researchers, including how technology could further be deployed in the future to help overcome similar pandemics in urban fabrics while still allowing cities to engage in their primary activities. This is part of a prevailing narrative, but there are other studies and perspectives on the topic of COVID-19 that have criticised the use of surveillance technologies in terms of their negative implications on society and civic values in the context of smart urbanism (see, e.g., [52–55]).

4.2. Influential Journals

Between the period in relevance to this study (1978–2022), a wide range of journals and publications have emerged focusing on different aspects of smart urban governance, as depicted in Table 1 below. While the table only captures 20 of the most influential journals and publications, that does not suppress the fact that there are other numerous publishing companies concentrating on research works touching on the 'smartness' of governance features. In Figure 3 below, the two most influential journals are *Cities* and *Government Information Quarterly*, with total link strengths of almost 29,900 and 21,297, respectively. Of interest is that journals with the highest Impact Factor are not necessarily the most influential, as some publish research particularly on issues of cities and governance, with their scope including some of the most influential research areas that have emerged over the entire period of study.

Table 1. Top 40 Most Influential Journals.

Title	Publication	Year	Authors
A Ladder of Citizen Participation	Journal of the American Institute of Planners	1969	Arnstein [56]
Internet of Things for Smart Cities	IEEE Internet of Things Journal	2014	Zanella et al. [57]
Smart Cities in Europe	Journal of Urban Technology	2011	Caragliu et al. [58]
Will the real smart city please stand up?	City	2008	Hollands [59]
Smart city as urban innovation: Focusing on management, policy, and context	International conference on theory and practice of electronic governance	2011	Nam and Pardo [60]
Understanding Smart Cities: An Integrative Framework	Hawaii International Conference on System Sciences	2012	Chourabi et al. [61]
Smart cities: Ranking of European medium-sized cities	Smart cities: Ranking of European medium-sized cities	2007	Giffinger and Pichler-Milanović [62]
Smart cities: Big data, civic hackers, and the quest for a new utopia	WW Norton & Company	2013	Townsend [63]
Smart Cities of the Future	The European Physical Journal Special Topics	2012	Batty et al. [64]
Current trends in Smart City initiatives: Some stylised facts	Cities	2014	Neirotti et al. [65]
Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation	The Future Internets	2011	Schaffers et al. [66]
From e-government to we-government: Defining a typology for citizen coproduction in the age of social media	Government Information Quarterly	2012	Linders [67]
Foundations for Smart Cities	IBM Journal of Research and Development	2010	Harrison et al. [68]
Is there anybody out there? The place and role of citizens in tomorrow's smart cities	Futures	2014	Vanolo [69]
A Smart City Initiative: the Case of Barcelona	Journal of the Knowledge Economy	2013	Bakıcı et al. [70]
Governing the smart city: a review of the literature on smart urban governance	International Review of Administrative Sciences	2016	Meijer and Bolívar [34]
Modelling the smart city performance	Innovation: The European Journal of Social Science Research	2012	Lombardi et al. [71]
What are the differences between sustainable and smart cities?	Cities	2017	Ahvenniemi et al. [72]
Big data, smart cities and city planning	Dialogue in Human Geography	2013	Batty [73]
Smart and Digital City: A Systematic Literature Review	Springer	2014	Coccia [74]
Conceptualizing smart city with dimensions of technology, people, and institutions	International Digital Government Research Conference: Digital Government Innovation in Challenging Times	2011	Nam and Pardo [75]
Smart cities as corporate storytelling	Cities	2014	Söderström et al. [76]
The role of big data in smart city	International Journal of Information Management	2016	Hashem et al. [77]
Smart city policies: A spatial approach	Cities	2014	Angelidou [78]
Smart sustainable cities of the future: An extensive interdisciplinary literature review	Sustainable Cities and Society	2017	Bibri and Krogstie [10]
Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco	Technological Forecasting and Social Change	2014	Lee et al. [79]
Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart	Cities	2018	Silva et al. [80]
The 'actually existing smart city'	Cambridge Journal of Regions, Economy and Society	2015	Shelton et al. [81]
Critical interventions into the corporate smart city	Cambridge Journal of Regions, Economy and Society	2015	Hollands [82]
Smart cities: A conjuncture of four forces	Cities	2015	Angelidou [6]
Making sense of smart cities: addressing present shortcomings	Cambridge Journal of Regions, Economy and Society	2014	Kitchin [83]
Programming Environments: Environmentality and Citizen Sensing in the Smart City	Environment and Planning D: Society and Space	2014	Gabrys [84]
New urban utopias of postcolonial India: 'Entrepreneurial urbanization' in Dholera smart city, Gujarat	Dialogues in Human Geography	2015	Datta [85]
Being a 'citizen' in the smart city: up and down the scaffold of smart citizen participation in Dublin, Ireland	Geo Journal	2019	Cardullo and Kitchin [86]
The governance of smart cities: A systematic literature review	Cities	2018	Ruhlandt [36]

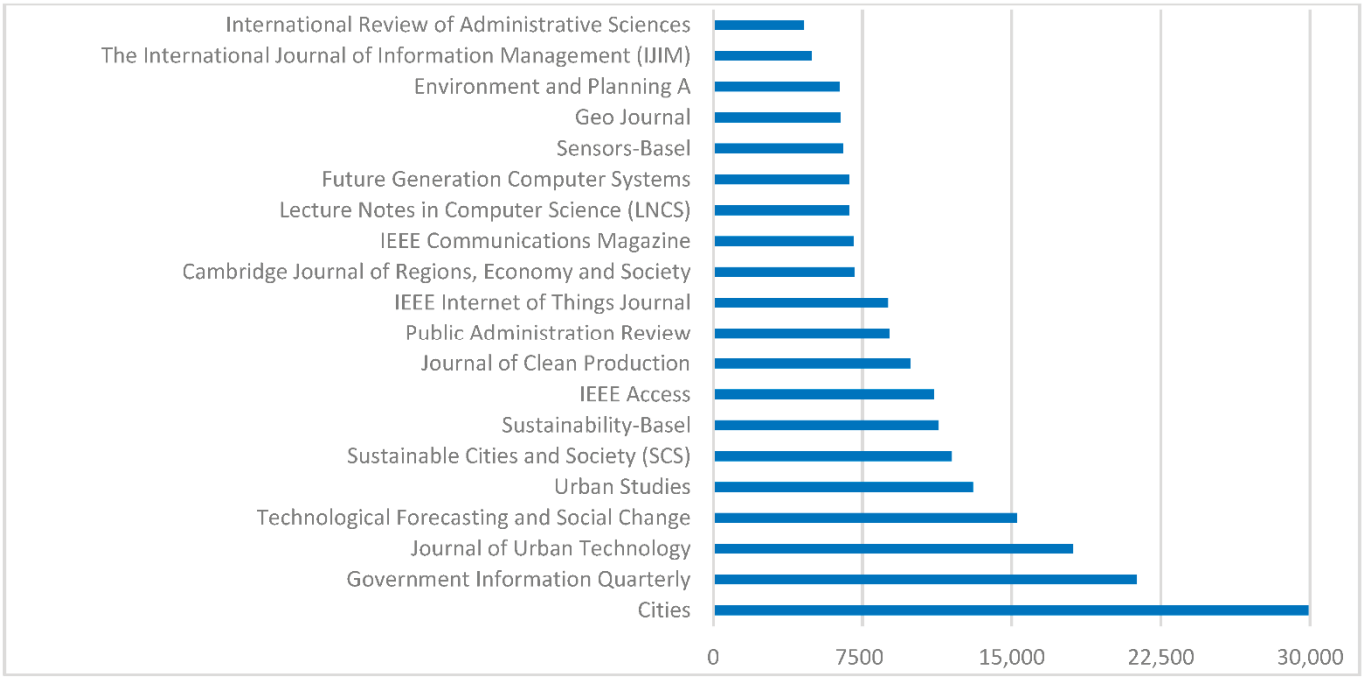

Figure 3. Top 20 most influential journals, where the x-axis shows the link strength.

Figure 4 below depicts the different influential journals and publications, including the clusters under which they fall. The publications are clustered into four distinct categories highlighted by blue, red, green and yellow colours. The red cluster comprises journals focusing more on urban sustainability, and it is evident that these subjects are very popular with most researchers, as most journals in this cluster have high linkages with the rest of the categories. The blue cluster comprises journals focusing more on public management and administration in cities. It is evident that the journals publishing works on governments and public administration are very popular, with high linkages to journals with a scope touching on cities and their sustainability agendas. The green cluster comprises journals focusing more on different aspects of Information Technology (IT) and their applicability in different facets of cities. Finally, the yellow cluster encompasses journals focusing on geographical aspects of cities.

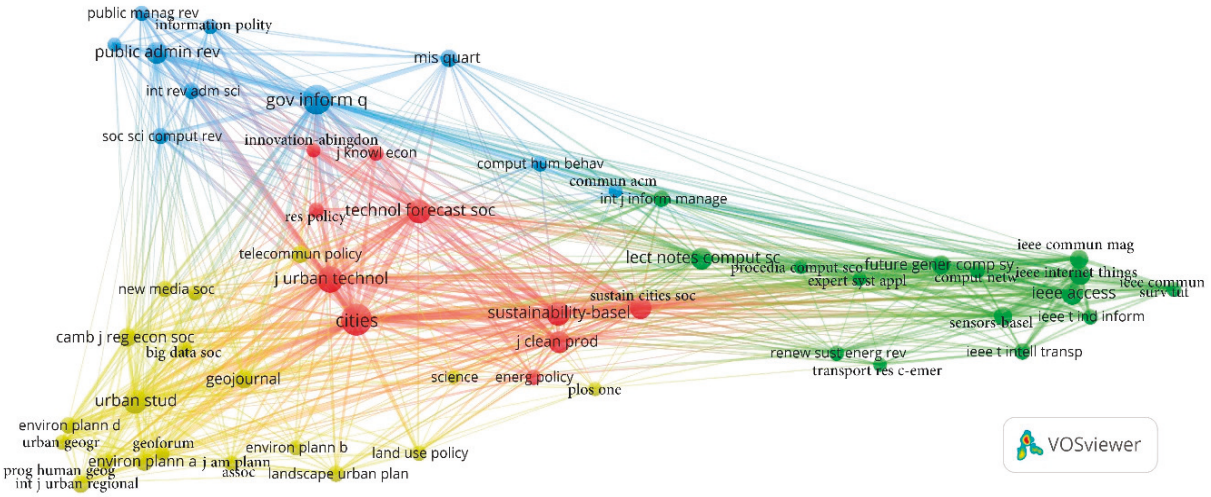

Figure 4. Most influential journals and publications. Illustration by authors.

The different clusters showcase the progress that has been made in publications focusing on smart cities. As highlighted in Figure 2 above, research works and research interests on technology use in urban areas has been progressive, with substantial momentum observed in 2015, and an exponential growth in 2020 and 2021. From the literature, it is observed that the aspect of 'smartness' in cities was focused on specific components of cities; that is, the administration aspect with the aim being to increase efficiency and performance. However, as more smart-based technologies emerged, the 'smartness' aspect gained traction in other urban dimensions such as urban mobility, energy production and consumption, sustainability, socioeconomic dimensions, and others. As a result, research works and publications expanded their scopes from administration to include these other aspects; hence, affirming why more influential publications are emerging, as attention on the smart city concept continues to grow.

4.3. Influential References

From the literature, it was highlighted that the quest to have smart cities began in the 1970s, and this quest materialized in a notable way in 2005, when large ICT corporations, driven by profit-making agendas [26], began to increase their attention and commitment toward the realization of this objective. The growth and interest amongst academics and researchers have likewise been increasing, as highlighted in Figure 2, capturing the number of publications between 1970 and 2022. At the heart of these publications are dedicated authors and researchers whom, as depicted in Table 2 below, have published ground-breaking works which emerge as the most cited compared to others.

As highlighted in Figure 5 below, those different influential references can be clustered into two categories characterised by the colours red and yellow. The red category encompasses all the references focusing on general contributions to sustainability, including aspects such as air pollution and economic growth. References in the yellow category, however, focused on aspects relating to urban planning and urban studies. From the figure, it is noticeable that most of the influential authors were more interested and focused on issues pertaining to sustainability, and this could be attributed to the fact that most cities, as noted from the literature, have been cited to have the potential to contribute substantially discourses perpetuating a bid to address the challenges of climate change.

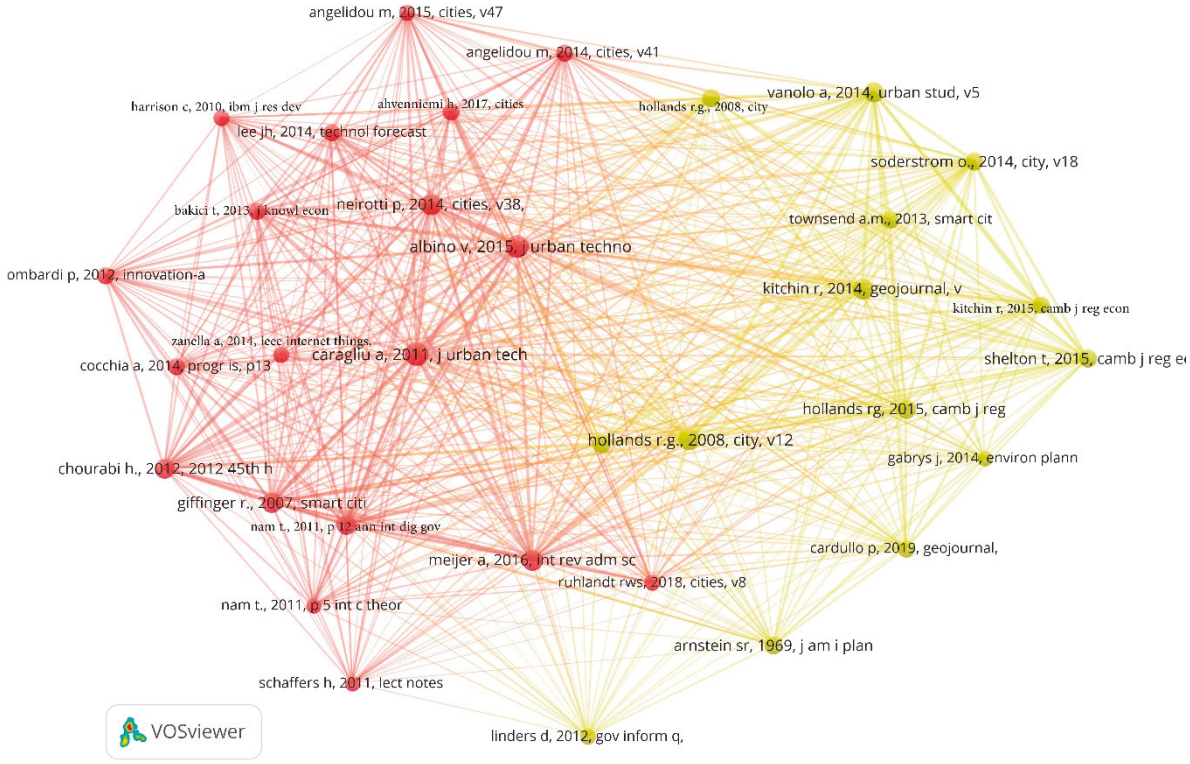

Figure 5. Most influential references. Illustration by authors.

Table 2. Top 40 Most Influential References.

Title	Publication	Year	Citations	Authors
A Ladder of Citizen Participation	Journal of the American Institute of Planners	1969	26,258	Arnstein [56]
Internet of Things for Smart Cities	IEEE Internet of Things Journal	2014	5564	Zanella, Bui, Castellani, Vangelista and Zorzi [57]
Smart Cities in Europe	Journal of Urban Technology	2011	4791	Caragliu, Del Bo and Nijkamp [58]
Will the real smart city please stand up?	City	2008	3494	Hollands [59]
Smart city as urban innovation: Focusing on management, policy, and context	International conference on theory and practice of electronic governance	2011	2979	Nam and Pardo [60]
Understanding Smart Cities: An Integrative Framework	Hawaii International Conference on System Sciences	2012	2939	Chourabi, Nam, Walker, Gil-Garcia, Mellouli, Nahon, Pardo and Scholl [61]
Smart cities: Ranking of European medium-sized cities	Smart cities: Ranking of European medium-sized cities	2007	2791	Giffinger and Pichler-Milanović [62]
Smart cities: Big data, civic hackers, and the quest for a new utopia	WW Norton & Company	2013	2702	Townsend [63]
Smart Cities of the Future	The European Physical Journal Special Topics	2012	2543	Batty, Axhausen, Giannotti, Pozdnoukhov, Bazzani, Wachowicz, Ouzounis and Portugali [64]
Current trends in Smart City initiatives: Some stylised facts	Cities	2014	2273	Neirotti, De Marco, Cagliano, Mangano and Scorrano [65]
Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation	The Future Internets	2011	2184	Schaffers, Komninos, Pallot, Trousse, Nilsson and Oliveira [66]
From e-government to we-government: Defining a typology for citizen coproduction in the age of social media	Government Information Quarterly	2012	2092	Linders [67]
Foundations for Smart Cities	IBM Journal of Research and Development	2010	1527	Harrison, Eckman, Hamilton, Hartswick, Kalagnanam, Paraszczak and Williams [68]
Is there anybody out there? The place and role of citizens in tomorrow's smart cities	Futures	2014	1390	Vanolo [69]
A Smart City Initiative: the Case of Barcelona	Journal of the Knowledge Economy	2013	1355	Bakıcı, Almirall and Wareham [70]
Governing the smart city: a review of the literature on smart urban governance	International Review of Administrative Sciences	2016	1308	Meijer and Bolívar [34]
Modelling the smart city performance	Innovation: The European Journal of Social Science Research	2012	1201	Lombardi, Giordano, Farouh and Yousef [71]
What are the differences between sustainable and smart cities?	Cities	2017	1130	Ahvenniemi, Huovila, Pinto-Seppä and Airaksinen [72]
Big data, smart cities and city planning	Dialogue in Human Geography	2013	1036	Batty [73]
Smart and Digital City: A Systematic Literature Review	Springer	2014	975	Coccia [74]
Conceptualizing smart city with dimensions of technology, people, and institutions	International Digital Government Research Conference: Digital Government Innovation in Challenging Times	2011	965	Nam and Pardo [75]
Smart cities as corporate storytelling	Cities	2014	949	Söderström, Paasche and Klauser [72]
The role of big data in smart city	International Journal of Information Management	2016	928	Hashem, Chang, Anuar, Adewole, Yaqoob, Gani, Ahmed and Chiroma [77]
Smart city policies: A spatial approach	Cities	2014	910	Angelidou [78]
Smart sustainable cities of the future: An extensive interdisciplinary literature review	Sustainable Cities and Society	2017	895	Bibri and Krogstie [10]
Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco	Technological Forecasting and Social Change	2014	882	Lee, Hancock and Hu [79]
Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart	Cities	2018	831	Silva, Khan and Han [80]
The 'actually existing smart city'	Cambridge Journal of Regions, Economy and Society	2015	780	Shelton, Zook and Wiig [81]
Critical interventions into the corporate smart city	Cambridge Journal of Regions, Economy and Society	2015	776	Hollands [82]
Smart cities: A conjuncture of four forces	Cities	2015	744	Angelidou [6]
Making sense of smart cities: addressing present shortcomings	Cambridge Journal of Regions, Economy and Society	2014	743	Kitchin [83]
Programming Environments: Environmentality and Citizen Sensing in the Smart City	Environment and Planning D: Society and Space	2014	731	Gabrys [84]
New urban utopias of postcolonial India: 'Entrepreneurial urbanization' in Dholera smart city, Gujarat	Dialogues in Human Geography	2015	682	Datta [85]
Being a 'citizen' in the smart city: up and down the scaffold of smart citizen participation in Dublin, Ireland	Geo Journal	2019	638	Cardullo and Kitchin [86]
The governance of smart cities: A systematic literature review	Cities	2018	496	Ruhlandt [36]

From the table, the most influential reference was authored by Arnstein [56], advancing the thematic aspect of public participation, which has become a cornerstone in the pursuit of the smart city concept. According to the author, citizens' power in contributing and shaping decisions can only be realised if they are actively engaged and allowed to participate at different levels. The second most influential reference in respect to the number of citations (5564) was authored by Zanella, Bui, Castellani, Vangelista, and Zorzi [57] in 2014, and their attention was on the impacts of the 'Internet of Things for Smart Cities'. From the literature, during this period, the number of IoT devices targeted on cities were increasing (increased by 20% between 2013 and 2014) to reach 16 billion products. Further, a projection during that period was that by 2020, the number of smart things would increase to over 40 billion products [87]; hence, supporting interest in this field. Overall, despite most of the influential references, as depicted in Figure 5, being skewed toward sustainability, it is evident from the number of citations, as shown in Table 2, that most of researchers and publications were interested in understanding the different aspects of smart cities.

4.4. Influential Authors

The subject matter of smart urban governance is emotive, as it does not only touch on the political aspirations, but also influences resources allocation in cities, economic growth, and security and privacy of residents and their properties, among other issues. As a result, as showcased in Figure 6 below, over the study period (1970–2022) the number of authors with interests on the aspect of smart cities, and by extension, smart urban governance, have continued to increase. These have been pursuing different issues, as highlighted in Figure 6, where different colouration has been adopted to categorize clusters. The red cluster encompasses authors focused on sustainability and how this is being applied in smart cities. The blue cluster comprises authors whose work majors on policies, frameworks, and structures of smart cities and how this could help in achieving smart urban governance. The yellow and green clusters comprise the most influential authors, as captured in Table 2 above. Those in the yellow cluster have published most works focusing on the general aspects of smart cities, while those in the green cluster are focused more on smart urban governance and how this impacts aspects such as citizen participation and city performance. They have also focused on the possible shortcomings that could be experienced in smart cities where aspects of smart governance are fully considered.

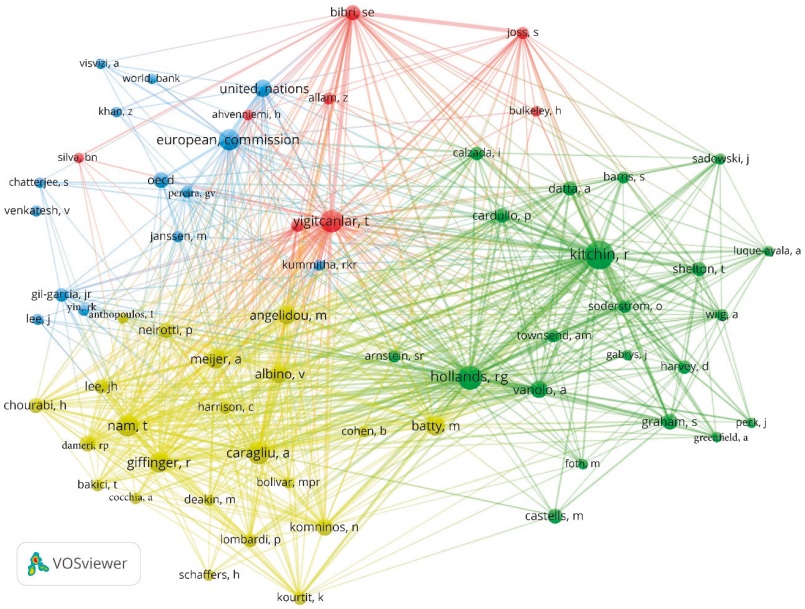

Figure 6. Most influential authors in the field of smart urban governance. Illustration by authors.

The categorization of influential authors on the subject matter of the smart city demonstrates the importance of the use of technology to enhance urban dimensions. The aspect of urban governance is critical, and this could explain why it has attracted such a sizeable interest from authors. In particular, from the different terminologies captured in the diagram, it is almost impossible to have successful smart cities if governance dimensions are not fully addressed. This is affirmed by how the different terminologies are closely linked together. From the literature, the success of smart urban governance, however, requires the cooperation of different stakeholders; hence, the need for sound policies, frameworks, and protocols. Considering this, it would be possible to pursue other related aspects such as sustainability agendas and improve and address the social and economic dimensions including areas such as liveability and others.

4.5. Thematic Focus Areas and Their Transition

This section focuses on the different themes and topics that researchers have favoured regarding aspects of urban governance within the entire period of the study. The section is ordered into different subheadings, each addressing a specific time period. An overall look at the general thematic focus is succeeded by subsections on each of the different periods.

4.5.1. Overall Thematic Focus and Structure

The quest to transform cities using data-driven approaches has been present since the 1970s; as showcased in the previous sections, the number of publications, references, and authors on different thematic issues have been on the rise. This is captured in Figure 7 (below), which highlights different dimensions that have been pursued since it became apparent that it was possible to influence urban governance, urban sustainability, urban planning, and other aspects using ICT. In Figure 7, different themes are categorized in four distinct clusters symbolized by the colours red, yellow, blue, and green. The red cluster focuses on issues related to urban governance and the subsequent benefits derived from its adoption in cities. Such issues include the sustainability agenda, economic growth, resilience, improved liveability status in cities, and others. The blue cluster captures issues related to the digital divide, political dimension, and related aspects such as policy formulation and crafting of different frameworks pertinent to the application of smart agendas in cities. The green cluster captures themes related to smart cities and smart technologies while the yellow cluster captures aspects of digitalisation, smart governance, and urban residents and their participation in smart agendas, amongst others.

The graphical representation of the different smart themes in cities illustrated in Figure 7 rightly coincides with findings from the current literature on the smart cities concept, mainly smart governance, and its influence on cities. From the literature, it is evident that smart governance plays significant roles in the global, regional, national, and local economies. It plays significant roles in influencing how cities can handle matters such as climate change, economic growth, and provision of services to residents and improve social welfare of the residents. As illustrated in Figure 7 (above), it is evident that during the entire period, the sustainability agenda has attracted substantial attention. From the literature, while policies on these emanate from global top leadership summits and transpire from agendas, it is local governments that shoulder the greatest responsibilities for their implementation. It has been established from the literature that the most successful cities in implementing projects and approaches with positive impacts on sustainability are those that have already embraced smart aspects. For instance, Singapore, which has been voted a number of times as one of the most liveable cities, is well established as being a 'smart' nation [88], with some sustainable aspects such as green spaces. While the impacts of climate change affect all cities, including those in the global north and developed economies [89–91], the aspect of smartness defines and influences the resilience and adaptability levels of different cities. That is, those with notable smart components have been argued to be more adaptable and resilient than their counterparts that have few

or no smart components installed [92–94]. This could explain why most cities, as shown in the figure above, have increased commitments towards transitioning to smart cities.

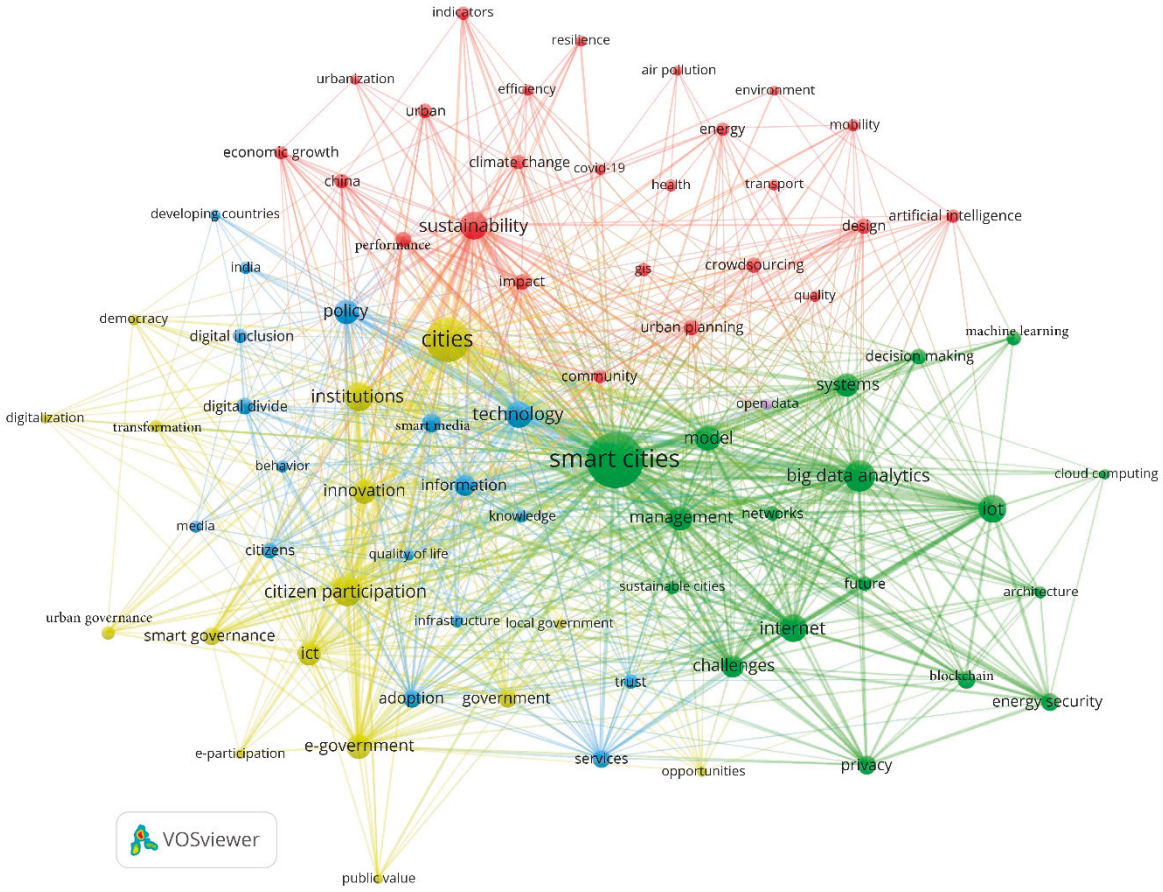

Figure 7. Overall thematic focus from 1978 to early 2022. Illustration by authors.

4.5.2. Evolution of Structure and Thematic Focus over Time

This subsection comprehensively addresses how research works and structures came about during the three periodical timeframes identified to have had significant impacts in the evolution of studies in the subject matter of urban governance. The classification of the three periods was done in respect to the timelines that a number of factors such as technological advancement, global sustainability agenda documents, the rise of the smart city concept, and the emergence of COVID-19 pandemic, among others, created, as highlighted in Figure 1 above and in the Methodology.

Period 1 (Until 2015)

Results of the study covering the first period (1978–2015) are captured in Figure 8 below. As noted from the literature, while the aspect of urban smartness may have been conceived earlier, it became vivid in 1974 in Los Angeles when the local government of the day initiated the use of data to influence certain aspects of its urban administration [5]. Later, in 1994, Amsterdam attempted to install smart government structures by adopting a 'virtual city' concept [95]. However, in the 2000's, as noted in Figure 2 (above), notable possibilities of incorporating digital solutions in cities began to gain traction due to gradual growth of the ICT sector, catalysed by the fourth industrial revolution. As highlighted in Figure 8, though the collection of thematic areas being pursued was not extensive, it is evident that the aspects of smart governance, smart citizens, and smart cities were present. During this period, at the global front, high-level meetings [96–98] highlighted pressing urban challenges such as climate change, the widening socioeconomic inequality gap,

and the unprecedented urban population growth. This, as can be deduced from Figure 8, prompted debates on areas such as sustainability and how such could be achieved through changes in policies driven by global institutions. The calls for action on different urban issues originated from different quarters, such as youth movements and from the global population, which leverage social media as a tool for communication. These communication platforms were spearheaded by growth and unprecedented penetration of the internet and the gradual infiltration of smart mobile devices with capacities to help share complex information [67]. As highlighted above, during this period, the number of smart 'things' (powered by IoT networks) had increased to approximately 16 billion globally [87].

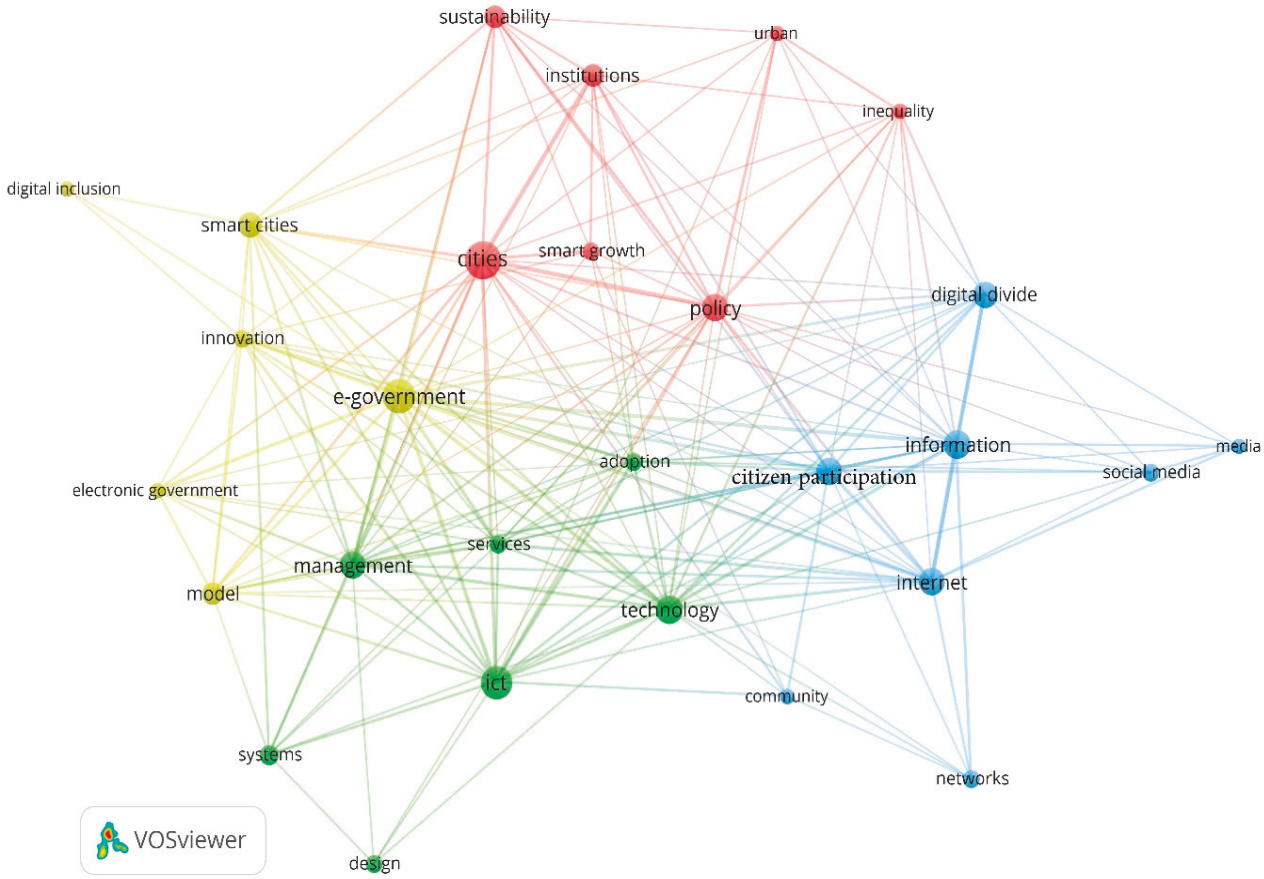

Figure 8. First period (1978–2015): illustration by authors.

In 2015, interest in different smart urban dimensions gained even more momentum, as ground-breaking documents, starting with the Paris Agreement, The Sustainable Development Goals, and the New Urban Agenda, were launched. While these captured different global aspects and themes, it is evident from the literature review that most of the solutions proposed converged on how urban areas need to be managed for increased sustainability, liveability, and resilience. Figure 7 above showcases how the full package of 'smartness' in cities started to gain traction during the period in question. For instance, in the question of climate change, it was appreciated in the different global accords, especially on how urban governance could help achieve low carbon, climate adaptation, and sustainable and liveable cities through adoption of innovations in varying sectors. A classic example is in the energy sector, where alternatives such as solar, wind, and hydro are becoming mainstream and require governance structures to allow for their deployment in urban areas [99]. Additionally, in the transportation and construction industries, amongst others, the role of urban governance was as critical then as it is today; already, sufficient urban challenges were originating from those sectors, as noted by Wen et al. [100]. Furthermore, it was appreciated that the achievement of those different global policies was determined by

how financial resources would be committed, and as such, the Paris Agreement proposed (Article 9) that developed economies commit at least $100 billion to assist developing economies achieve their climate action agenda [101]. From the literature, it has been argued that smart governance is very critical in the sourcing and allocation of finances in different programs and projects that would ultimately lead to the 'smartness' in cities. While Figure 8 above showcases that there were limited activities happening in the academic circles in terms of publication, this period formed the backbone for cities in their quest to adopt smart technologies as tools to address the aforementioned challenges. In summary, this period outlined that:

- The global agendas of the Paris Agreement, SDGs, New Urban Agenda, and others influenced pursuits to smart growth.
- Citizen participation in urban governance started to gain traction since early in the concept.
- The technology was infancy in the beginning, outlining only a few technical dimensions, and focusing more on broad objectives.
- Some social themes such as the digital divide and inequality were already apparent then.

Period 2 (2016–2019)

The period between 2016 and 2019 experienced an increase in research interests on the subject matter of 'smartness', as showcased in Figure 9 below. From Figure 1, it was clearly noted that approximately 731 publications were made during this period, with research works growing gradually each year. From Figure 9, it is also evident that the number of terminologies increased substantially on each of the four thematic areas (sustainability, smart cities, smart governance, citizen participation, and policy/political Issues) categorised under red, green, yellow and blue clusters. For instance, on the thematic area of sustainability and smart cities, Bibri and Krogstie [102] provide novel insights and a number of new terminologies as a result of a synthesis of a large body of interdisciplinary and transdisciplinary literature. Additionally, there was increased attention in respect to smart governance, with new interest areas such as crowdsourcing, local governments, social media, and adaptation arising. Furthermore, regarding policies' formulation and political influences in the achievement of 'smartness' in cities, it is evident from Figure 9 that this period experienced substantial interests and publications, with research works covering new grounds such as Energy, Climate Change, Economic Growth, China, India, Quality of Life, and others. Regarding smart cities, it is evident that there was increased attention, especially following emergence and popularization of new technologies such as the Internet of Things (IoT), Big Data, Artificial Intelligence, Blockchain, and others. In terms of sustainability, new innovations in areas like mobility, infrastructure development, and energy, prompted by emergence and adoption of smart technologies, further helped develop more interests (see [103,104], for illustrative case studies between 2016 and 2020).

From the literature, this period was critical in most cities, prompted by a number of factors. First, the global accords and agreements that were launched in 2015 prompted new ways and approaches in areas of urban planning aimed at achieving different sets of objectives. For instance, in regard to addressing the challenge of climate change, which had attracted notable interests from different quarters, including calls from youth movements [105], C40 cities [106], Small Island Developing States (SIDS) [107], and others for decarbonisation, technology adoption in cities became inevitable [108,109]. Aspects of smart governance became clear, even in global summits, with participation of 'minority groups' such as youths, Small Island Developing States, and indigenous groups becoming apparent. The issues they raised coincided with what had already been anticipated and captured in documents such as the Paris Agreement [110]. For instance, in respect to SIDS, a report 'Emerging Issues for Small Island Developing States' published in by the United Nations Environment Programme (UNEP) [111] started to elicit much interest, as the details and facts contained therein mirrored what had been captured in the Paris Agreement.

During this period, attention on use of technology to alter traditions in areas such as energy production with adoption of renewable energies as a substitute to fossil fuel started to gain much traction. Indeed, as noted by the International Renewable Energy Agency (IRENA), it was during this period that costs of producing basic components such as solar panels became relatively cheaper; hence, popularity of this option increased. Overall, the aspect of 'smartness' advanced during this period, with numerous benefits being experienced, especially in increased efficiency and performance in cities such as Barcelona, London, Singapore, New York, and others that had embraced the aspect of smart governance. In summary, this period outlines that:

- Smart urban governance gained traction with inclusion of minority groups.
- The use of technology became more apparent, specifically in energy fields.
- Technology integration gained more ground in city administration.
- The aspect of community involvement grew more rapidly than business models for smart cities, showcasing that the model was moving from more profit-driven models to human-driven models.
- The technological cluster was expanding, underlining the need for local governments to reinforce their capacities.

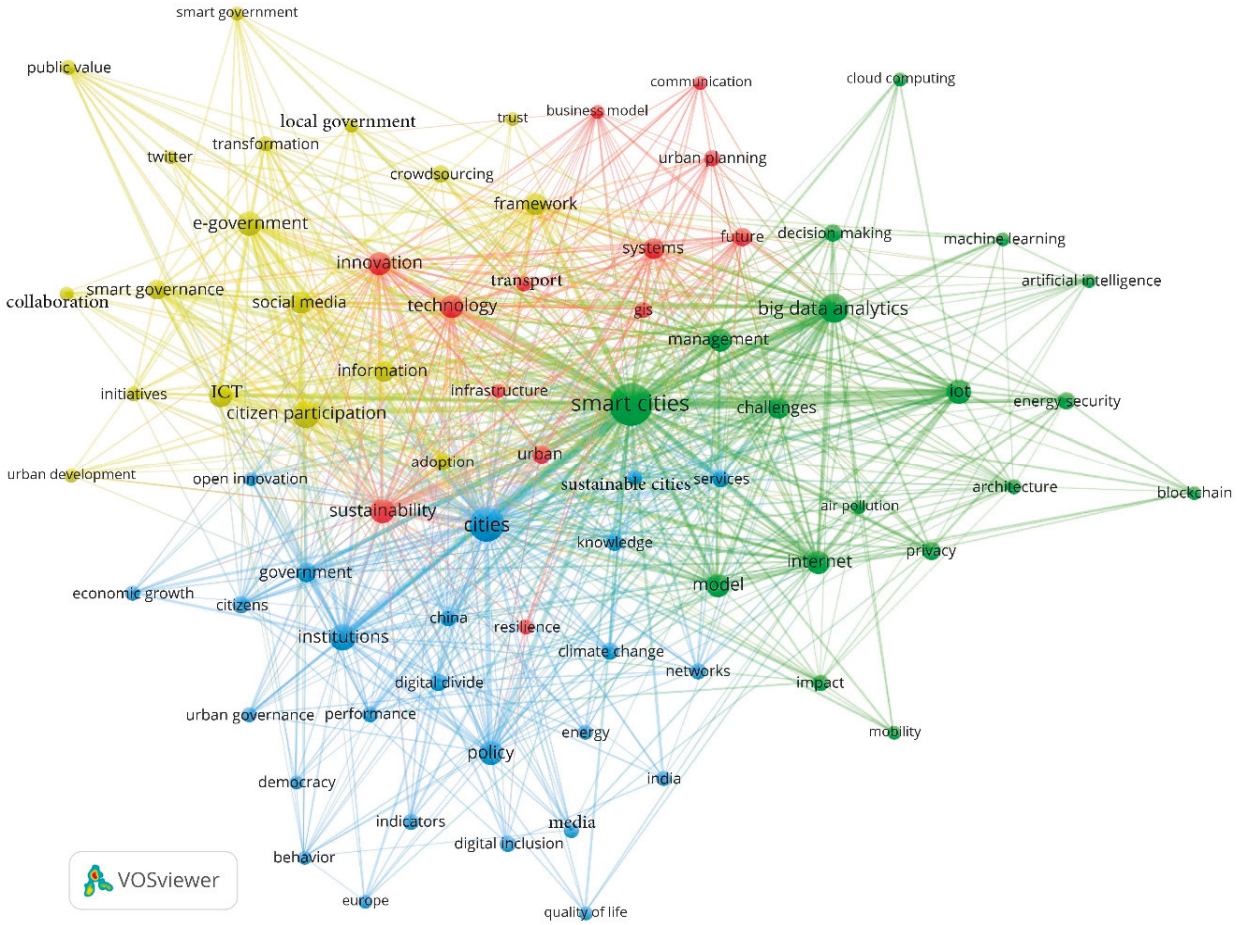

Figure 9. Second Period (2016–2019): Illustration by authors.

Period 3 (2020–Early 2022)

The period year 2020 to early 2022, which was extraordinary for the global community, was prompted by the unprecedented widespread outbreak of the COVID-19 pandemic. Unlike other recent global challenges such as climate change, COVID-19 disrupted normal activities in almost all facets of life, with urban areas and cities being the most affected, especially noting the high population density, over-reliance on transportation, and nature

of works [89]. With most countries taking drastic actions to contain the spread, delivery of services in many sectors become almost impossible (especially in the transport [112,113] and education sectors [114,115]) and others such as the health sector were, in most cities, almost overwhelmed [116]. However, it was noted in different fora [94], that cities that had embraced the smart agenda had some relief. This was especially evident in cities where the aspect of smart urban governance had gained some roots, as some services continued to be offered virtually albeit in limited scopes compared to normal [95]. Conversely, Kitchin [52] questioned the technical and practical efficacy of surveillance technologies used for contact tracing, quarantine enforcement, social distancing/movement monitoring, and symptom tracking (e.g., smartphone apps, facial recognition cameras, biometric wearables, smart helmets, drones, and predictive analytics), and examined their implications for civil liberties, governmentality, surveillance capitalism, and public health. Regardless, as depicted in Figure 10 below, despite the evident disruptions that COVID-19 posed, adoption and application of different aspects of smart city concepts continued to gain popularity even more than the previous years. There was increased attention on issues focused on digitalisation, smart governance, and citizen participation, as highlighted in the diagram using the colour yellow. Maximum research attention was focused on governance and how such would influence issues such as security and provision of services, more so in the health sector, in formulation of policies to guide emerging trends such as working from home, reduced mobility options, and adoption of smart technologies in different government departments to enhance virtual service delivery.

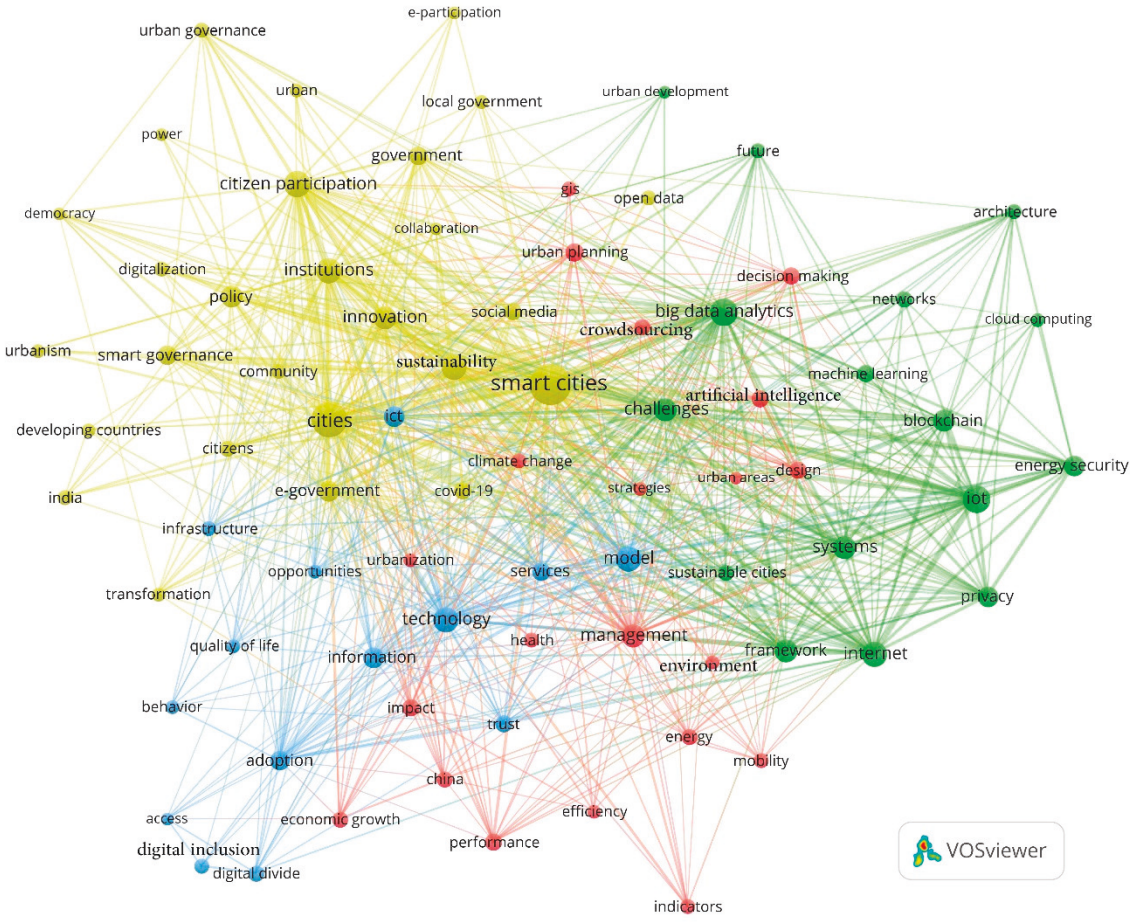

Figure 10. Period 2020: Illustration by authors.

During this period, aspects (symbolized using the colour red in Figure 10) such as sustainability, economic growth, mobility, and resilience of communities gained popularity with publishers, as the pandemic prompted mixed trends. For instance, before the

emergence of COVID-19, cities had been reported to be the greatest contributors to climate change (with of 70% of the total global GHG emissions). However, in 2020, an unprecedented decline in emissions were reported, with aspects such as urban air and water quality reported to have improved immensely [117]. Such were influenced by reduced activities in transport sectors [118,119], manufacturing sectors [120], and other energy intensive frontiers [121]. However, such reductions were seen as 'carbon bubbles' that would burst immediately as soon as countries started their economic recovery journey [122]. As a result, many researchers and publishers produced articles and publications highlighting the need for 'green' policies to be adopted during economic recovery pursuits. The adoption of modern smart technologies was identified as among potential strategies that could be used to help accelerate the 'green' recovery, as those had already worked in areas such as the work-from-home concept and in virtual communications, thus, helping to reduce energy consumption from non-renewable sources. In summary, this section outlines that:

- The pandemic provoked mixed trends in sustainability, economic growth, mobility, and resilience of communities.
- The human factor, showcased in yellow, grew more significantly than others.
- The need for higher quality of life emerged in this period.
- An emergence of 'green' policies was observed as a result of post-COVID economic pursuits.

5. Discussion

During this century, the global landscape has changed significantly following unmetered population growth and rapid urbanisation. This twin phenomenon has in turn prompted diverse critical issues such as climate change, increased resource consumption, urban congestion, and increased socioeconomic inequalities, amongst others. However, as expressed by Jiang, Geertman, and Witte [13], these different challenges greatly differ in scope and intensity in different cities, with the main underlying component being the governance structures in place. It has been established that cities that have already embraced and instituted some form of 'smartness' in their governance structures are relatively several steps ahead of their peers in addressing different issues in diverse urban sectors [70,123,124]. The popularity of urban smartness, as established in this study, started to draw some attention as early as the 1970s and grew steadily until 2014. The bibliometric analysis has established that within this period, most publications were centred on a limited number of issues, including how the application of smart technologies could be unpacked in cities and how such could help address emerging issues such as sustainability, e-governance, enhanced citizen participation, and the digital divide prompted by proliferation of smart devices and the rise of social media, amongst others.

On the global scene, attention during this period was focused on finding solutions for the looming urban challenges prompted by climate change [125]. This quest was particularly catalysed by the formation of the Kyoto Protocol in 1997, and from the result analysis, it is true that it was after this global agenda that an increase in related publications was observed. In cities, in the mid-2000s, the attention was on integrating information and data technology components in different dimensions to complement and enhance existing infrastructures. Large ICT corporations such as Cisco and IBM had increased their activities in research and development of smart cities, rising hope of finding digital solutions to major urban challenges, including on the governance front [126].

In the academic realm, researchers also increased their activities, and as depicted in Figure 2 above, the number of publications during this period reached a high of 220. In Table 1, displaying the most influential references, it is evident that most of those were written between 2000 and 2014, highlighting the importance of the fourth Industrial Revolution (Industry 4.0) in regard to publications on smart governance in cities. This is not surprising, as cities were on a transition path in respect to adopting new planning approaches (smart city concept) as well as in relation to adopting climate change mitigation strategies that were eventually formalized in 2015 in the Paris Agreement and the SDGs [110,127]. From

2015 to 2019, the research agrees with the argument by Angelidou [6], which expressed that cities experienced unprecedented forces; technology push and demand pulls saw an almost exponential increase in activities, particularly in the publication realm. In cities, the push was prompted by a rapid increase in digital innovations targeting different urban challenges. For instance, as noted in a report by the Statista Research Department [128], it is during this period that smart technologies increased exponentially and their applicability in different urban fabrics became more evident. This could be witnessed by the increase in the number of smart devices (IoT- based) from 16 billion products as of 2014, to a high of more than 50.1 billion devices by 2020, and a projection of reaching 75 billion devices by 2025 [129].

One of the major challenges that researchers were interested in after it became apparent that cities could benefit from the use of data in terms of efficiency and performance increase was the issue of privacy and security of data [24,130,131]. This invoked a sizeable volume of research output focusing on citizens' perception of smart cities and smart governance and their take on privacy and security of their personal information. However, the gradual potential rise and of use of different technologies such as Blockchain, as highlighted in Section 4, gradually started to help build confidence on privacy of urban residents. While the fears have not been fully arrayed, especially noting that data management in most cities is still being undertaken by third parties (with profit-making agendas), Blockchain technologies such as smart contracts, cryptocurrencies, and others have given some glimpse of hope for guaranteeing privacy (though to some extent due to invested interests).

In regard to the demand pull, it is posited that new technologies such as big data, the IoT, and AI have increased cities' capacity to offer innovative solutions to a myriad of challenges. Those technologies have enabled cities to achieve environmental sustainability, efficiency, resilience, equity, socioeconomic parity, and other qualities, thus making the smart city concept even more attractive during the second period [6,92,132]. This has created numerous research opportunities giving rise to new approaches to smart urbanism, notably data-driven cities (e.g., [133]), data-driven smart cities (e.g., [103,134–136]), sustainable smart cities (e.g., [132,137]), data-driven smart sustainable cities, and environmentally data-driven sustainable smart cities [104]. These emerging paradigm shifts to smart urbanism are seen to bring more innovative solutions to a number of complex problems and challenges pertaining to sustainability and urbanization, as well as to governance as to how to address them. This could hence explain why terminologies such as Innovation, Transportation, Environment, and Business Models increased in the publication realm during the second and third periods. Through technology, a wide range of urban solutions emerged during this period in sectors such as energy, transport, environmental monitoring, economy, health, culture and art, education, and others. For instance, in the transport sector, technology inspired new modes of mobility including the use of electric vehicles [138], car and ride sharing [139], and the use of bicycles, amongst others [140,141]. In the health sector, there has been a rise in wearables that, with the emergence of new technologies such as minimally invasive surgery [142] and the use of 3D printing technologies, have been helping address emergencies [143,144]. On the economic front, cities such as Singapore, Barcelona, and others managed to enhance their service-oriented business models, thereby increasing employment opportunities for their residents. The expansion on scope of what the smart city concept could help cities achieve consequently opened new opportunities for research and publications, thus, explaining why research works have maintained an upward trajectory since the concept gained traction in the urban planning realm.

Adoption of smart governance in cities, as showcased in Figure 9 depicting publications in 2020, sums up the influence and capacities of technologies in urban areas. From face value, the unfortunate happening during this year as prompted by the emergence of COVID-19 could have had the potential to paralyse and jeopardise activities in cities as well as in the publishing industry. This is not surprising, as during this period, activities, including in most institutions of higher learning, were almost completely halted [145]. However, courtesy of advanced technologies that allowed for remote working, virtual learning, and

collaboration [146], and continued generation of relevant data, a substantial number of publications was completed. In cities, smart governance allowed for the containment measures instituted by governments [147], and from Figure 9, it is evident that research touching on or linked to Governance, Smart Cities, and Citizen participation increased substantially. For instance, regarding social distancing, it was observed that most residents relied on technologies such as e-commerce, P2P, and others for their supplies [148]. Social media platforms became popular tools for sharing and exchanging information, while virtual communication technologies allowed for virtual meetings, virtual learning, and other activities, which all helped reduce in-person interactions [146]. While research increased the benefits accrued from adoption of smart technologies, there were some concerns on the fate of cities and economies that had not yet embraced smart technologies and the challenges they were facing. Such diverse research areas could explain why there were such extensive activities in research as depicted in Figure 9, then the rest of the periods despite the real challenge that COVID-19 had posed.

This paper presents results from the mapping of emerging trends and structures, and further research can help complement some of the findings, specifically relating to exploring the:

- Emerging factors from the COVID-19 pandemic on smart urban governance and their reasons.
- Institutional policies guiding the conceptualisations and development of smart governance solutions.
- The equality of development from cities in the global north and those in the global south, and across cities of different scales and capacities.
- The digital divide and the barriers of smart city governance implementation, and the associative solutions.
- The comprehensive mapping of 'human' dimensions emerging so as to map the needs for developers of future technologies to respond to.

6. Conclusions

Overall, from this analysis, it is evident that the aspects of smart governance and smart technologies are gaining even more attention from researchers, and in the future, with many cities focusing on embracing and implementing more dimensions of smart cities, it is expected that more research will continue to be published, with new emerging terminologies. However, smart city governance has been criticized, since it is strongly driven by government policies and the interests and agenda of high-tech companies and corporations (e.g., Hollands [82], Allam [149], Grossi et al. [150]). Many studies have focused on the potential risks and negative implications of the technocratic, corporate-led approach to smart city governance (e.g., Cardullo and Kitchin [86], Grossi, Meijer and Sargiacomo [150], Bina et al. [151], León and Rosen [152], McFarlane and Söderström [153]). Much of the criticism in this respect relates to social sustainability and the balance between the three dimensions of sustainability, especially in relation to citizen participation. Therefore, several studies have argued for the urgency and need for a transformative perspective on smart urban governance as a context-based, socio-technical way of governing cities (e.g., Jiang, Geertman and Witte [14], Pereira et al. [154], Webster and Leleux [155]), as well as new forms of human collaboration to attain the desired outcomes, including sustainable mobility to increase the quality of life in cities [156].

While the analysis has made it possible to achieve the objectives and answer the questions set in the introductory section, there are limitations that need to be addressed in future research. One key limitation is that this study is only based on peer-reviewed literature. Considering grey literature would make it possible to gain more comprehensive insights and should be prioritized in the future. Additionally, during the height of COVID-19, it became apparent that the world was braced to a 'new normal', where technology use would become mainstream and more embedded into almost every urban dimension. This would undoubtably prompt further paradigm shifts on how urban areas are governed.

On the academic realm, such developments would prompt an increase in the number of publications focusing on the new frontiers, including on digitally infused solutions. It would therefore be interesting to have research conducted to establish the publication landscape post-pandemic to map out the influences that the coronavirus had on urban policy making and its governance features.

Author Contributions: Conceptualization, Z.A., A.S. and S.E.B.; validation, A.S.; writing—original draft preparation, Z.A., A.S., S.E.B. and D.C.; writing—review and editing, Z.A., A.S., S.E.B. and D.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The search string: TS = (((“smart” OR “intelligent” OR “digital” OR “digitali*ation” OR “Information and communication technolog*” OR “ict” OR “information technology” OR “internet of things” OR “iot” OR “artificial intelligence” OR “AI” OR “machine learning” OR “blockchain” OR “virtual reality” OR “VR” OR “augmented reality” OR “AR” OR “cloud computing” OR “big data” OR “5G” OR “6G” OR “industry 4*” OR “society 5*” OR “robotic*” OR “automation” OR “automated”) NEAR/5 (“governance” OR “government” OR “e-governance” OR “e-government” OR “e-planning” OR “public service” OR “participatory” OR “participation” OR “public engag*” OR “public administration” OR “public procurement“ OR “democra*” OR “open innovation” OR “crowdsourcing” OR ”politics” OR “political” OR “urban policy” OR “corruption” OR “accountab*” OR “trust” OR “ownership” OR “decision-making” OR “decision making” OR “transparen*” OR “citizen” OR “stakeholder” OR “inclus*” OR “institutional” OR “public sector”)) AND (“city” OR “cities” OR “urban”)).

References

1. Lewarne, S.; Snelbecker, D. *Economic Governance in War Torn Economies: Lessons Learned from the Marshall Plan to the Reconstruction of Iraq*; USAID: Washington, DC, USA, 2004; p. 133.
2. United Nations. *World Economic and Social Survey 2017: Reflecting on Seventy Years of Development Policy Analysis*; UN Publication: New York, NY, USA, 2017.
3. UN DESA. 68% of the World Population Projected to Live in Urban Areas by 2050, Says UN. Available online: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html (accessed on 5 January 2021).
4. World Bank. Urban Development: Overview. Available online: https://www.worldbank.org/en/topic/urbandevelopment/overview#:~{}:text=With%20more%20than%2080%25%20of,and%20new%20ideas%20to%20emerge (accessed on 27 September 2021).
5. Bibri, S.E. Data-driven smart eco-cities and sustainable integrated districts: A best-evidence synthesis approach to an extensive literature review. *Eur. J. Futures Res.* **2021**, *9*, 16. [CrossRef]
6. Angelidou, M. Smart cities: A conjuncture of four forces. *Cities* **2015**, *47*, 95–106. [CrossRef]
7. UNEP. *Resilience and Resource Efficiency in Cities*; United Nations Environment Programme: New York, NY, USA, 2017.
8. Anthopoulos, L.G. *Understanding Smart Cities: A Tool for Smart Government or an Industrial Trick*; Springer International Publishing: Berlin/Heidelberg, Germany, 2017; Volume 22, p. 293.
9. Anttiroiko, A.V.; Valkama, P.; Bailey, S.J. Smart cities in the new service economy: Building platforms for smart services. *Artif. Intell. Soc.* **2014**, *29*, 323–334. [CrossRef]
10. Bibri, S.E.; Krogstie, J. Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustain. Cities Soc.* **2017**, *31*, 183–212. [CrossRef]
11. Allam, Z.; Bibri, S.E.; Jones, D.S.; Chabaud, D.; Moreno, C. Unpacking the “15-Minute City” via 6G, IoT, and Digital Twins: Towards a New Narrative for Increasing Urban Efficiency, Resilience, and Sustainability. *Sensors* **2022**, *22*, 1369. [CrossRef] [PubMed]
12. Bibri, S.E. Data-driven smart sustainable cities of the future: An evidence synthesis approach to a comprehensive state-of-the-art literature review. *Sustain. Futures* **2021**, *3*, 100047. [CrossRef]

13. Jiang, H.; Geertman, S.; Witte, P. Smart urban governance: An alternative to technocratic "smartness". *GeoJournal* **2020**. [CrossRef] [PubMed]
14. Jiang, H.; Geertman, S.; Witte, P. Smartening urban governance: An evidence-based perspective. *Reg. Sci. Policy Pract.* **2021**, *13*, 744–758. [CrossRef]
15. INRIX. Global Traffic Scorecard. Available online: https://inrix.com/scorecard/ (accessed on 5 February 2022).
16. Allam, Z.; Dhunny, Z.A. On big data, artificial intelligence and smart cities. *Cities* **2019**, *89*, 80–91. [CrossRef]
17. Howley, P.; Scott, M.; Redmond, D. Sustainability versus liveability: An investigation of neighbourhood satisfaction. *J. Environ. Plan. Manag.* **2009**, *52*, 847–864. [CrossRef]
18. Valcárcel-Aguiar, B.; Murias, P.; Rodríguez-González, D. Sustainable Urban Liveability: A Practical Proposal Based on a Composite Indicator. *Sustainability* **2019**, *11*, 86. [CrossRef]
19. Iglesias, C.A.; Favenza, A.; Carrera, Á. A Big Data Reference Architecture for Emergency Management. *Information* **2020**, *11*, 569. [CrossRef]
20. Tan, S.Y.; Taeihagh, A. Smart City Governance in Developing Countries: A Systematic Literature Review. *Sustainability* **2020**, *12*, 899. [CrossRef]
21. UN Environment Programme. Goal 11: Sustainable Cities and Communities. Available online: https://www.unenvironment.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-11 (accessed on 17 January 2020).
22. Tomor, Z.; Meijer, A.; Michels, A.; Geertman, S. Smart Governance for Sustainable Cities: Findings from a Systematic Literature Review. *J. Urban Technol.* **2019**, *26*, 3–27. [CrossRef]
23. El Emam, K.; Rodgers, S.; Malin, B. Anonymising and sharing individual patient data. *BMJ* **2015**, *350*, h1139. [CrossRef] [PubMed]
24. Ismagilova, E.; Hughes, L.; Rana, N.P.; Dwivedi, Y.K. Security, Privacy and Risks Within Smart Cities: Literature Review and Development of a Smart City Interaction Framework. *Inf. Syst. Front.* **2020**. [CrossRef] [PubMed]
25. Martinez-Balleste, A.; Perez-Martinez, P.; Solanas, A. The Pursuit of Citizens' Privacy: A privacy-Aware Smart City is Possible. *IEEE Commun. Manag.* **2013**, *51*, 136–141. [CrossRef]
26. Zoonen, L.v. Privacy concerns in smart cities. *Gov. Inf. Q.* **2016**, *33*, 472–480. [CrossRef]
27. Rathee, G.; Khelifi, A.; Iqbal, R. Artificial Intelligence- (AI-) Enabled Internet of Things (IoT) for Secure Big Data Processing in Multihoming Networks. *Wirel. Commun. Mob. Comput.* **2021**, *2021*, 5754322. [CrossRef]
28. Mark, R.; Anya, G. Ethics of Using Smart City AI and Big Data: The Case of Four Large European Cities. *ORBIT J.* **2019**, *2*, 1–36. [CrossRef]
29. Fernandes, R.; Queiroz, A.; Wilmers, J.; Hoffmann, W. Urban governance in Latin America: Bibliometrics applied to the context of smart cities. *Transinformação* **2019**, *31*, e190014. [CrossRef]
30. Sharifi, A.; Allam, Z. On the taxonomy of smart city indicators and their alignment with sustainability and resilience. *Environ. Plan. B Urban Anal. City Sci.* **2021**, 23998083211058798. [CrossRef]
31. Pereira, G.; Parycek, P.; Falco, E.; Kleinhans, R. Smart governance in the context of smart cities: A literature review. *Inf. Polity* **2018**, *23*, 143–162. [CrossRef]
32. Barns, S. Out of the loop? On the radical and the routine in urban big data. *Urban Stud.* **2021**, *58*, 3203–3210. [CrossRef]
33. Allam, Z.; Newman, P. Redefining the Smart City: Culture, Metabolism and Governance. *Smart Cities* **2018**, *1*, 4–25. [CrossRef]
34. Meijer, A.; Bolívar, M.P.R. Governing the smart city: A review of the literature on smart urban governance. *Int. Rev. Adm. Sci.* **2015**, *82*, 392–408. [CrossRef]
35. Klingberg, D. *Smart Cities*; Planning News: Los Angeles, CA, USA, 2020; pp. 18–19.
36. Ruhlandt, R.W.S. The governance of smart cities: A systematic literature review. *Cities* **2018**, *81*, 1–23. [CrossRef]
37. Przeybilovicz, E.; Cunha, M.A. Government Characteristics to Achieve Smart Urban Governance: From Internal to External Transformation. In *Smart Cities and Smart Governance*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 43–66.
38. Birkle, C.; Pendlebury, D.A.; Schnell, J.; Adams, J. Web of Science as a data source for research on scientific and scholarly activity. *Quant. Sci. Stud.* **2020**, *1*, 363–376. [CrossRef]
39. Guerrero-Bote, V.P.; Chinchilla-Rodríguez, Z.; Mendoza, A.; de Moya-Anegón, F. Comparative Analysis of the Bibliographic Data Sources Dimensions and Scopus: An Approach at the Country and Institutional Levels. *Front. Res. Metr. Anal.* **2021**, *5*, 593494. [CrossRef]
40. Pranckutė, R. Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World. *Publications* **2021**, *9*, 12. [CrossRef]
41. Visser, M.; van Eck, N.J.; Waltman, L. Large-scale comparison of bibliographic data sources: Scopus, Web of Science, Dimensions, Crossref, and Microsoft Academic. *Quant. Sci. Stud.* **2021**, *2*, 20–41. [CrossRef]
42. Jacso, P. As we may search—Comparison of major features of the Web of Science, Scopus, and Google Scholar citation-based and citation-enhanced databases. *Curr. Sci.* **2005**, *89*, 1537–1547.
43. Mora, L.; Bolici, R.; Deakin, M. The First Two Decades of Smart-City Research: A Bibliometric Analysis. *J. Urban Technol.* **2017**, *24*, 3–27. [CrossRef]
44. Cobo, M.J.; López-Herrera, A.G.; Herrera-Viedma, E.; Herrera, F. Science mapping software tools: Review, analysis, and cooperative study among tools. *J. Am. Soc. Inf. Sci. Technol.* **2011**, *62*, 1382–1402. [CrossRef]

45. Moral-Munoz, J.A.; López-Herrera, A.G.; Herrera-Viedma, E.; Cobo, M.J. Science Mapping Analysis Software Tools: A Review. In *Springer Handbook of Science and Technology Indicators*; Glänzel, W., Moed, H.F., Schmoch, U., Thelwall, M., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 159–185.
46. Moral-Muñoz, J.A.; Herrera-Viedma, E.; Santisteban-Espejo, A.; Cobo, M.J. Software tools for conducting bibliometric analysis in science: An up-to-date review. *Prof. Inf.* **2020**, *29*. [CrossRef]
47. Van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef]
48. Perianes-Rodriguez, A.; Waltman, L.; van Eck, N.J. Constructing bibliometric networks: A comparison between full and fractional counting. *J. Informetr.* **2016**, *10*, 1178–1195. [CrossRef]
49. Brasuell, J. The Early History of the 'Smart Cities' Movement in 1974 Los Angeles. Available online: https://www.planetizen.com/node/78847 (accessed on 20 January 2021).
50. World History Encyclopedia. City Timeline. Available online: https://www.worldhistory.org/timeline/city/ (accessed on 27 January 2022).
51. Philantropy News Digest. IBM Launches $50 Million Smarter Cities Challenge. Available online: https://philanthropynewsdigest.org/news/ibm-launches-50-million-smarter-cities-challenge (accessed on 3 February 2022).
52. Kitchin, R. Civil liberties or public health, or civil liberties and public health? Using surveillance technologies to tackle the spread of COVID-19. *Space Polity* **2020**, *24*, 362–381. [CrossRef]
53. Allam, Z.; Jones, D.; Biyik, C.; Allam, Z.; Raisah Takun, Y. Rewriting city narratives and spirit: Post-pandemic urban recovery mechanisms in the shadow of the global 'black lives matter' movement. *Res. Glob.* **2021**, *3*, 100064. [CrossRef]
54. Allam, Z. *Surveying the Covid-19 Pandemic and Its Implications: Urban Health, Data Technology and Political Economy*; Elsevier Science: Amsterdam, The Netherlands, 2020.
55. Allam, Z.; Jones, D.S. Pandemic stricken cities on lockdown. Where are our planning and design professionals [now, then and into the future]? *Land Use Policy* **2020**, *97*, 104805. [CrossRef]
56. Arnstein, S.R. A Ladder of Citizen Participation. *J. Am. Inst. Plan.* **1969**, *35*, 216–224. [CrossRef]
57. Zanella, A.; Bui, N.; Castellani, A.; Vangelista, L.; Zorzi, M. Internet of Things for Smart Cities. *IEEE Internet Things J.* **2014**, *1*, 22–32. [CrossRef]
58. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart Cities in Europe. *J. Urban Technol.* **2011**, *18*, 65–82. [CrossRef]
59. Hollands, R.G. Will the real smart city please stand up? *City* **2008**, *12*, 303–320. [CrossRef]
60. Nam, T.; Pardo, T.A. Smart city as urban innovation: Focusing on management, policy, and context. In Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance, Tallinn, Estonia, 26–28 September 2011; pp. 185–194.
61. Chourabi, H.; Nam, T.; Walker, S.; Gil-Garcia, J.R.; Mellouli, S.; Nahon, K.; Pardo, T.A.; Scholl, H.J. Understanding Smart Cities: An Integrative Framework. In Proceedings of the 2012 45th Hawaii International Conference on System Sciences, Maui, HI, USA, 4–7 January 2012; pp. 2289–2297.
62. Giffinger, R.; Pichler-Milanović, N. *Smart Cities: Ranking of European Medium-Sized Cities*; Centre of Regional Science, Vienna University of Technology: Vienna, Austria, 2007.
63. Townsend, A.M. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*; WW Norton & Company: New York, NY, USA, 2013.
64. Batty, M.; Axhausen, K.W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y. Smart cities of the future. *Eur. Phys. J. Spec. Top.* **2012**, *214*, 481–518. [CrossRef]
65. Neirotti, P.; De Marco, A.; Cagliano, A.C.; Mangano, G.; Scorrano, F. Current trends in Smart City initiatives: Some stylised facts. *Cities* **2014**, *38*, 25–36. [CrossRef]
66. Schaffers, H.; Komninos, N.; Pallot, M.; Trousse, B.; Nilsson, M.; Oliveira, A. Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation. In *Lecture Notes in Computer Science*; Springer: Berlin/Heidelberg, Germany, 2011; pp. 431–446.
67. Linders, D. From e-government to we-government: Defining a typology for citizen coproduction in the age of social media. *Gov. Inf. Q.* **2012**, *29*, 446–454. [CrossRef]
68. Harrison, C.; Eckman, B.; Hamilton, R.; Hartswick, P.; Kalagnanam, J.; Paraszczak, J.; Williams, P. Foundations for Smarter Cities. *IBM J. Res. Dev.* **2010**, *54*, 1–16. [CrossRef]
69. Vanolo, A. Is there anybody out there? The place and role of citizens in tomorrow's smart cities. *Futures* **2016**, *82*, 26–36. [CrossRef]
70. Bakıcı, T.; Almirall, E.; Wareham, J. A Smart City Initiative: The Case of Barcelona. *J. Knowl. Econ.* **2013**, *4*, 135–148. [CrossRef]
71. Lombardi, P.; Giordano, S.; Farouh, H.; Yousef, W. Modelling the smart city performance. *Innov. Eur. J. Soc. Sci. Res.* **2012**, *25*, 137–149. [CrossRef]
72. Ahvenniemi, H.; Huovila, A.; Pinto-Seppä, I.; Airaksinen, M. What are the differences between sustainable and smart cities? *Cities* **2017**, *60*, 234–245. [CrossRef]
73. Batty, M. Big data, smart cities and city planning. *Dialogues Hum. Geogr.* **2013**, *3*, 274–279. [CrossRef] [PubMed]
74. Coccia, A. Smart and Digital City: A Systematic Literature Review. In *Smart City. Progress in IS*; Rosenthal-Sabroux, C., Ed.; Springer: Cham, Switzerland, 2014.

75. Nam, T.; Pardo, T.A. Conceptualizing smart city with dimensions of technology, people, and institutions. In Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times, College Park, MA, USA, 12–15 June 2011; pp. 282–291.
76. Söderström, O.; Paasche, T.; Klauser, F. Smart cities as corporate storytelling. *City* **2014**, *18*, 307–320. [CrossRef]
77. Hashem, I.A.T.; Chang, V.; Anuar, N.B.; Adewole, K.; Yaqoob, I.; Gani, A.; Ahmed, E.; Chiroma, H. The role of big data in smart city. *Int. J. Inf. Manag.* **2016**, *36*, 748–758. [CrossRef]
78. Angelidou, M. Smart city policies: A spatial approach. *Cities* **2014**, *41*, S3–S11. [CrossRef]
79. Lee, J.H.; Hancock, M.G.; Hu, M.-C. Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technol. Forecast. Soc. Change* **2014**, *89*, 80–99. [CrossRef]
80. Silva, B.N.; Khan, M.; Han, K. Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustain. Cities Soc.* **2018**, *38*, 697–713. [CrossRef]
81. Shelton, T.; Zook, M.; Wiig, A. The 'actually existing smart city'. *Camb. J. Reg. Econ. Soc.* **2014**, *8*, 13–25. [CrossRef]
82. Hollands, R.G. Critical interventions into the corporate smart city. *Camb. J. Reg. Econ. Soc.* **2014**, *8*, 61–77. [CrossRef]
83. Kitchin, R. Making sense of smart cities: Addressing present shortcomings. *Camb. J. Reg. Econ. Soc.* **2014**, *8*, 131–136. [CrossRef]
84. Gabrys, J. Programming Environments: Environmentality and Citizen Sensing in the Smart City. *Environ. Plan. D Soc. Space* **2014**, *32*, 30–48. [CrossRef]
85. Datta, A. New urban utopias of postcolonial India: 'Entrepreneurial urbanization' in Dholera smart city, Gujarat. *Dialogues Hum. Geogr.* **2015**, *5*, 3–22. [CrossRef]
86. Cardullo, P.; Kitchin, R. Being a 'citizen' in the smart city: Up and down the scaffold of smart citizen participation in Dublin, Ireland. *GeoJournal* **2019**, *84*, 1–13. [CrossRef]
87. Press, G. Internet of Things by the Numbers: Market Estimates and Forecasts. Available online: https://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/?sh=3a909d41b919 (accessed on 3 February 2022).
88. Lien, L. Liveability in Singapore. Available online: https://www.worldscientific.com/page/9564-chap01 (accessed on 5 February 2022).
89. Alipour, A.; Ahmadalipour, A.; Moradkhani, H. Assessing flash flood hazard and damages in the southeast United States. *J. Flood Risk Manag.* **2020**, *13*, e12605. [CrossRef]
90. Fleming, S. This is how European Cities are Fighting Back Against Heatwaves. Available online: https://public.wmo.int/en/media/news/heavy-rains-and-flooding-hit-large-parts-of-asia (accessed on 1 December 2021).
91. Forzieri, G.; Bianchi, A.; Silva, F.B.e.; Marin Herrera, M.A.; Leblois, A.; Lavalle, C.; Aerts, J.C.J.H.; Feyen, L. Escalating impacts of climate extremes on critical infrastructures in Europe. *Glob. Environ. Chang.* **2018**, *48*, 97–107. [CrossRef]
92. Angelidou, M.; Psaltoglou, A.; Komninos, N.; Kakderi, C.; Tsarchopoulos, P.; Panori, A. Enhancing sustainable urban development through smart city applications. *J. Sci. Technol. Policy Manag.* **2018**, *9*, 146–169. [CrossRef]
93. Butler, L.; Yigitcanlar, T.; Paz, A. How Can Smart Mobility Innovations Alleviate Transportation Disadvantage? Assembling a Conceptual Framework through a Systematic Review. *Appl. Sci.* **2020**, *10*, 6306. [CrossRef]
94. Deloitte. Smart Cities Acing COVID-19 Response Using Smart Technology and Data Governance Solutions. Available online: https://www2.deloitte.com/content/dam/Deloitte/in/Documents/about-deloitte/in-about-deloitte-WEF-report-noexp.pdf (accessed on 4 February 2022).
95. Alberts, G.; Went, M.; Jansma, R. Archaeology of the Amsterdam digital city; why digital data are dynamic and should be treated accordingly. *Internet Hist.* **2017**, *1*, 146–159. [CrossRef]
96. United Nations Framework Convention on Climate Change. Documents of the Conference of the Parties COP1 Berlin 1995 (COP1). Available online: https://unfccc.int/cop4/resource/cop1.html (accessed on 8 August 2021).
97. United Nations Framework Convention on Climate Change. Kyoto Protocol to the United Nations Framework Conventon on Climate Change. Available online: https://unfccc.int/resource/docs/convkp/kpeng.pdf (accessed on 8 August 2021).
98. Nations, U. United Nations Framework Convention on Climate Change: Timeline. Available online: http://unfccc.int/timeline/ (accessed on 17 April 2018).
99. Haselip, J.; Hansen, U.; Puig, D.; Trærup, S.; Dhar, S. Governance, enabling frameworks and policies for the transfer and diffusion of low carbon and climate adaptation technologies in developing countries. *Clim. Chang.* **2015**, *131*, 363–370. [CrossRef]
100. Wen, L.; Kenworthy, J.; Guo, X.; Marinova, D. Solving Traffic Congestion through Street Renaissance: A Perspective from Dense Asian Cities. *Urban Sci.* **2019**, *3*, 18. [CrossRef]
101. UNFCCC. Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat. In Proceedings of the Conference of the Parties Serving as the Meeting of the Parties to the Paris Agreement, Glasgow, Scotland, 17 September 2021.
102. Bibri, S.E. On the Sustainability and Unsustainability of Smart and Smarter Urbanism and Related Big Data Technology, Analytics, and Application. In *Big Data Science and Analytics for Smart Sustainable Urbanism*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 183–220.
103. Bibri, S.E.; Krogstie, J. The emerging data–driven Smart City and its innovative applied solutions for sustainability: The cases of London and Barcelona. *Energy Inform.* **2020**, *3*, 5. [CrossRef]
104. Bibri, S.E.; Krogstie, J. Environmentally data-driven smart sustainable cities: Applied innovative solutions for energy efficiency, pollution reduction, and urban metabolism. *Energy Inform.* **2020**, *3*, 29. [CrossRef]

105. Mudombi, S.; Nzeyimana, E.; Weisheit, A. A Youth Perspective on Climate Change Opportunities and Challenges for Climate Resilient Development. In Proceedings of the Africa Adapt Climate Change Symposium, Addis Ababa, Ethiopia, 8–9 March 2011; ACADEMIA: San Francisco, CA, USA, 2011.
106. C40 Cities. Why Cities? Ending Climate Change Begins in the City. Available online: https://www.c40.org/ending-climate-change-begins-in-the-city (accessed on 23 February 2021).
107. United Nations. SAMOA PATHWAY: High-Level Midterm Review 2019. Available online: https://sustainabledevelopment.un.org/sids/samoareview (accessed on 8 August 2021).
108. Bataille, C.; Åhman, M.; Neuhoff, K.; Nilsson, L.J.; Fischedick, M.; Lechtenböhmer, S.; Solano-Rodriquez, B.; Denis-Ryan, A.; Stiebert, S.; Waisman, H.; et al. A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. *J. Clean. Prod.* **2018**, *187*, 960–973. [CrossRef]
109. Tilburg, X.V.; Lamboo, S.; Luijten, J.; Minderhout, S.; Emmrich, J.; Roeser, F. *Sector Decarbonisation Pathways from Different Angles: Technology, Modellling, Politics*; TNO Publication: Amsterdam, the Netherlands, 2019; p. 40.
110. United Nations framework Convention on Climate Change. Paris Agreement. Available online: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed on 8 August 2021).
111. UNEP. *Emerging Issues for Small Island Developing States*; UNEP: Nairobi, Kenya, 2014.
112. Habib, M.A.; Anik, M.A.H. Impacts of COVID-19 on Transport Modes and Mobility Behavior: Analysis of Public Discourse in Twitter. *Transp. Res. Rec.* **2021**, 03611981211029926. [CrossRef]
113. Ibold, S.; Medimorec, N.; Wagner, A.; Peruzzo, J.; Platzer, L. The COVID-19 Outbreak and Implications to Sustainable Urban Mobility—Some Observations. Available online: https://www.transformative-mobility.org/news/the-covid-19-outbreak-and-implications-to-public-transport-some-observations (accessed on 5 November 2020).
114. Donnelly, R.; Patrinos, H.A.; Gresham, J. The Impact of COVID-19 on Education—Recommendations and Opportunities for Ukrain. Available online: https://www.worldbank.org/en/news/opinion/2021/04/02/the-impact-of-covid-19-on-education-recommendations-and-opportunities-for-ukraine (accessed on 3 February 2022).
115. Osman, M.E. Global impact of COVID-19 on education systems: The emergency remote teaching at Sultan Qaboos University. *J. Educ. Teach.* **2020**, *46*, 463–471. [CrossRef]
116. James, P.; Das, R.; Jalosinska, A.; Smith, L. Smart cities and a data-driven response to COVID-19. *Dialogues Hum. Geogr.* **2020**, *10*, 255–259. [CrossRef]
117. Kumar, P.; Hama, S.; Omidvarborna, H.; Sharma, A.; Sahani, J.; Abhijith, K.V.; Debele, S.E.; Zavala-Reyes, J.C.; Barwise, Y.; Tiwari, A. Temporary reduction in fine particulate matter due to 'anthropogenic emissions switch-off' during COVID-19 lockdown in Indian cities. *Sustain. Cities Soc.* **2020**, *62*, 102382. [CrossRef]
118. DeWeese, J.; Ravensbergen, L.; El-Geneidy, A. Travel behaviour and greenhouse gas emissions during the COVID-19 pandemic: A case study in a university setting. *Transp. Res. Interdiscip. Perspect.* **2022**, *13*, 100531. [CrossRef]
119. Schulte-Fischedick, M.; Shan, Y.; Hubacek, K. Implications of COVID-19 lockdowns on surface passenger mobility and related CO_2 emission changes in Europe. *Appl. Energy* **2021**, *300*, 117396. [CrossRef]
120. Sikarwar, V.S.; Reichert, A.; Jeremias, M.; Manovic, V. COVID-19 pandemic and global carbon dioxide emissions: A first assessment. *Sci. Total Environ.* **2021**, *794*, 148770. [CrossRef] [PubMed]
121. Le Quéré, C.; Jackson, R.B.; Jones, M.W.; Smith, A.J.P.; Abernethy, S.; Andrew, R.M.; De-Gol, A.J.; Willis, D.R.; Shan, Y.; Canadell, J.G.; et al. Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement. *Nat. Clim. Chang.* **2020**, *10*, 647–653. [CrossRef]
122. Lambert, J. Emissions Dropped during the COVID-19 Pandemic. The Climate Impact Won't Last. Available online: https://www.sciencenews.org/article/covid-19-coronavirus-greenhouse-gas-emissions-climate-change (accessed on 3 February 2022).
123. Abdel-Razek, S.A. Governance and SDGs in smart cities context. In *Smart Cities and the un SDGs*; Visvizi, A., Hoyo, R.P.D., Eds.; Elsevier: Amsterdam, The Netherlands, 2021; pp. 61–70.
124. Argyriou, I. 9—The smart city of Hangzhou, China: The case of Dream Town Internet village. In *Smart City Emergence*; Anthopoulos, L., Ed.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 195–218.
125. European Commission. Questions & Answers: The Entry into Force of the Kyoto Protocol. Available online: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_04_245 (accessed on 8 August 2021).
126. Swabey, P. IBM, Cisco and the Business of Smart Cities. Available online: https://www.information-age.com/ibm-cisco-and-the-business-of-smart-cities-2087993/ (accessed on 21 July 2020).
127. United Nations Development Programme (UNDP). *Sustainable Development Goals*; UNDP: Geneva, Switzerland, 2015; p. 24.
128. Statista Research Deparment. Internet of Things-Number of Connected Devices Worldwide 2015–2025. Available online: https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/ (accessed on 3 February 2021).
129. Burhan, M.; Rehman, R.A.; Kim, B.-S.; Khan, B. IoT Elements, Layered Architectures and Security Issues: A Comprehensive Survey. *Sensors* **2018**, *18*, 2796. [CrossRef] [PubMed]
130. Braun, T.; Banjamin, C.M.F.; Iqbal, F.; Shah, B. Security and privacy challenges in smart cities. *Sustain. Cities Soc.* **2018**, *39*, 499–507. [CrossRef]
131. Yao, X.; Farha, F.; Li, R.; Psychoula, I.; Chen, L.; Ning, H. Security and privacy issues of physical objects in the IoT: Challenges and opportunities. *Digit. Commun. Netw.* **2021**, *7*, 373–384. [CrossRef]

132. Bibri, S.E. On the sustainability of smart and smarter cities in the era of big data: An interdisciplinary and transdisciplinary literature review. *J. Big Data* **2019**, *6*, 25. [CrossRef]
133. Nikitin, K.; Lantsev, N.; Nugaev, A.; Yakavleva, A. Data-Driven Cities: From Concept to Applied Solutions. Available online: http://docplayer.net/50140321-From-concept-to-applied-solutions-data-driven-cities.html (accessed on 3 February 2022).
134. Sutherland, M.K.; Cook, M.E. Data-Driven Smart Cities: A Closer Look at Organizational, Technical and Data Complexities. In Proceedings of the 18th Annual International Conference on Digital Government Research, Staten Island, NY, USA, 7–9 June 2017; pp. 471–476.
135. Kühne, B.; Heidel, K. How Could Smart Cities Use Data? -Towards a Taxonomy of Data-Driven Smart City Projects. In Proceedings of the 16th International Conference on Wirtschaftsinformatik, Duisburg und Essen, Germany, 9–11 March 2021; Elsevier: Amsterdam, The Netherlands, 2011.
136. Dornhöfer, M.; Weber, C.; Zenkert, J.; Fathi, M. A data-driven Smart City Transformation Model utilizing the Green Knowledge Management Cube. In Proceedings of the 2019 IEEE International Smart Cities Conference (ISC2), Casablanca, Morocco, 14–17 October 2019; pp. 691–696.
137. Heitlinger, S.; Bryan-Kinns, N.; Comber, R. The Right to the Sustainable Smart City. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, Glasgow, Scotland, 4–9 May 2019; p. 287.
138. Dixit, A.; Kumar Chidambaram, R.; Allam, Z. Safety and Risk Analysis of Autonomous Vehicles Using Computer Vision and Neural Networks. *Vehicles* **2021**, *3*, 36. [CrossRef]
139. Gambella, C.; Monteil, J.; Dekusar, A.; Cabrero Barros, S.; Simonetto, A.; Lassoued, Y. A city-scale IoT-enabled ridesharing platform. *Transp. Lett.* **2019**, *12*, 706–712. [CrossRef]
140. Stamatiadis, N.; Pappalardo, G.; Cafiso, S. Use of technology to improve bicycle mobility in smart cities. In Proceedings of the 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, Italy, 26–28 June 2017; pp. 86–91.
141. Yang, Y.; Wu, X.; Zhou, P.; Gou, Z.; Lu, Y. Towards a cycling-friendly city: An updated review of the associations between built environment and cycling behaviors (2007–2017). *J. Transp. Health* **2019**, *14*, 100613. [CrossRef]
142. Tonutti, M.; Elson, D.S.; Yang, G.Z.; Darzi, A.W.; Sodergren, M.H. The role of technology in minimally invasive surgery: State of the art, recent developments and future directions. *Postgrad. Med. J.* **2017**, *93*, 159–167. [CrossRef]
143. Gahren, I. How 3D Printing Is Revolutionizing Disaster Relief. Available online: https://www.tbd.community/en/a/how-3d-printing-revolutionizing-disaster-relief (accessed on 4 July 2021).
144. Savonen, B.L.; Mahan, T.J.; Curtis, M.W.; Schreier, J.W.; Gershenson, J.K.; Pearce, J.M.J.T. Development of a resilient 3-D printer for humanitarian crisis response. *Technologies* **2018**, *6*, 30. [CrossRef]
145. El Said, G.R. How Did the COVID-19 Pandemic Affect Higher Education Learning Experience? An Empirical Investigation of Learners' Academic Performance at a University in a Developing Country. *Adv. Hum. Comput. Interact.* **2021**, *2021*, 6649524. [CrossRef]
146. Wang, B.; Liu, Y.; Qian, J.; Parker, S.K. Achieving Effective Remote Working During the COVID-19 Pandemic: A Work Design Perspective. *Appl. Psychol.* **2020**, *70*, 16–59. [CrossRef] [PubMed]
147. Kummitha, R.K.R. Smart technologies for fighting pandemics: The techno- and human- driven approaches in controlling the virus transmission. *Gov. Inf. Q.* **2020**, *37*, 101481. [CrossRef]
148. Private Equity Wire. European Business P2P Lending Industry to Reach USD 6.5bn Value This Year. Available online: https://www.privateequitywire.co.uk/2020/03/24/284143/european-business-p2p-lending-industry-reach-usd65bn-value-year (accessed on 4 September 2021).
149. Allam, Z. The Emergence of Anti-Privacy and Control at the Nexus between the Concepts of Safe City and Smart City. *Smart Cities* **2019**, *2*, 96–105. [CrossRef]
150. Grossi, G.; Meijer, A.; Sargiacomo, M. A public management perspective on smart cities: 'Urban auditing' for management, governance and accountability. *Public Manag. Rev.* **2020**, *22*, 633–647. [CrossRef]
151. Bina, O.; Inch, A.; Pereira, L. Beyond techno-utopia and its discontents: On the role of utopianism and speculative fiction in shaping alternatives to the smart city imaginary. *Futures* **2020**, *115*, 102475. [CrossRef]
152. León, L.F.A.; Rosen, J. Technology as Ideology in Urban Governance. *Ann. Am. Assoc. Geogr.* **2020**, *110*, 497–506. [CrossRef]
153. McFarlane, C.; Söderström, O. On alternative smart cities. *City* **2017**, *21*, 312–328. [CrossRef]
154. Pereira, R.; Figueiredo, J.; Melicio, R.; Mendes, V.M.F.; Martins, J.; Quadrado, J.C. Consumer energy management system with integration of smart meters. *Energy Rep.* **2015**, *1*, 22–29. [CrossRef]
155. Webster, C.; Leleux, C. Smart governance: Opportunities for technologically-mediated citizen co-production. *Inf. Polity* **2018**, *23*, 95–110. [CrossRef]
156. Allam, Z.; Sharifi, A. Research Structure and Trends of Smart Urban Mobility. *Smart Cities* **2022**, *5*, 539–561. [CrossRef]

geographies

MDPI

Commentary

Addressing Knowledge Gaps for Global Climate Justice

Zaheer Allam [1,2,3,*], David S. Jones [4,5] and Phillip Roös [2]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW 2007, Australia
[2] Live+Smart Research Laboratory, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia; phillip.roos@deakin.edu.au
[3] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France
[4] Wadawurrung Traditional Owners Aboriginal Corporation, Geelong, VIC 3220, Australia; davidsjones2020@gmail.com
[5] Cities Research Institute, Griffith University, Nathan, QLD 4111, Australia
* Correspondence: zaheerallam@gmail.com

Abstract: The Conference of Parties (COP) 26 highlighted the need for global-level deep decarbonization and provided financial instruments to aid climate mitigation in the global south, as well as compensation avenues for loss and damage. This narrative reiterated the urgency of addressing climate change, as well as aiding advances in green products and green solutions whilst shifting a portion of responsibility upon the global south. While this is much needed, we argue that the science rhetoric driving this initiative continues to be advantageous to the global north due to their capacity to control consumption gaps and to access human knowledge and resource extraction. If not addressed, this will reinforce a continuing unjust north/south narrative, highlighting neo-climate colonialism precepts.

Keywords: climate justice; global north; global south; climate change; COP26; science; climate knowledge; mining

Citation: Allam, Z.; Jones, D.S.; Roös, P. Addressing Knowledge Gaps for Global Climate Justice. *Geographies* **2022**, *2*, 201–203. https://doi.org/10.3390/geographies2020014

Academic Editors: Luca Salvati and Xu Chen

Received: 14 March 2022
Accepted: 11 April 2022
Published: 14 April 2022

1. Introduction

Discussions at the Conference of Parties (COP) 26, supported by the latest findings from the IPCC, pointed to the urgent need for global deep decarbonization [1,2]. This is supported by the fact that if all countries committed to their nationally determined contributions (NDC), temperatures could still increase by as much as 2.7 °C, exceeding the Paris Agreement target of 2 °C, preferably 1.5 °C [3]. The Intergovernmental Panel on Climate Change (IPCC) further points to the need for deep rooted policies on climate mitigation and suggests possible pathways, painting a bleak picture if urgent actions are not pursued [1]. This will demand a new focus and an increasing need for new products that can respond to climate needs. With a growing consensus upon the subject from private sector agencies, it can be expected that a race for 'green products' and 'green solutions' will be witnessed to supply the demand for sustainability transitions and mechanisms. The design, purchase and implementation of those products and solutions, however, can be expensive. It will place further demand on access to expertise and raw materials that are inequitably distributed around the world, adding to the challenge of addressing the global north/south disparity. This is a key subject in attaining climate justice and just transitions. It must therefore be at the forefront of global discussions but must not be seen as a linear objective. So, while the subject of climate financing instruments and provisions for loss and damage as addressed in the Glasgow Climate Pact [2] have been well received, there is an equal need to look at the capacity of the global south in developing solutions for an upcoming 'green' race, there being a need for 'green' technology to satisfy increasing market demands.

Building capacity for the global south to provide its own solutions for its local problems is a valid means of empowerment. But this capacity building, which has sound economic merits, assumes cheaper product provision, nurturing knowledge quarters and niches, all of which can be 'exported' and 'traded' at a regional level to service the global north. We expect that post-COP26, this approach will emerge from global south territories to harvest opportunities brought about by the global north's reinforced need for deep decarbonization and sustainability transitions. This calls for the acceleration of innovation within both academia and industries and furthermore for urgent fiscal measures to reduce the price of 'green premiums' on sustainable products. Green premiums in this case refers to the increased margin for product development. As innovation is largely driven within techno-academic centers and industrial corporates, there will be a need to ensure that access to 'science' within all realms is made possible so that development of solutions can be accessible to all.

While this sounds logical, academics often stumble on 'pay-walls', where access to data and knowledge is expensive, and post-pandemic academia and knowledge in particular has been financially emasculated. While global north universities can afford subscription fees to students and researchers with access, this is still an issue in the global south [4]. Similarly, the global north controls the hardcopy and electronic knowledge publication institutions and vehicles, negating easy access by the global south. Additionally, providing access to data is only perceived as being free when authors bear the cost of 'Open Access' fees. However, those are often inaccessible to global south researchers, hence further limiting the dissemination of solutions and knowledge emerging from those geographies. The 'green race' will continue to provide economic opportunities for techno-academias and industrial corporates and will encourage private sector investment in innovation. One challenge in this area is that some 'green' solutions can have global applications and could therefore place global south technology providers in direct competition with those in the global north (albeit with more resources). Within this competition, will be potential disputes of Copyright and Intellectual Property for emerging products and ideas, that will cascade into patent races to capture economic opportunities. It is foreseen that some patents, submitted by parties in the global north, will limit the development of localized products in the global south. This issue will have to be addressed and could potentially be resolved via bilateral agreements between countries, acknowledging the global demand for green products, to ensure technology transfer with the prospect of servicing a larger customer base.

Cementing equitable agreements, where both the global south and north can be equal partners, will be a challenge when factoring in the investment and resource mining capacities of both. With the demand for rare earth minerals such as lithium, copper, cobalt, and others, underpinning the rise of power batteries, electronics, and global semi-conductor shortages will be determined by financial capacity as to who obtains the most economic and knowledge profits. Thus, while bilateral agreements may be seen as a 'quick-win', one must also look at reinforcing local capacities to ensure that local companies can better be better positioned to supply the growing global green market.

Local policies such as 'Green New Deals' can offer potent solutions in stimulating actions across different sectors [5,6]. These can be contextualized to equally support the production of 'green solutions', but the appropriate fiscal landscape must be present. Bill Gates, in his latest book [7], speaks about the issue of 'Green Premiums' and the need to provide solutions that are at par with the pricing of traditional solutions. Indeed, this will be a key challenge to address, and this can potentially be delivered through well-planned fiscal incentives, which can accelerate the speed of innovation while lowering the cost of production. Climate justice is gaining increasing interest of varied stakeholders, including academics, policy makers, and the broader public, but the larger implications for international cooperation and varied decision-making have only begun to receive empirical attention. Thus, our argument posits this subject as being a fairly new, but important, field [8].

In this respect, there is need to ponder on the ethical and moral global trade structures in line with the transition needs of global and emerging economies. Doing so, and ensuring that an equitable development agenda across geographies is achieved, while pursuing sustainability goals) will be paramount for our shared future. Therefore, there is a need to address climate justice as a multi-dimensional process. This is a theme, within climate discourses, that receives extensive noise and rhetoric to the needs for addressing 'emissions gap' [9], which is crucial in limiting emissions to reduce the impacts of global warming. However, there is also an equal need to recognize 'knowledge gaps' by the global south to contribute to this need. Without this, the ethical dimensions of climate change will be eluded, contributing to unjust foundational precepts, and leading to the continued precept of climate-colonialism by cementing the global south as perpetual customers of the global north for mitigation products (designed for a problem largely caused by the global north).

Author Contributions: Conceptualization, writing—original draft preparation, review and editing, Z.A., D.S.J. and P.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC. Climate Change 2021: The Physical Science Basis. In *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Geneva, Switzerland, 2021.
2. UNFCCC. *Glasgow Climate Pact*; UNFCCC: Bonn, Germany, 2021; pp. 1–10.
3. UNFCCC. *Nationally Determined Contributions under the Paris Agreement*; UNFCCC: Bonn, Germany, 2021.
4. Kanwar, A.; Kodhandaraman, B.; Umar, A. Toward Sustainable Open Education Resources: A Perspective From the Global South. *Am. J. Distance Educ.* **2010**, *24*, 65–80. [CrossRef]
5. Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. Green new deals could be the answer to COP26's deep decarbonisation needs. *Sustain. Horiz.* **2022**, *1*, 100006. [CrossRef]
6. Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals. *Sustainability* **2021**, *13*, 12529. [CrossRef]
7. Gates, B. *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*; Penguin Books Limited: London, UK, 2021.
8. Pearson, A.R.; Tsai, C.G.; Clayton, S. Ethics, morality, and the psychology of climate justice. *Curr. Opin. Psychol.* **2021**, *42*, 36–42. [CrossRef] [PubMed]
9. UNEP. *Emissions Gap Report 2020*; UN Environment Programme: Nairobi, Kenya, 2020.

Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-021-00937-0 OPEN

Check for updates

Introducing a global planetary ecosystem accounting in the wake of the Amazon Forest fires

Zaheer Allam [1,2,3]✉, David S. Jones[4,5] & Can Biyik[6]

Since the 19th century, rapid urbanisation coupled with a demographic boom has increased pressures on the global exploitation of natural resources leading to an array of issues at planetary scale. Even though there have been significant ecologically driven human policy efforts, with frameworks addressing ecosystem accounting and management, such are principally constricted at sub-global levels; being regionally focussed, and hence lacking both cohesivity and accountability. Resource management viewed through this lens leads to a number of geopolitical factors as demonstrated recently with the Amazon Forest fires. This incident witnessed calls from numerous countries calling for rapid remediation even though their own policies are harbingers of equally damaging the environments through other means. This disparity in resource accounting and management on a planetary scale is apparent from diverse local and regional groups and needs to be addressed in order to sustain a truly sustainable and liveable ecosystem and their failures in realising a viable ecosystem accounting system. This perspective paper explores this theme and proposes a 'Global Planetary Ecosystem Accounting' system based on the principle that ecologically sensitive areas benefiting the global ecosystem need to be economically weighted and its preservation equated to a revenue-generating activity.

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia. [2] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris – Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France. [3] Live +Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia. [4] Wadawurrung Traditional Owners Aboriginal Corporation, 86 Mercer Street, Geelong, VIC 3220, Australia. [5] Cities Research Institute, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia. [6] Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Ankara Yıldırım Beyazıt University, 06010 Ankara, Turkey. ✉email: zaheerallam@gmail.com

Introduction

> 'Tribes from the Amazon have called for urgent action to protect the world's largest rainforest in a formal motion to the International Union for Conservation of Nature (IUCN), to be considered at its global congress in France next month' [in September 2021] (Moloney, 2021).

We know that the Amazon Forests play a key role in mediating and regulating the Earth's climate by filtering, absorbing, and storing planet-heating carbon dioxide. Deforestation is largely fuelled by illegal logging and gold mining availed by landscape-scale fires, as well as land clearance and burning to enable soy and beef farming in Brazil to plant coco crops in Colombia and Peru. In moving the above motion, the Coordinating Body for Indigenous Organisations of the Amazon Basin (COICA), an IUCN Member, the COICA General Co-ordinator José Gregorio Diaz Mirabel has observed that with minimal political and economic voice, Indigenous Peoples from the Amazon Basin's nine countries often struggle to be heard on the global stage where decisions affect their lands and waters and receive little international funding. Diaz stated that 'The call we will make is that finance should go to Indigenous People who conserve and protect the territory' (Moloney, 2021). But, how do we as a society craft a multi-political boundary ecosystem accounting model to validate and support this endeavour?

The world has experienced an unprecedented increase in consumption, both of natural resources and artificially manufactured products, and these have had far-reaching ramifications. In particular, natural resources are under immense pressure due to wanton and uncontrolled exploitation, as well as from increased pollutions. This conclusionary thread draws upon the recent past evidence, in the shadow of this global exponential demographic boom and increased urbanisation rates, with the majority of the human population now seen to be preferring urban habitats. Statistics on these two phenomena are captured in an United Nation's report (United Nations, 2018a), which underscores that these two patterns have led to the conspicuous consumption of resources especially those related to water, energy, forests and marine resources. Tajrin and Hossain (2018) note that the consumption of these resources in cities is insatiable and that there is no foreseeable end to this devouring, noting that over 2/3 of the world's population is expected to find abodes in cities by 2050 (United Nations, 2018b).

The unfortunate truth about these trends is that they continually accentuate a disbalance on a global planetary scale, where large areas (especially 'natural' reserves) are being put at risk in the efforts to accommodate and settle densely populated urban areas, and the actions being taken on this are critically insufficient. We say 'natural' because all global landscapes have experienced the conscious or unconscious of the human hand in transforming, manipulating, or intergenerationally managing these tracts that are seemingly 'natural' today. Thus, 'landscape is a cultural construct, ['that largely manmade tapestry'], a mirror of our memories and myths encoded with meanings which can be read and interpreted' (Lowenthal, 1975; Taylor, 2017).

In particular, as Tu (2017) notes, of the many issues that emanate from this disbalance, global attention is seen to be passionately focused upon an emissions perspective and other dimensions that are equally important in sustaining thriving ecosystems are relegated to lower levels of concern. This is evidenced in the numerous calls from different researchers, both from regional and international spheres, calling for decarbonisation (IRENA, 2018; Kelsey and Meckling, 2018; Mazzucato and Semieniuk, 2018; USAID/NREL, 2018) and/or even planetary emission accounting systems (La Notte et al., 2019; Vargas et al., 2018), But there is little, or no, high level calls on other dimensions; even though they are of equal importance for sustaining human liveability (Ajani et al., 2013).

Thus, it is evident that recent calls about decarbonisation have not been universally embraced, especially in regard to the adoption of a conventional, cohesive ecosystem model. The friction here emanates from a number of issues including the lack of goodwill in having an integrated system that satisfies both ecological needs as well as economic dimensions. While this is globally understood, there are strong societal preferences in advance of ecological imperatives, leading to disbalances that are often criticised by different quarters advocating for singular motives. This friction is underpinned by geopolitical influences driving climate change, especially the narratives from powerful economies that are competing to take charge of the reigns of global power (Scott et al., 2016). In addition, some of those economies interpret decarbonisation and reduction of emissions as threats in disrupting their existing economic models and policies. Thus, there has been noticeable reticence, mainly from developed economies, for a global consensus on climate change agreements (Zhang et al., 2017). On the other hand, increasing societal pressures are leading to global movements, such as Greta Thunberg's 'Youth for Climate', calling for deep policy reversals, and aligning with the recommendations of the Intergovernmental Panel on Climate Change (IPCC, 2021). But, as these climate change and planetary ecosystem tensions continue, the consequence from applied inaction is becoming increasingly evident with far-reaching implications.

The Amazon Forest fires, in this context, offer an interesting case study. Even though this environmental change does not result from conscious climate change human activities, the Amazon traditionally plays a critical role in sustaining a healthy ecosystem through decarbonisation. The fires are a threat to this balance and oxygenation not only to that ecosystem but to the global ecosystem, therefore amplifying the calls by the global community for immediate action (Salazar-Lopez and Allen, 2019; Watts, 2019). Surprisingly, even though that these global community calls are paramount in seeking to protect the ecological stability of this water catching, they will carry little weight in the long run because they do not highlight a need to re-evaluate the current planetary ecosystem management regime. That is, the calls are mainly directed towards the need to address the fires. But, the central theme of the issue is unquestioned: which is, 'what is the economic potential of this natural resource?' Answering this may be an important factor in understanding the direct and indirect benefits and the opportunity costs of natural systems, and their place in immediate, medium- and long-term green economy policies. Additionally, this can help to better frame the economic responsiveness of the Brazilian Government regarding its local policies ill-aligning with national economic agendas leading towards more effective strategies for the safeguarding of the Amazon Forest from dangers linked to unfettered urban development and its associative resource exploitation needs.

Against the above background, this perspective paper explores the case of the Amazon Forest fires and approaches the thematic of natural resource preservation from an economic viewpoint. We would argue for the implementation of a 'Planetary Ecosystem Accounting' model that aims to economically incentivize governments to protect their natural resources primordial in sustaining the global ecosystem.

Planetary boundaries and ecosystem accounting

The subject of ecosystem accounting is not new. An analysis of literature suggests that since 2012, several international efforts have focused upon this endeavour, and also a United Nations-authored *System of Environmental-Economic Accounting* (SEEA) offering a 'a framework that integrates economic and environmental data to provide a more comprehensive and multipurpose view of the interrelationships between the economy and the environment and the stocks and changes in stocks of environmental assets, as they bring benefits to humanity' (UN, 2020). The SEEA was adopted in June 2021 (UN, 2014). The aim of SEEA is to promote the measurement of environmental activities in relation to their contributions to the economy.

Mäler et al. (2008) note that environmental accounting has been a key tool in assisting researchers to take stock of assets playing a primordial role in sustaining our ecosystem; such as forests, wilderness, wetlands, and others (Hein et al., 2016). Hein et al. argue that the process of ecosystem accounting not only helps to map assets but also offers a coherent and integrated measurement system to map the flow of different ecosystems services into the economy while taking into account related human activities. Further, Vačkářů and Grammatikopoulou (2018) highlight how ecosystem accounting is becoming an important tool in efforts toward sustainability and shifting banking so that economic assets serve as natural capital essential for ecosystem service delivery.

One notable limitation in ecosystem accounting is the absence of information on emissions alone in contrast to dimensions including biodiversity conservation and resource depletion (Mace et al., 2012). A review of literature on ecosystem accounting models, as summarised in Table 1, confirms this.

But, ecosystem accounting models traditionally capture both the physical and monetary data of different ecosystem assets, but little envelopes other dimensions like benefits and beneficiaries of the said assets. By doing this, as noted by Symbol of Statistics Canada (2018), accounting efforts can be expanded beyond geographical boundaries and structural limitations enabling their adoption. Bartelmus (2015) notes that an integrated approach, where different dimensions including emissions, depletion, and conservation efforts are considered together, is recommended especially in the formulation of policies of sustainable economic performance and growth related to ecosystems. According to Bartelmus, doing this would incorporate human well-being within accounting systems. Such is essential because humans play a key role in impacting the ecosystem, both in its degradation and in its conservation, especially when population growth and urbanisation are considered. Mace (2019) supports this by arguing that ecosystem accounting should not only entail the measurement of flows of goods and services and their quality and quantity from the ecosystem into the economy, but that ecosystem accounting should also recognise that ecosystem accounting entails natural capital which is malleable and adaptable that regrow, change and reorganize beyond specific geographical boundaries.

The idea of adopting physical boundaries in the thematic of ecosystem accounting has been viewed as facilitating easy data computation and analysis because data from particular regions can be considered independently. While there is applied practicality in seeking to align with geographical boundaries, some regions with more natural endowment can be seen as benefiting more than the others, and this has prompted region-specific legislations and structures, such as carbon trading or avian migration agreements. This underlines an inequitable distribution of resources towards natural capital and similarly unequal distribution of economic benefits. Both of these demonstrate the need to solve political boundary-specific challenges to ensure global equity. This convenience demands the sharing and merging of data from all regions. However, such an approach can complicate reliable methodologies for data collection between different regions, thereby negating the integration and formulation of a unified cohesive model that would otherwise serve all regions.

In support, Notte and Dalmazzone (2018) argue that most of the planetary ecosystem models, that exclude current ecosystem accounting approaches, are equally significant to ecosystem accounting approaches that incorporate emissions because they also contribute towards economic and human activities. Thus, Notte and Dalmazzone argue that changes in biodiversity composition, within a given region, impacts greatly upon different aspects of an economy including tourism, conservation, agricultural practices, and land use amongst others. For this reason, La Notte et al. (2019) conclude that extending the measurement boundaries and incorporating other dimensions in addition to emissions, would allow the establishment of a causality nexus between the ecosystem assets and the benefits accrued by both economic actors and households.

The case of the Amazon Forest fires

The case of the Amazon Forest fires and their consequences upon world climate and climate change is not new; rather our Western human memory is short (Blom, 2019).

Blom (2019) has provocatively argued that dramatic changes in the South American landscape management regimes long-intergenerationally manipulated and managed by its First

Table 1 Dimensions of ecosystem accounting.

Authors	Emissions	Conservation	Biodiversity	Socio-economic	Economic
Notte and Dalmazzone (2018)	X				
Ajani et al. (2013)	X				
Hein et al. (2016)	X	X			
UN (2018)	X	X	X		
Ellison et al. (2011)	X				
Bockstael et al. (2000)			X		X
Lomas and Giampietro (2017)		X			
Edens and Hein (2013)	X		X		
Zhou et al. (2016)	X			X	
Vallecillo et al. (2019)				X	X
Yang et al. (2018)		X	X		X
Cazalis et al. (2018)		X		X	
Ruijs et al. (2018)	X				
Eriksson (2018)	X				

Nations People's changes, collapsed due to Spanish and Portuguese colonialization activities, resulted in the great European climate crisis of the 1600s that triggered the transformation of the entire social and political fabric of Europe. Central to these changes was the military and biological invasion of the Amazon region and its surroundings. While formative clues of climate change appeared as early as the 1570s, by the end of the 16th century the temperatures in Europe plummeted by 2 °C, so drastically that Mediterranean harbours were covered with ice, birds literally dropped out of the sky, and 'frost fairs' were erected on a frozen Thames River—with kiosks, taverns, and even brothels that become a semi-permanent part of the city. This 'Little Ice Age' with its apocalyptic weather patterns destroyed entire harvests and incited mass human migrations giving rise to the growth of European cities, the appearance of early capitalism, and the vigorous stirrings of the Enlightenment (Miller, 2019). Such disruptions in First Nations People's intergeneration management of landscape also flowed into North America (Foster, 2012), and both contributed as also being affected by microclimate changes (Pyne, 1997, 2015).

In a different tract of geography, Gammage (2011) has pointed to the cessation of First Nations People's 'fire-stick farming' (Jones, 2012) management of the Australian continent—'the biggest estate on earth'—with the advent of British military and biological colonization activities in the 1820s–1860s period, in part due to their paranoia about fires destroying their squatting infrastructure and their prized sheep and cattle assets (Pyne and Cronon, 1998). The climate change effects were equally felt in the United Kingdom where temperatures again dropped, crop harvests were affected, inclement weather prevailed negating industrial aerial pollutant dispersal in part disguised the formative environmental and societal ravages of industrialization in central England and lower vale Scotland.

The Amazon Forest has been the subject of countless literary fiction narratives. Therefore, it is of no surprise that the recent fire incidents have caught global attention. This focus denotes the global importance of this tropical rain forest, taunted as the 'lungs' of the earth, given its capability to produce over 20% of the world's oxygen (O_2), and in its capacity to store substantial amounts of carbon dioxide (CO_2). The same forest is said to be home to over 20% of the global tree species in excess of any other forest in the world, and hosts more terrestrial wildlife, birds, and aquatic life than any other region of the world. Additionally, it is also considered to be the richest ecosystem in terms of natural resources, that are of international recognition. These values have, on the negative side, attracted substantial attention from human invaders with an aim to exploit and capitalize on this rich biodiversity for their own personal and/or corporate selfish benefits.

Tucker (1996) note that such exploitive trends date back to colonialism when European 'explorers' invaded the region and started exploiting its biodiversity resources (e.g., economic botany, horticulture, birds, etc.) dreams of gold (Au) and mythical empires, to supply insatiable European populace scientific pursuits and or collecting passions. More recently, the forest has been under immense pressure from corporate entities, business persons, politicians, and other groups who have perpetuated wanton degradation of the forest through illegal logging, illegal wildlife trade, and other environmental degrading practices (Cowie, 2017). Such degenerative practices are leading to increasing calls for environmental conservation or preservation, including voices from the younger generation who are witnessing first-hand the lost benefits of thriving natural ecosystems.

The forest has also experienced challenges from urbanisation, as more of the land is being cleared and converted into urban areas as local people settle near the forest and draw resources from it. Richards and VanWey (2016) showcase how such urbanisation trends are instigated by global demands for forest tradable products and these have prompted the creation of different infrastructures that allow for the extraction and transportation of resources to different global destinations. Noting this scenario, Sonter et al. (2017) argue that the natural capital and value harbored in the Amazon forest, especially in terms of natural minerals, has resulted in massive losses of the forest coverage, with over 9% of the forest cover being lost between 2005 and 2012. Most of this loss occurred as a consequence of land clearance to create space for mining activities and its associated infrastructure as well as to accommodate and service the increasing migrant transitory workers who want to partake in the numerous economic and human activities enabled by the forest resources.

The recent fires in the Amazon forests are just the tipping point for the numerous but rarely spoken about challenges that the forests have witnessed throughout their contemporary history. From diverse global centres, experts are attributing these fires to human-induced activities, while others are pointing an accusing finger to climate-change-induced environmental conditions. As shown in Figs. 1 and 2, the fires have spread rather rapidly, when this is compared to other fires from previous years, where this ravaged wilderness areas. The fast pace of fire dispersal and spread is additionally ecologically disruptive in its own right in negating the successional regenerational composition and response of this extant rich biodiversity. Woodward (2019) reports that the over 76,000 fire incidences in 2019 are almost double what was statistically experienced in 2018 alone which experienced only 40,000 fires. Therefore, Cammelli and Angelsen (2019) argue that these thousands of fires are causing irreversible damage not only in the forest's ecosystem but upon the region and also on a global scale. These forest ecosystem damages not only implicate the biodiversity and the environment but also implicate political spheres, where there is already evidence of escalating political tensions between international groups, nations, First Nations People's and local governments in combating the ravaging fires.

Disregarding the local and international geopolitical politics that this fire has sparked; the conventional argument has been that external politics should not interfere in local policies. As in local politics enable and supports economically to local welfare of both the communities and the forests (Meyer, 2019). In addition, the repeated international calls for speedy action, and unsolicited assistance being offered to the Brazilian government is internally criticized as being insincere, poli-exploitive, as most of the countries extending help, and advocating for forest protection, have equally been criticized as being the leaders of our emissions generation. Thus, they are subtly attempting to shift eco-responsibility to lesser more compliant voices in their efforts to combat global climate change. With this argument, it behoves the Brazilian government to establish and implement strengthened policies that focus on the conservation of the forests, as well as protecting the First Nations Peoples who live in the forests and the rich diversity of wildlife that teem inside this larger ecosystem.

Ensuring appropriate policy responses to conserving the Amazon Forest is apparent in terms of the preservation of cultural attributes and policies towards global public good and carbon sequestration. The quantitative analysis highlights that the opportunity cost can amount to an average of USD$797 per ha of land (Silva et al., 2019). However, it has been noted that investments to save the Amazon Forest fires can amount up to 50 times less (Lapola et al., 2018), positing that significant cost savings can be achieved in terms of alternative policies and that there is a need to review structures at both local and global levels.

As much as local policies work towards balancing economic growth and environmental conservation, the latter should take

Fig. 1 Space photograph for forest fires. Depicting intensity and rapid spread of fires in the Amazon Forest. Image by Stevens (2019), sourced from NASA's Earth Observatory, under a CC BY license.

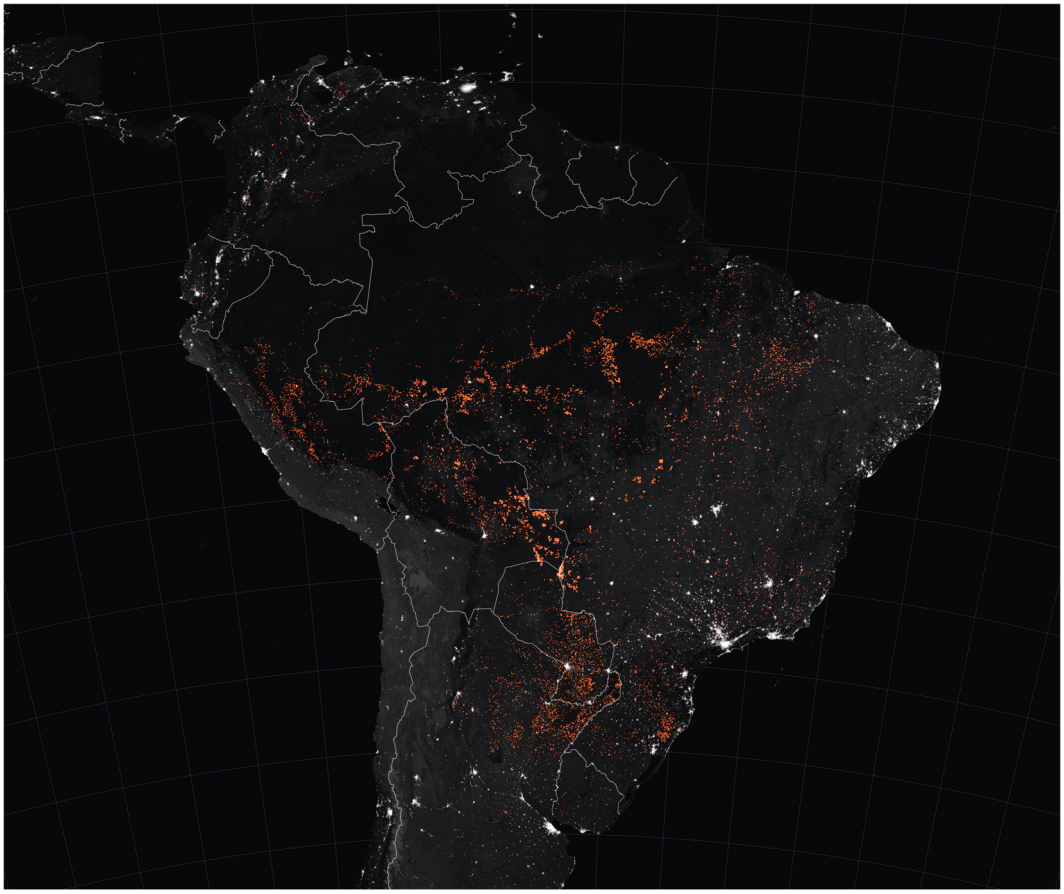

Fig. 2 Mapping of forest fires. Fire detections from August 15 to 22, from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). Image by Stevens (2019) and sourced from NASA's Earth Observatory, under a CC BY license.

precedence as the entire planetary ecosystem relies on its health and vitality. Such efforts could benefit from applying an integrated ecosystem accounting model that streamlines both economic and human benefits and considers the welfare of the larger planetary ecosystem.

The global ecosystem accounting model

An environment of disbalance is evident in polluting countries (those that are effectively contributing to climate change) who are seeking to influence the politics of least developing economies thereby passively and subtly attempting to economically control foreign sovereignties. Within this shadow, the responsiveness of the Brazilian government in rejecting 'foreign' assistance (BBC, 2019) is understood.

This is not saying that the Brazilian government denies, morally, the contribution of the forest to the planet's ecological systems and does not recognise the consequences thereof when the Amazon Forest is destroyed. But rather they are questioning the motivations as to why the financial assistance was being advanced in the first place. On face value, such a gesture should be welcomed, as the forests host priceless resources that merit obvious conservation efforts, but there are notable arguments in hindsight for this assistance. This is affirmed by far-right leader Brazilian president, Jair Bolsonaro, who argues that some of the members of the G7 Coalition (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States; France in particular) were more concerned about their agricultural competition 'war' with Brazil, and the economic calamity faced by G7 competition policies that are seeking to maintain their artificial competitiveness (Togoh, 2019). Recognizing that the G7 comprises some of the largest polluters, their financial support can be argued as arising from their internal economic concerns as such offers were tabled well past the advent of the forest fires. While it is also valid to state that these countries are also active consumers of some of the products derived from the rainforest, they do face internal political pressures emanating from pressures upon these countries' domestic markets. Nevertheless, there is a need for a more robust framework accompanied by active policies on planetary ecosystem management and conservation to ensure a more cohesive and globally sustainable approach.

Figure 3 introduces a Global Ecosystem Accounting Model. The concept supports an economic accounting of various assets to achieve ecosystem conservation, on the basis that developments could be hindered on ecologically important assets as there would be an economic value being paid to ensure their conservation. This is further discussed in the following section.

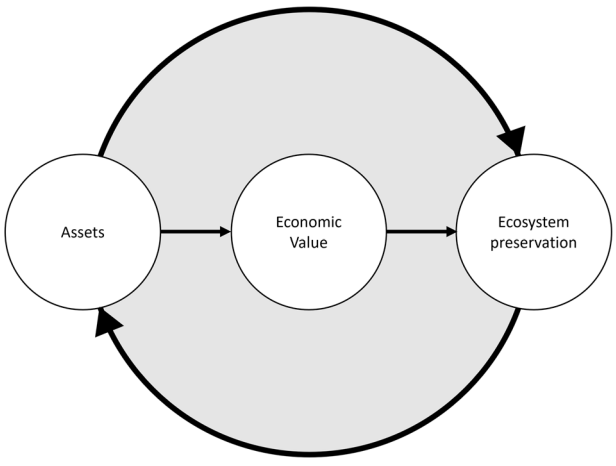

Fig. 3 Global ecosystem accounting model. Proposed model underlines that assets, provided with an economic value, can lead to ecosystem preservation. Illustration by authors, available for re-use.

Discussion

The above model is predicated upon the premise that every ecological asset that brings an added value to the global planetary ecosystem needs to be weighted economically. Thus, there is a need to construct a formula to ensure that conservation is the subject of contribution and global management agreements. This model departs from previous ecosystem accounting models by treating ecological assets as being localized. While past advocates and researchers have promulgated the need to find alternate ecosystem accounting models, few have unpacked and conceptualised an alternate model as discussed in this paper. The past advocates and researchers recognize that their accounting systems are limited to geographical boundaries, and thus, the global audience (or group of countries) has had little or no direct influence on conservation actions. However, the model proposal tabled here does not remove the authority of local governments in the management and conservation of natural resources within their jurisdictions. On the contrary, it opens doors for the global community to participate and take responsibility in the protection of these assets, which are part of the global planetary ecosystem principles.

Against the above background, local authorities would be discouraged or limited in allowing developments or engagements of different economic activities inside ecologically sensitive zones, as such would be compensated economically in protecting them. Ecologically sensitive zones require special attention as there are biodiversity niches containing key systems that are representative of past and existing biodiversity profiles but also are witnessing a natural evolutional change in response to both time and climate change. Such niches require additional valuable and weighted escalating scales rather than the conventional equal values. The compensation price tag aligns with the premise of a land lease agreement, where the ecological assets in question would be leased to a global entity, and recompensation paid on a regular basis. The positive aspect of this approach is that it would curtail any fraudulent practices, rent-seeking behaviour or political influence on the part of local governments when dealing with resources narrated as being 'of global importance' as the global community would have an influence on how activities in local ecosystems are conducted.

In the same vein, as noted above, the responsibility of protecting sensitive areas, like the Amazon Forests, would still be vested upon the shoulders of local authorities while still enabling the indirect participation of the global community. This approach thereby calls for the use of more efficient and advanced equipment, infrastructures and technologies, and with the global community being part of the participants these mechanisms would obviously be subsidized by global efforts. This is particularly important, especially in discouraging the illegal demand of ecological resources, like wildlife and their products, where there would be concerted efforts to negate illegal forms of trade within or outside the borders of the ecologically sensitive areas. The same approach would also allow local governments to capitalize on their ecological assets as these would be seen as revenue-generating areas and assets where a return in value would be borne by the global community.

This approach could further lead to reinforcing protection and on-ground 'policing' measures by local authorities towards illegal ecological resource extraction from protected areas. This is because, together with global actors, they would be able to

better address loopholes in regional policies which arise with trade between two or more jurisdictions and to delimit black markets that encourage illegal practices. On this, local governments would not feel short or undermined when global assistance is offered like what was evident in the recent case between the G7 coalition and the Brazilian Government (Marshall, 2019).

While the above is paramount, it should not be lost that the economic weightage of ecologically sensitive assets is a difficult topic to quantify (Ogilvy, 2015). For instance, with climate change, the values keep increasing as the impacts, mainly fueled by rapid urbanization and demographic booms, take a toll on those values (Rannow et al., 2014; Rohr et al., 2013). The economic quantification of these values is of a further challenge when recognizing that computing the impacts of climate change is not uniform across regions, rendering inconsistencies in valuation prices. Nevertheless, adopting a global economically inclined model, like the one proposed above, to natural resource management would lead to concrete and long-lasting solutions that could transcend physical boundaries and avoid geopolitical influences on foreign matters. Adopting the above planetary ecosystem accounting model could mean that ecological assets are valued almost uniformly across the globe. Hence, attention given to them would be similar regardless of the geographical location would receive global attention without being dragged or derailed by geopolitical influences or disagreements.

On a broader scale, when it comes to the planetary ecosystem and ecological assets, there is a need to adopt a global outlook, although may deem to be a local issue, always has far reaching impacts on the global context (Kattumuri, 2017). Recognising that there have been disasters in different global ecosystems, the Amazon Forest fires offer a precedent pointer as to how much the global ecosystem can be affected when the management and conservation efforts of ecological assets of global magnitudes are micro-managed without the input of the global community that benefits or suffers directly from any action or inaction on a major ecosystem. The rapid spread of the Amazon Forest fires has exposed the limitations of geographically based ecosystem accounting models and has prompted the need for models like the one proposed above to cater to a larger global context.

Conclusion

This paper explores the literature on ecosystem management and underlines how such existing tools prompt geopolitical influences, creating tensions, and putting at risk ecologically sensitive areas. The case of the Amazon Forest fires is explored within the context of a landscape of unfairness when sovereign-polluting countries advocate for environmental conservation external to their physical jurisdictional boundaries. Diaz's voice, quoted above, is a voice from the ground-level, but carries little weight in an upper-level controlled eco-political system, so such First Nation's People's voices need credible applied science to support and validate their long-standing intergenerational responsibilities. While this is historically a recurrent geopolitical issue, this paper offers a perspective on how natural resources and ecologically sensitive areas, that benefit the global community, can be more effectively managed and accounted for through a proposed Global Planetary Ecosystem Accounting Model that could better enable their conservation through the lens of a revenue-generating activity.

Received: 18 January 2021; Accepted: 12 October 2021;
Published online: 28 October 2021

References

Ajani JI, Keith H, Blakers M, Mackey BG, King HP (2013) Comprehensive carbon stock and flow accounting: a national framework to support climate change mitigation policy. Ecol Econ 89:61–72. https://doi.org/10.1016/j.ecolecon.2013.01.010

Bartelmus P (2015) Do we need ecosystem accounts? Ecol Econ 118:292–298. https://doi.org/10.1016/j.ecolecon.2014.12.026

BBC (2019) Amazon fires: Brazil to reject G7 offer of $22m aid. BBC News https://www.bbc.com/news/world-latin-america-49479470. Accessed 28 Aug 2019

Blom P (2019) Nature's Mutiny: how the little ice age transformed the west and shaped the present. Pan Macmillan

Bockstael N, Freeman AM, Kopp RJ, Portney PR, Smith VK (2000) On measuring economic values for nature. Environ Sci Technol 34:1384–1389

Cammelli F, Angelsen A (2019) Amazonian farmers' response to fire policies and climate change. Ecol Econ 165:106359. https://doi.org/10.1016/j.ecolecon.2019.106359

Cazalis V, Loreau M, Henderson K (2018) Do we have to choose between feeding the human population and conserving nature? Modelling the global dependence of people on ecosystem services. Sci Total Environ 634:1463–1474. https://doi.org/10.1016/j.scitotenv.2018.03.360

Cowie S (2017) Brazil's worst month ever for forest fires blamed on human activities. The Guardian https://www.theguardian.com/world/2017/sep/28/brazil-forest-fires-deforestation-september-record-amazon. Accessed 28 Aug 2019

Edens B, Hein L (2013) Towards a consistent approach for ecosystem accounting. Ecol Econ 90:41–52. https://doi.org/10.1016/j.ecolecon.2013.03.003

Ellison D, Lundblad M, Petersson H (2011) Carbon accounting and the climate politics of forestry. Environ Sci Policy 14(8):1062–1078. https://doi.org/10.1016/j.envsci.2011.07.001

Eriksson FA (2018) Denmark's Green National Accounting Framework in support of the sustainable development goals. Joint OECD/UNECE seminar on implementation of SEEA, Geneva

Foster WC (2012) Climate and culture change in North America AD 900–1600. University of Texas Press

Gammage B (2011) The Biggest Estate on Earth: how Aborigines made Australia. Allen & Unwin

Hein L, Bagstad K, Edens B, Obst C, de Jong R, Lesschen JP (2016) Defining ecosystem assets for natural capital accounting. PLoS ONE 11(11):e0164460. https://doi.org/10.1371/journal.pone.0164460

IPCC (2021) Climate Change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

IRENA (2018) Global energy transformation: a roadmap to 2050. International Renewable Energy Agency

Jones R (2012) Fire-stick farming. Fire Ecol 8(3):3–8. https://doi.org/10.1007/BF03400623

Kattumuri R (2017) Sustaining natural resources in a changing environment: evidence, policy and impact. Contemp Soc Sci 13(1):1–16. https://doi.org/10.1080/21582041.2017.1418903

Kelsey N, Meckling J (2018) Who wins in renewable energy? Evidence from Europe and the United States. Energy Res Soc Sci 37:65–73

La Notte A, Vallecillo S, Marques A, Maes J (2019) Beyond the economic boundaries to account for ecosystem services. Ecosyst Serv 35:116–129. https://doi.org/10.1016/j.ecoser.2018.12.007

Lapola DM, Pinho P, Quesada CA, Strassburg BBN, Rammig A, Kruijt B, Brown F, Ometto JPHB, Premebida A, Marengo JA, Vergara W, Nobre CA (2018) Limiting the high impacts of Amazon forest dieback with no-regrets science and policy action. Proc Natl Acad Sci USA 115(46), 11671. https://doi.org/10.1073/pnas.1721770115

Lomas PL, Giampietro M (2017) Environmental accounting for ecosystem conservation: linking societal adn ecosystem metabolisms. Ecol Model 346:10–19. https://doi.org/10.1016/j.ecolmodel.2016.12.009

Lowenthal D (1975) Past time, present place: landscape and memory. Geogr Rev 65(1):1–36. https://doi.org/10.2307/213831

Mace GM (2019) The ecology of natural capital accounting. Oxf Rev Econ Policy 35(1):54–67. https://doi.org/10.1093/oxrep/gry023

Mace GM, Norris K, Fitter AH (2012) Biodiversity and ecosystem services: a multilayered relationship. Trends Ecol Evol 27(1):19–26

Mäler G, Aniyar S, Jansson A (2008) Accounting for ecosystem services as a way to understand the requirements for sustainable development. Proc Natl Acad Sci USA 105(28), 9501–9506 https://doi.org/10.1073/pnas.0708856105

Marshall E (2019) Bolsanaro says Macron must take back 'insults' for Brazil to accept 57 Amazon aid. Telegraph https://www.telegraph.co.uk/news/2019/08/27/brazil-rejects-g7-aid-amazon-fires-saying-funds-relevant-reforest/. Accessed 28 Aug 2019
Mazzucato M, Semieniuk G (2018) Financing renewable energy: Who is financing what and what it matters. Technol Forecast Soc Change 127:8–22. https://doi.org/10.1016/j.techfore.2017.05.021
Meyer R (2019) The Amazon cannot be recovered once it's gone. Atlantic https://www.theatlantic.com/science/archive/2019/08/amazon-fires-are-political/596776/. Accessed 28 Aug 2019
Miller P (2019) Climate change and human history. N Y Times https://www.nytimes.com/2019/03/05/books/review/philipp-blom-natures-mutiny.html. Accessed 23 Aug 2021
Moloney A (2021) Tribes launch bid to protect Amazon forest at global conservation forum. Age https://www.theage.com.au/world/south-america/tribes-launch-bid-to-protect-amazon-forest-at-global-conservation-forum-20210827-p58mkt.html. Accessed 29 Aug 2021
Notte AL, Dalmazzone S (2018) Sustainability assessment and causality nexus through ecosystem service accounting: the case of water purification in Europe. J Environ Manag 223:964–974. https://doi.org/10.1016/j.jenvman.2018.06.072
Ogilvy S (2015) Developing the ecological balance sheet for agricultural sustainability. Sustain Account Manag Policy J 6(2):110–137. https://doi.org/10.1108/SAMPJ-07-2014-0040
Pyne SJ (1997) Vestal fire an environmental history, told through fire, of Europe and Europe's encounter with the world. University of Washington Press
Pyne SJ (2015) Between two fires a fire history of contemporary America. University of Arizona Press
Pyne SJ, Cronon W (1998) Burning bush: a fire history of Australia. http://site.ebrary.com/id/11137376
Rannow S, Mcgregor NA, Albrecht J, Crick HQ, Forster M, Heiland S, Janauer G, Morecroft MD, Neubert M, Sarbu A, Sienkiewicz J (2014) Managing protected areas under climate change: challenges and priorities. Pubmed 54(4):732–743. https://doi.org/10.1007/s00267-014-0271-5
Richards P, VanWey L (2016) Where deforestation leads to urbanization: how resource extraction is leading to urban growth in the Brazilian Amazon. HHS Public Access 105(4):806–823. https://doi.org/10.1080/00045608.2015.1052337
Rohr JR, Johnson P, Hickey CW, Helm RC, Fritz A, Brasfield S (2013) Implications of global climate change for natural resource damage assessment, restoration, and rehabilitation. Environ Toxicol Chem 32(1):93–101. https://doi.org/10.1002/etc.2036
Ruijs A, Van der Heide M, Van den Berg J (2018) Natural capital accounting for the sustainable development goals. P.N.E.A. Agency
Salazar-Lopez L, Allen L (2019) We are facing a global emergency in the Amazon. Here's what we can do. CNN. https://edition.cnn.com/2019/08/24/opinions/global-emergency-in-the-amazon-salazar-lopez-allen/index.html. Accessed 28 Aug 2019
Scott D, Hall CM, Gössling S (2016) A report on the Paris Climate Change Agreement and its implications for tourism: why we will always have Paris. J Sustain Tour 24(7):933–948
Silva FdF, Perrin RK, Fulginiti LE (2019) The opportunity cost of preserving the Brazilian Amazon forest. Agric Econ 50(2):219–227. https://doi.org/10.1111/agec.12478
Sonter LJ, Herrera D, Barrett DJ, Galford GL, Moran CJ, Soares-Filho BS (2017) Mining drives extensive deforestation in the Brazilian Amazon. Nation Commun 8(1):1013. https://doi.org/10.1038/s41467-017-00557-w
Stevens J (2019) Uptick in Amazon fire activity in 2019. NASA Earth Observatory. https://earthobservatory.nasa.gov/images/145498/uptick-in-amazon-fire-activity-in-2019. Accessed 29 Aug 2021
Symbol of Statistics Canada (2018) Ecosystem accounting. Symbol of statistics Canada. https://www150.statcan.gc.ca/n1/pub/16-509-x/2016001/7-eng.htm. Accessed 28 Aug 2021
Tajrin S, Hossain B (2018) Rural-Urban migration and its causes and consequences on Migrant Street Hawker in Khulna City. Int J Humanit Soc Stud 7:223–236
Taylor K (2017) Landscape, culture and heritage. Changing perspectives in an Asian context. Ph.D. thesis, Deakin University
Togoh I (2019) Brazilian President Blames political motives for Amazon Fires as Macron warns 'our house is burning'. Forbes. https://www.forbes.com/sites/isabeltogoh/2019/08/23/bolsonaro-blames-political-motives-for-amazon-fires-as-macron-warns-our-house-is-burning-down/#3272c2ca24d5. Accessed 28 Aug 2019
Tu Y (2017) Urban debates for climate change after the Kyoto Protocol. Urban Stud 55(1):3–18. https://doi.org/10.1177/0042098017717363.
Tucker CM (1996) Traditional peoples and the struggle for land in the Amazon Basin. Arizona Anthropol 12:123–149
UN (2014) System of environmental-economic accounting 2012 Central Framework. W. B. United Nations
UN (2018) The role of the system of environmental-economic accounting as a measurement framework in support of the post-2020 Agenda. S.o.E.E. Accounting
UN (2020) How natural capital accounting contributes to integrated policies for sustianability. https://seea.un.org/sites/seea.un.org/files/seea_-_overview_-_web_ready.pdf
United Nations (2018a) The World's Cities in 2018—Data Booklet. United Nations
United Nations (2018b) World urbanization prospects—the 2018 revision. Population Division, United Nations
USAID/NREL (2018) Greening the grid: Solar and Wind Grid Integration Study for the Luzon-Visayas System on the Philippines. USAID/NREL
Vačkářů D, Grammatikopoulou I (2018) Toward development of ecosystem asset accounts at the national level. Ecosyst Health Sustain 5(1):36–46. https://doi.org/10.1080/20964129.2018.1560233
Vallecillo S, La Notte A, Zulian G, Ferrini S, Maes J (2019) Ecosystem services accounts: valuing the actual flow of nature-based recreation from ecosystems to people. Ecol Model 392:196–211. https://doi.org/10.1016/j.ecolmodel.2018.09.023
Vargas L, Willemen L, Hein L (2018) Linking planetary boundaries and ecosystem accounting, with an illustration for the Colombian Orinoco river basin. Reg Environ Change 18(5):1521–1534
Watts J (2019). Amazon rainforest fires: global leaders urged to divert Brazil from 'suicide' path. Guardian. https://www.theguardian.com/environment/2019/aug/23/amazon-fires-global-leaders-urged-divert-brazil-suicide-path. Accessed 28 Aug 2019
Woodward A (2019). The Amazon is burning at a rate not seen since we started keeping track. The smoke is reaching cities 2000 miles away. Business Insider. https://www.pulselive.co.ke/bi/tech/the-amazon-is-burning-at-a-rate-not-seen-since-we-started-keeping-track-the-smoke-is/xz3pyb5. Accessed 28 Aug 2019
Yang Q, Liu G, Casazza M, Campbell ET, Giannetti BF, Brown MT (2018) Development of a new framework for non-monetary accounting on ecosystem services valuation. Ecosyst Serv 34:37–54. https://doi.org/10.1016/j.ecoser.2018.09.006
Zhang Y-X, Chao Q-C, Zheng Q-H, Huanga L (2017) The withdrawal of the U.S. from the Paris Agreement and its impact on global climate change governance. Adv Clim Change Res 8(4):213–219. https://doi.org/10.1016/j.accre.2017.08.005
Zhou Z, Ou J, Li S (2016) Ecological accounting: a research review and conceptual framework. J Environ Prot 07:643–655. https://doi.org/10.4236/jep.2016.75058

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to Zaheer Allam.

Reprints and permission information is available at http://www.nature.com/reprints

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Sustainable Horizons 1 (2022) 100006

Contents lists available at ScienceDirect

Sustainable Horizons

journal homepage: www.elsevier.com/locate/horiz

Green new deals could be the answer to COP26's deep decarbonisation needs

Zaheer Allam[a,b,c,*], Ayyoob Sharifi[d], Damien Giurco[a], Samantha A. Sharpe[a]

[a] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia
[b] Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia
[c] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris – Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, Paris 75013, France
[d] Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan

ARTICLE INFO

Keywords:
COP26
Decarbonization
Green new deals
Climate change
Sustainability
Paris agreement
Global prosperity

ABSTRACT

The 2021 Conference of Parties (COP) 26 was expected as a landmark meeting, noting the increased impacts of climate change and the subsequent warning reports by the Intergovernmental Panel on Climate Change (IPCC) and that of the United Nations Framework Convention on Climate Change (UNFCCC). With global temperatures gradually increasing, COP26 underlined the need for deeper commitments, fueling a race to decarbonization. However, Nationally Determined Contributions (NDCs), where countries make their climate pledges, do not reflect the need for just transition models with dimensions of inclusivity and economic equity in mind. A measure that can emerge at national levels post-COP26 is 'Green New Deals,' which can respond to contextual needs while accelerating sustainability transitions with social protection frameworks if carefully designed. With proper structuring, while taking into account immediate, short- and medium-term goals, Green New Deals can be designed as a critical tool to ensure the attainment of sustainability agendas while pursuing social and economic justice.

Climate talks have been ongoing for three decades since the first Conference of Parties (COPs) in 1992, but negative climate impacts continue to increase both in terms of frequency and intensity. The United Nations Framework Convention of Climate Change (UNFCCC) points out that if all countries commit to their Nationally Determined Contributions (NDC), temperatures could still increase by as much as 2.7 °C (UNFCCC 2021), exceeding the Paris Agreement target of 2 °C, preferably below 1.5 °C. This will demand deep decarbonization and adequate financing needs. Still, it is now understood that wealthy governments will not be fulfilling their pledge of USD 100 billion, aimed at helping developing economies in their pursuit of climate mitigation programs, until at least 2023 (OECD 2021), while it was initially proposed in 2009 and captured in the Paris Agreement (Article 9). The initial target was for the developed economies to raise at least $100 billion by 2020, but, as reported by the OECD (OECD 2020), only $78 billion was noted to have been raised by the end of 2019.

With the frequency and intensity of climate events such as storm surges, flash floods, desertification, and droughts, among others, is on the rise, Developing, Least Developed Countries (LDCs) and Small Island Developing States (SIDS) continue to be exposed. These challenges continue to impact the livelihood of communities in those economies. The resilience gap between these and developed economies can be huge, while developed economies are the largest carbon emitters (Ari and Sari, 2017) that induced climate changes. The inequitable resilience levels contributed to increasing climate migrations. For instance, the number of climate migrants had risen by over 30.7 million by the end of 2020 (UNEP 2014). Additionally, in contrast with the Global North, which has financial means and capacities, SIDS experienced at least four times the costs of infrastructure investments due to high dependency on the importation, prompted by limited inland resources, and low resilience levels climate change (Mycoo and G.Donovan, 2017). This then points to a disproportionally high budgetary need to warrant investing in projects that match anticipated climate risks, as well as capacities to promote adaptability, resilience, and economic growth.

The challenges for building economic resilience are made more complex when computing the realities of COVID-19, prompting a need for new strategies. The World Meteorological Organization (World Meteorological Organization 2021) highlights that during the height of the pandemic in 2020, emissions had significantly reduced due to widespread global lockdowns and reduced economic activities. However, as countries eased restrictions and gradually resumed economic activities, an increase in emission levels was noted, reaching an all-time

* Corresponding author.
E-mail address: zaheerallam@gmail.com (Z. Allam).

https://doi.org/10.1016/j.horiz.2022.100006
Received 26 November 2021; Received in revised form 6 January 2022; Accepted 9 January 2022

Fig. 1. The European Union's Green New Deal. Showcasing cross-cutting objectives while sustaining green growth and sustainable transitions. Illustration by Authors.

high –far above the average reported in the past decade. While the steep emissions increase is being argued to result from activities supporting economic growth, this perception is gnawed long-term. With the impacts of climate change projected to continue increasing in the coming years, accumulated wealth would be at risk if sustainable practices are not incorporated in economic recovery programs, posing a direct threat to economic growth.

The COP26 came at a critical moment where deep decarbonization is required. At a time, countries were engaging in economic recovery agendas, including reconceptualizing resource use in circular economy models (Allam, 2020). Beyond the need for universally agreed economic models, such as fiscal models for regeneration and common areas such as the Blue Economic model for coastal economies and the Silver Economy for rapidly aging areas, there will be a need to ponder community-centric economic models. This approach will aid in creating ownership of projects and aid in their success as sustainability approaches must be embraced at all levels. Currently, NDCs only represent emissions reduction and do not factor in this scaled approach. Hence, it could be argued to be dissociated with social frameworks. To ensure that economic resilience is inclusive and equitable, it will thus be paramount to ensure that recovery models (from both climate and the COVID-19 pandemic) align with NDC targets while also including social frameworks, as this will prompt community acceptability and ensure that wealth and green jobs are equally distributed, leading to economic stability and growth.

Green New Deals (GND) can be positioned as a potent model to pursue green growth. It simultaneously pursues economic growth, societal resilience, and community empowerment while addressing the core challenges of sustainability transitions. Regarding this, GNDs can be defined as a resolution agreed by either governments, institutions, or organizations to mobilize different aspects of economies and societies to ensure the transition to cleaner energy, production, and operation of varying human activities while increasing job opportunities for all people via a guarantee for social protection by authorities (Allam et al., 2021). As of 2021, a variety of GNDs existed, varying dynamics. An example of such is the European Union's GND Model illustrated in Figure 1 below, which showcases the breadth of scope that the model can be made to approach. Similarly, other geographies can implement such strategies regarding contextual needs, where policies can be made to respond to localized socio-economic needs while collectively building towards global emissions reduction targets.

The GND concept has gained traction in the last decade, with different regions formulating their versions. However, it is appreciated that the concept started to gain global popularity in 2008 after the United Nations announced a global Green Deal (Barbier, 2009). Following this, former United States President Barack Obama 2008 attempted, with no success, to introduce a GND for the U.S in 2008. However, in 2019, Representative Ocasio-Cortez and Senator Markey championed the policy and successfully advocated for its passing, which could be credited to the efforts of the civil societies firmly demanding an economic paradigm shift (Conte, 2019). In other jurisdictions such as Europe, the GND concept has gained similar popularity, especially with the proposal for the EU region to embrace and adopt a circular economy model, incorporating the aspects of a GND (European Commission 2019).

The popularity of GNDs is due to the promise of addressing sustainability agendas and focusing on social and economic justice, side-lined in linear economic and climate action discourses. With a solid cross-cutting approach, GNDs are structured to favour rapid transition frameworks, including the popular area of energy, focusing on the phasing out of fossil fuels to lower emissions. The U.S. GND version, for instance, proposes the need to make fossil fuels unattractive by rising fuel prices, akin to approaches like carbon taxation and carbon offsets (Fischer and Jacobsen, 2021). While the latter is subject to contemporary debates about its moral purpose in business milieus, it will play a key role in bringing financial capacities to southern geographies, should the concept be extended to other economies. GNDs can further be crafted to encourage governments to undertake Research and Development (R & R&D) in green technologies to supply the upcoming market demand in many sectors, such as renewable energies, housing, and others. Interestingly, in the European GND, the target transcends national boundaries and instead cements a regional aim of achieving net-zero emissions by 2050 (European Commission 2019). This is to be completed by ensuring that economic growth is decoupled from resource use and by addressing socioeconomic issues via extensive jobs creation and increased supply of basic amenities like food and clean water and quality healthcare, to name a few. This perspective is interesting, as it highlights possibilities for country-specific GND policies aligning with regional net-zero objectives while ensuring healthy and sustainable cross-border transactions, being key to ensure that geopolitical balances are maintained.

While varying versions of GNDs are geared to become successful shortly, thus, boosting climate actions in different regions, a few areas

would still need to be furnished to increase their global acceptability. First, country and region-specific GND policies would need to be emphasized to ensure that most local challenges' solutions emanate from communities themselves rather than from being proposed by governments. This would provide room for the bottom-up approaches being championed within economic recovery programs in different geographies. By so doing, this will have positive bearings on how limited financial resources are to be utilized; by specifically pressing programs that would have both short-term and long-term impacts on the livelihoods of local communities and how fiscal mechanisms could be used in an equitable way to revitalize local economic landscapes. Without considering this, GNDs may face the threat of being categorized as neo-capitalist philosophical discourse aimed at dictating policy on financially constrained economies. It would further be a strategy to extend the existing inequality gap between different geographical locations and regions. However, suppose the GNDs are to be crafted to embrace an inclusive approach, supporting the formulation, and structuring of country-specific GNDs. In that case, it will be possible to align shareholder and stakeholder interest and further attract the private sector. This way, it will be possible to secure larger financial capacities to support R&D programs required for the development of green technologies and to invest in climate mitigation programs via Public-Private Partnership (PPP) ventures.

Addressing equitable Public-Private financial needs is essential as sustainability transitioning is an expensive undertaking and a potentially disruptive one (Táíwò, 2019; Chatzky and Siripurapu, 2021). Carefully crafted GNDs can thus be positioned as a powerful solution at the national level while promoting economic justice through social frameworks and meeting national, regional, and global targets. This would, however, demand political support across the board. The popularity of the American version reflects this, as even though the proposal could be argued to address both economic and social justice, it received sharp criticisms from republicans (Bloomfield and Steward, 2020), outlining that sustainability transitions may suffer from political polarisation. It would thus be essential to approach sustainability as a cross-cutting theme, beyond politics, and from a multi-scaled lens.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Allam, Z., Sharifi, A., Giurco, D., Sharpe, S.A., 2021. On the theoretical conceptualisations, knowledge structures and trends of green new deals. Sustainability 13, 12529.

Allam, Z. in Surveying the Covid-19 pandemic and its implications (ed Zaheer Allam) 97-105 (Elsevier, 2020).

Ari, I., Sari, R., 2017. Differentiation of developed and developing countries for the Paris agreement. Energy Strat. Rev. 18, 175–182. doi:10.1016/j.esr.2017.09.016.

Barbier, E.B., 2009. Rethinking the Economic Recovery: A Global Green New Deal. UNEP, Wyoming.

Bloomfield, J. & Steward, F. The politics of the green new deal. 91, 770-779, doi:10.1111/1467-923X.12917 (2020).

Chatzky, A. & Siripurapu, A. Envisioning a green new deal: a global comparison, <https://www.cfr.org/backgrounder/envisioning-green-new-deal-global-comparison> (2021).

Conte, N. Green new deal, <https://wtpartnership.co/green-new-deal/> (2019).

European Commission. The European green deal: questions & answers, <https://ec.europa.eu/commission/presscorner/detail/en/QANDA_19_6690> (2019).

Fischer, C. & Jacobsen, G. D. The green new deal and the future of carbon pricing 40, 988-995, doi:10.1002/pam.22313 (2021).

Mycoo, M. & G.Donovan, M. A blue urban agenda: adapting to climate change in the coastal cities of the Caribbean and pacific small island developing states (Inter-American Development Bank, New York, NY, 2017).

OECD. Climate finance for developing countries rose to USD 78.9 billion in 2018 <https://www.oecd.org/newsroom/climate-finance-for-developing-countries-rose-to-usd-78-9-billion-in-2018oecd.htm> (2020).

OECD. Forward-looking scenarios of climate finance provided and mobilised by developed countries in 2021-2025. (2021).

Táíwò, O. m. O. How a green new deal could exploit developing countries, <https://theconversation.com/how-a-green-new-deal-could-exploit-developing-countries-111726> (2019).

UNEP. Emerging issues for small island developing states. (UNEP, Nairobi, Kenya, 2014).

UNFCCC. Nationally determined contributions under the Paris agreement. (2021).

World Meteorological Organization. The state of greenhouse gases in the atmosphere based on global observations through 2020. (World Meteorological Organization, 2021).

Dr. Zaheer Allam is a Research Candidate at the Institute of Sustainable Futures at the University of Technology Sydney. He holds a Ph.D. in Humanities, a Master of Arts (Res) in Political Economy, an MBA, and a Bachelor of Applied Science in Architectural Science from universities in Australia and the United Kingdom. Based in Mauritius, is the Chairperson of the National Youth Environment Council, Board Member of the Mauritius Renewable Energy Agency, the African Representative of the International Society of Biourbanism (ISB), member of the Advisory Circle of the International Federation of Landscape Architects (IFLA), and a member of several other international bodies. For his contributions to society, he holds numerous awards and commendations. He authored over 90 peer-reviewed publications and seven books about Sustainable, Smart, and Future Cities.

sustainability

MDPI

Review

On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals

Zaheer Allam [1,2,3,*], Ayyoob Sharifi [4], Damien Giurco [1] and Samantha A. Sharpe [1]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia; Damien.Giurco@uts.edu.au (D.G.); Samantha.sharpe@uts.edu.au (S.A.S.)
[2] Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong 3220, Australia
[3] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, 75013 Paris, France
[4] Graduate School of Humanities and Social Sciences & Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima 739-8511, Japan; sharifi@hiroshima-u.ac.jp
* Correspondence: zaheerallam@gmail.com

Abstract: The increasing impacts of climate change, coupled with the Greta Thunberg effect, the findings of the Intergovernmental Panel on Climate Change (IPCC) reports, and varied environmental policy documents, are pointing to the need for urgent and cohesive climate action and mitigation frameworks. One potent solution, gaining global acceptance, is that of the Green New Deal (GND), positioned as a radical rethinking of political and economic structures in view of pushing sustainability at the forefront of national, regional, and global issues. With the model rapidly gaining ground in various geographies, and in different forms in view of contextualization needs, there is a need to better understand its evolution, knowledge structures, and trends. This paper thus sets forth to provide an understanding of the evolution and implementation of GND through a bibliometric analysis and science mapping techniques using VOSviewer and CiteSpace to identify the thematic focus of 1174 articles indexed in the Web of Science since 1995. To understand the thematic evolution of the field over time, we divided the study period into three sub-periods, namely 1995–2014, 2015–2019, and 2020–2021. These sub-periods were determined considering important milestones related to GNDs. Term co-occurrence analyses were then conducted to understand thematic focus and associated trends. Also, co-citation analysis and bibliographic coupling were other methods applied to identify major sources, authors, publications, and countries that have made more contributions to the development of research on GNDs. The findings of this paper can help both researchers and policy makers understand the evolution and trends of GNDs to better formulate GNDs strategies and policies in accordance with varying needs and geographies.

Keywords: green new deal; green growth; bibliometric analysis; environmental policy; decarbonization; COVID-19; sustainability; climate change; negative externalities

Citation: Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals. *Sustainability* **2021**, *13*, 12529. https://doi.org/10.3390/su132212529

Academic Editor: Marc A. Rosen

Received: 21 October 2021
Accepted: 9 November 2021
Published: 12 November 2021

1. Introduction

The increasing impacts and challenges of climate change are more apparent and have been widely documented, with consequences ranging from increasing incidences of heatwaves and increased precipitation, leading to flashfloods, such as those lately witnessed in Western Europe where over 200 deaths were reported in July 2021 alone [1]. Climate change is also credited for the increasing incidences of drought, especially in sub-Saharan Africa, affecting regions are experiencing food insecurity, increased cases of water shortage and numerous challenges amongst pastoralists as vast lands experience desertification [2,3], and, amongst others, visible water sea-levels threatening some coastal regions with submersion and increases in vector diseases, to name a few [4].

According to the latest report by the IPCC [5], it is possible that the climate goals set in a number of global accords such as the Paris Agreement, aimed at ensuring that global temperatures are kept below 2 °C, preferably 1.5 °C, will not materialize, affirming similar findings documented by the same body in 2018 [6]. In the latest IPCC report, it is made clear that Earth is likely to exceed temperatures of 1.5 °C above pre-industrial levels and by 2100 [5], with the possibility that temperatures will have risen by between 3 °C and 3.5 °C. This is reinforced in the Nationally Determined Contributions (NDC) Synthesis report, published on the 17 September, outlining that even though the global rate of carbon emissions is decreasing, it is expected to peak by 2030 (with a 16% comparative rate of increase to 2010 levels, suggesting an increase in temperature rise of about 2.7 °C). Hence, further efforts have been demanded by countries to achieve the Paris Agreement targets [7].

The Paris Agreement, as noted in the UN Climate change report [8], required that member parties commit to meet at least 45% reduction on their emissions by 2030, but it was found that commitments could only be achieved if each party doubled their efforts. The scenario has further been complicated by emergence of COVID-19, which Shan, et al. [9] posited would prompt a 16.4% global increase in emissions as from 2020 depending on economic stimulus governments advance in their economies. On this, the UNEP [10] reports that only 18% of all the global recovery spending has some 'Green' elements. Temperatures above 1.5 °C will translate to devastating climate events such as heatwaves, flooding, desertification, acidification of water sources, and tropical cyclones among others. This may be disastrous for many regions of the world, and especially for small island developing states (SIDS), where cases of forced climate migration is expected to increase with sea water level rise, with others losing considerable amount of habitable spaces, fishing ground, tourism attraction sites, and essential infrastructures, leaving little options other than to migrate [4].

Failing to meet the agreed targets in the Paris Agreement will consequently impact the achievement of other agreements, such as the sustainable development goals [11] and that of other COPs that were reached earlier. This, however, will be a result of human inducement, especially after the COVID-19 pandemic where economies have been found to revert to fossil-fuel intensive industries in their effort to revive the economies [12]. On this, Shan, Ou, Wang, Zeng, Zhang, Guan, and Hubacek [9] note that if fossil-fuel intensive activities continue to prevail, the aftermath will be a chaotic global environment that will not only be unsustainable for the current generation, but make sustainable development more difficult for future generations. As expressed by The European Commission [13], there will be need for deep re-thinking and reversal in policies to ensure global extraction of resources, production of products, and their consumption and their ultimate disposal align with sustainability agendas. Additionally, there are needs to re-assess the cost or benefits of production or consumption of goods and services in sustainability narratives, introducing the notion of 'Negative Externalities' where damages from pollution are not factored in. This however calls for a cohesive ecosystem re-think with respect to both consumers and producers.

One solution that emerged in 2019, and has been gaining traction in the past two years, is the 'Green New Deal' that was first introduced in America after years of negotiations [14], and was subsequently adopted in varying forms by numerous countries, including country blocks such as the European Union [15]. This is further explored in the next section.

2. Surveying Green New Deals

The concept of Green New Deals can be argued to be an emerging, broad, and transformative approach toward addressing a series of issues impacting modern societies. It thus aims to address climate concerns in different geographies, while attempting to solve social and economic inequalities. According to Conte [16], the idea of the Green New Deal was conceived in 2006 in the United States, under the care of a taskforce that had been formed to deliberate and propose solutions on how different sectors engage in a sustainable transition as per the concept of the 'Global Greens'. This is interesting

noting that the emergence of associated terms such as 'Green Economy' and 'Green Growth' in 1989 and 2005, respectively [17], leading to foundational precepts to the Green New Deal. However, the proposed GND, as noted above and highlighted by Mastini, et al. [18], goes beyond economic growth in relative terms and aims to address other aspects such as social, economic, and environmental justice. In fact, the concept of 'growth' should not be a precursor for the GND, as expressed by Mastini, Kallis and Hickel [18], as degrowth policies also need to be part of the 'GND' narrative. This is true, noting that some green growth pursuits also have the potential to violate absolute planetary boundaries rather than solely improving environmental capital, or at least in the preservation of existing environmental resources [19]. The main inspiration for the Green New Deal is historical; its name was borrowed to mirror President Franklin D. Roosevelt's approach of helping the U.S. recover from the Great Depression by instating a total makeover of his government, or the 'New Deal' as it was called [20]. Activism on climate action began in the 1970s after the oil crisis, but progressive actions were only arguably taken in 2006 [16]. The agitation for climate change, gained more support from the political class, where some politicians with Jill Stein, a presidential candidate in 2012 and 2016 under her Green Party, banked on the climate change debate as a campaign tool for the presidential position [21]. However, the main breakthrough of the political class came in 2018 after a youthful group that was protesting on the government inaction against climate change was joined by Rep. Alexandria Ocasio-Cortez and Senator ED Markey [14], who formulated the groundwork for what became a joint resolution passed by congress in 2019. The resolution mandated the Federal Government to create a Green New Deal that would address a raft of issues, including touching on the foundational challenges of climate, economic, and social justice.

On climate, the Green New Deal (GND) as passed by the Congress targeted to have the country (U.S.) achieve net-zero greenhouse gas emissions by 2050 by adopting transition mechanisms that would not be injurious to communities or workers. The achievement of reduced emissions would be championed by ensuring the country transitions 100% to the use of alternative renewable energies in all sectors, through deep transformation of the transport sector, such as ensuring electric vehicles and mass transit systems were the main mode of transport. Since the objectives of the GND matches the calls for climate action [22], there seems to have been an increase in popularity, not just in the United States but globally, towards the model. Indeed, an analysis, represented through a line diagram in Figure 1, of the popularity of the term 'Green New Deal' for the period from 2008 to 2021 showcases a peak in 2019, aligning with the time of the GND passing in congress in the USA. Additionally, it is observed (Figure 2) that the first five geographies where interest by regions is peaking are: Guatemala, South Korea, Singapore, the United States, and New Zealand, respectively.

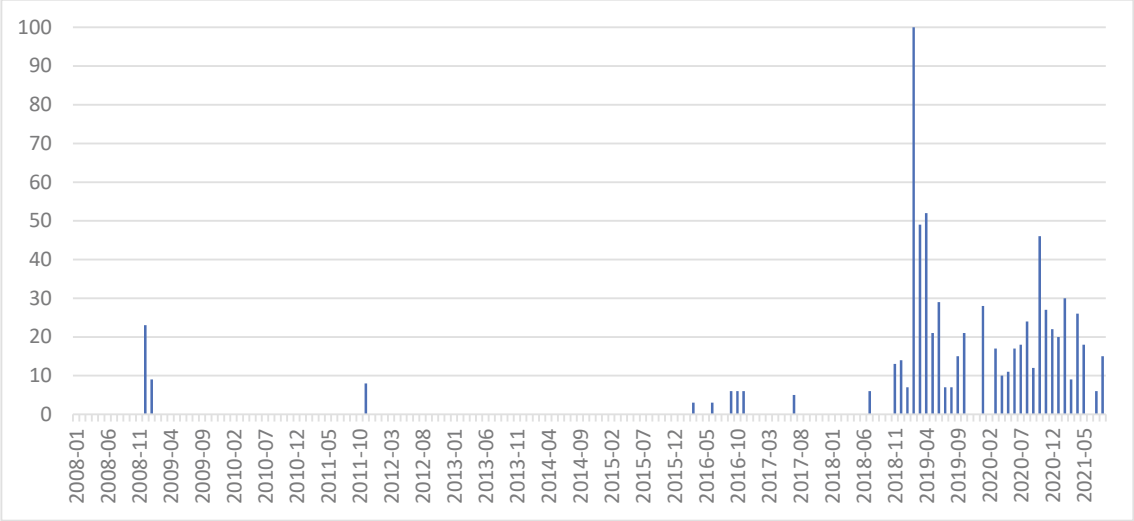

Figure 1. Web popularity of the term 'Green New Deal' from 2008 to 2021, with popularity ranging from 0 to 100. Sourced from Google Trends [23].

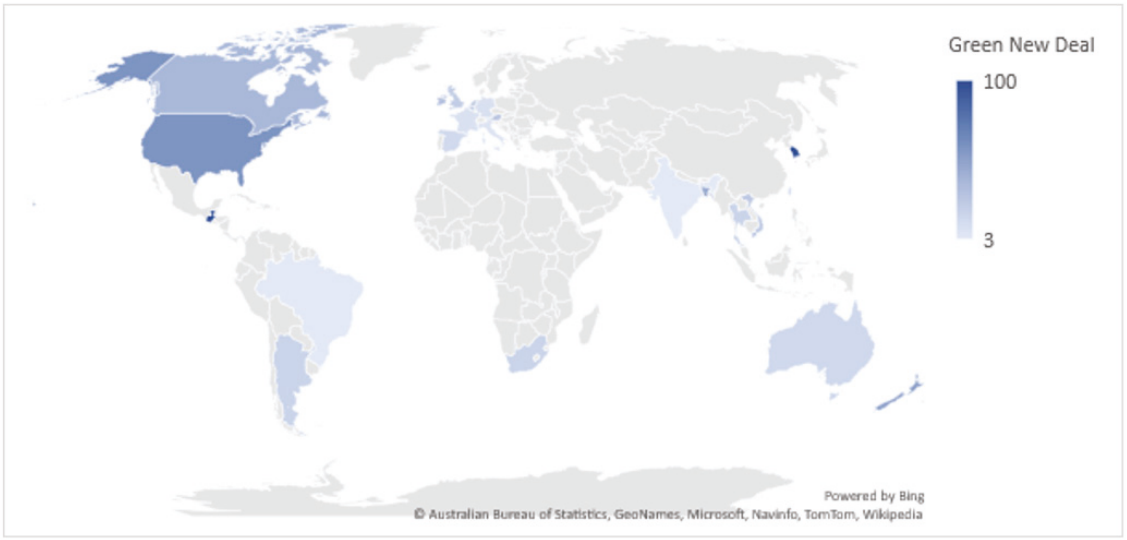

Figure 2. Web popularity of the term 'Green New Deal' (2008 to 2021), interest by region. The popularity ranges from 3 to 100, where 100 is the most popular. Sourced from Google Trends [24].

Since the adoption of the Green New Deal in the U.S Congress in 2019, there have been substantial number of other countries that have adopted similar approaches under different names, as shown in Table 1 below. Though they vary from each other, they all seem to have a convergence of intentions, especially regarding the need to reduce emissions and concentrate on attaining net-zero emissions in the future while achieving equity and inclusivity in the socio-economic fabric. In the table, China and India are included, but their commitment to reduction of emissions is not expressly defined in their Green New Deal agendas [25]. However, notable and practical actions have been taken. These include increased efforts and investments in renewable energy, adoption of technologies in their manufacturing industries, and introduction of fiscal mechanism such as the use of emission trading schemes (ETS) [26] are evident, especially in China.

Table 1. Mapping Green New Deal national policy proposals and name variations.

Country	Name of Policy	Year Proposed	Source
Canada	Pact for a Green New Deal	2019	[27]
United Kingdom	Green Recovery Act	2019	London Assembly [28]
South Korea	Green New Deal	2020	Chowdhury [29]
The European Union	European Green New Deal	2019	European Commission [15]
China	Ecological Civilization	2020	Paszak [30]
United States of America	Green New Deal	2019	Congress [14]
Mexico	Green New Deal	2020	Moreno-Brid and Gallagher [31]
Singapore	Green Plan	2021	Government of Singapore [32]

Besides individual countries and regions pursuing the GND, it is interesting that there are also notable organizations that support Green New Deal policies, pushing sectoral and thematic agendas on sustainability transitions. Those are outlined in Table 2 below. Most of those are domiciled in countries and regions such as the U.S. and Europe that have already pioneered in forming models of their GND. However, even in countries such as Australia where there is no formal announcement of the GND program, from the federal government, some states within the republic are seen to actively advocate for its acknowledgement and the embracement of deep sustainable transitions [33]. However, there appears to be clear disagreement on what constitutes a 'green deal', especially in view of criticisms on an AUD 2 billion renewable energy project between the New South Wales (NSW) government and the federal government [34].

Table 2. Mapping organizational adoption of Green New Deals.

Organizations	Year	Source
The Climate Mobilization	2017	The Climate Mobilization [35]
The European Green Party	2006	Green Party [36]
The Green-European Free Alliance	2011	The Greens/EFA [37]
The Democracy in Europe Movement 2025	2019	DiEM25 [38]
Green Party of the United States	2006	Green Party of the United States [39]
Heinrich Böll Foundation	2009	French, et al. [40]
League of Conservation Voters	2019	League of Conservation Voters (LCV) [41]
The New Economic Foundation	2008	New Economics Foundation [42]
Open Democracy	2018	Robinson [43]
The United Nations Environmental Program	2009	UNEP [44]
The Global Marshall Plan Initiative	2020	Saha, et al. [45]
The United Nations Economic and Social Commission for Asia and the Pacific	2012	Ministry of Environment [46]

Bradshaw, et al. [47] note that while the concept is gaining attention, leading to a rapid acceptability and adoption in diverse geographies and quarters (specifically with civil societies pressuring legislative makers) and underlining evidence of diversification in terms of the content advanced in the different countries or regional specific models. This has led to confusion on the specific underlying principles that the varied models aim to address thus, pointing to the need for countries to first address underlying market failures, such that the GND is not seen as a knee-jerk reaction to failures that could be sorted using other means. In fact, even in country specific models, such as the Green New Deal in the U.S., there is still confusion noted from leaders from different political divides (i.e., Democrats vs. Republicans), as to who are against the deal (notably mostly Republicans, who perceive some of the issues such as social justice as being unrealistic, and hence are dismissive of the proposal) [47]. While the variations may be deemed to represent interests that different countries have in their pursuit and conviction of the best way to address climate change, rising oil prices, and unsustainable energy consumption, there is need for some uniformity in order to address common goals and principles. This is affirmed when a critical

consideration of models such as the EU's Green Deal, which will be expanded beyond EU as explained by Dartford [48]. While the intention is deemed as sincerely aiming at ensuring that Europe's pursuit of climate action is achieved, it may have deeper implications as the region's trading partners may not have any contextual plans for GND. The resulting implications from both the trading partners and the EU may be hostile with institution of stringent measures that may somehow disrupt the existing trading relationship. In the case of countries in the global south that in some ways rely on their counterparts on the global north, they may be inevitably forced to agree to some measures, which sometimes may be incoherent with their domestic policies. On this, Táíwò [49] argues that some of the policies engendered in the New Green Deal and other models, if they are eventually formalized to become guiding policies, have the potential to increase inequalities, akin to what scholars coin as being 'climate colonialism' [50]. While examples would vary in accordance to contextual needs and capacities, there are notable needs by countries for land and financial resources to develop renewable energy plants as alternatives for fossil fuel plants. This is further represented in the NDC Synthesis Report [7], stating the popularity of renewable energy projects, as a means to curb climate change, amounts to 84% in countries around the world. While this measure is welcomed globally, most economies in the global south may have sufficient land, without the associated financial capacities to support nationwide projects, and thus often rely on debt financing, grants, and other such sources [51–53]. This conventional approach could force nations to secure more debts, increasing an unsustainable dependency on developed economies, leading to the arguments of 'neo' and 'climate' colonialism [54]. In this case therefore, economies in the global south, just like is the case with their counterparts on the north should be allowed to pursue and craft their own sustainability plans, addressing their unique challenges, as well as allowing them to align with their commitments as per the Paris Agreement as well as SDGs (and hence calling towards contextualized models for Green New Deals).

While pursuing proposals for new models that would somehow apply conventionally (and hence acceptability in countries and by different organizations), it will be paramount to understand the underlying issues pertaining GND in terms of how it emerged, its evolution, and trends. This is particularly important in a time where GNDs are politically equated as an 'ecology-centered' economic stimulus program, which can help significant political attention [55]. This is key, especially when GNDs can be viewed as a strong narrative to help economic growth, hence posing as a self-funding mechanism to the crucial question as how to finance transitions. From this perspective, proponents of GNDs are largely unaligned with those of degrowth who argue growth makes it more difficult to accomplish emissions reductions [18]. This interestingly builds an alignment of agendas on GNDs between both the environmental and political class, with the agenda of economic growth as a mutual ground. Additionally, funding transitions across multiple sectors are required, and in this regard numerous innovations need to be fostered, which can also lead to white space opportunities for corporates. This is leading to emerging Green funds, aligning with the underlying GND theme, applicable at both national and regional levels, and which could provide some reprieve to global south economies without capacities to fully finance GNDs agendas.

In view of the above, countries looking at engaging in GND agendas will need to craft contextualized policies aiming at solving an array of socio-economic challenges, while introducing economic stimulus programs across numerous sectors. Of interest, would also be the careful drafting of policies to tap into emerging policies and green funds, a criteria which would be particularly key to developing and least economies and small island developing states, which often do not have the capacity to finance green transitions [53,56].

To align with this constant shift in global policies, including in view of the current COVID-19 pandemic (at the time of writing), there is a need for an updated review of literature on GNDs and associated strategies for Green Growth, as new economic challenges present itself, causing larger inequalities and posing a threat to long term sustainability agendas [57]. In view of this, a macroscopic perspective is required on the larger themes,

providing an overview of its evolution over time, including during the pandemic period, to better understand past, current, and future directors. This paper thus, through a bibliometric analysis, undertakes to advance our knowledge on GNDs to present findings that can help countries seeking to associate with GNDs would have substantial information, leading to the potentiality of crafting models with the potential to address local priorities and challenges.

3. Methods

Keeping pace with the rapid growth of scholarly publication has made literature review challenging in the recent years. One way to deal with this challenge is utilizing bibliometric analysis techniques that allow gaining an overview of specific fields. Such macroscopic overviews can be used to highlight major thematic focus areas and research trends. Various bibliometric analysis software tools such as SciMAT, CiteSpace, and VOSviewer have been developed in the past two decades. All of these tools can be used to explore thematic evolution and identify keys authors, references, and sources. VOSviewer was used for the purpose of this study since it has a user-friendly interface, the outputs are more suitable for identifying and analyzing thematic clusters, and it can also provide detailed information on influential authors, references, sources, countries, and institutions [58]. Input data for bibliometric analysis using VOSviewer can be obtained from academic databases such as Scopus and the Web of Science (WoS). Here, we used WoS, given its broad coverage of quality peer-reviewed articles related to the topic. In addition. WoS bibliographic outputs are more compatible with VoSviewer and allow obtaining more detailed results. To retrieve literature relevant to GNDs, we developed the following broad-based search string that includes different related terms: TS = ("New Green Deals" OR "New Green Deal" OR "Green New Deal" OR "Green Deal" OR "Green Recovery" OR "Green Growth"). Using this search string in the WoS on 5 August 2021, returned 1403 articles. It should be noted that we only searched for English articles and the search period was not restricted (i.e., all papers indexed until 5 August 2021, were considered). We screened the titles and abstracts of these articles and 1174 articles related to the aims and objectives of this study were selected for final analysis in the VOSviewer. Three types of analyses are used in VOSviewer to map knowledge structure and trends. These are, namely, bibliographic coupling, co-citation analysis, and term co-occurrence analysis. Van Eck and Waltman [58] describes bibliographic coupling as "a link between two items that both cite the same document", where it can be used to identify major contributing countries and institutions and their interactions. Furthermore, co-citation links are described as "a link between two items that are both cited by the same document" [58]. As citation frequency is widely considered as a measure of scholarly impact, results of co-citation analysis are used to identify the most influential authors, publications, and sources. Finally, a term co-occurrence analysis is used to identify major thematic focus areas of the field. In addition to highlighting major terms, this analysis also provides information on important thematic clusters within the field. As one of the aims of this study was to explore thematic evolution over time, we divided the study period into three sub-periods considering major milestones that may have influenced the evolvement of the field and the total number of papers published in each sub-period. The first period started on 1995, coinciding with the introduction of the Environmental Bill of Rights to the U.S. Congress [59], this being a major milestone leading to subsequent green policies and increasing research in the area.

As shown in Figure 3, there has been a surge in the number of publications around 2015. This could be linked to the introduction and adoption of international policy frameworks such as the Paris Climate Agreement and the 2030 Agenda for Sustainable Development in 2015. Accordingly, 2015 was designated as the first milestone. The figure also shows another surge in 2020 which could be linked to the emergence of the COVID-19 pandemic. Based on these milestones, the study period was divided into three sub-periods, namely 1995–2014, 2015–2019, and 2020–2021. In addition to an overall term co-occurrence analysis, we conducted separate term co-occurrence analyses for the three study periods to understand

thematic evolution. Outputs of all VOSviewer analyses are presented as a network of nodes and links (e.g., see Figure 4). The node size is an indication of the relative importance. For instance, in case of term co-occurrence analysis, node size is proportional to the frequency of term occurrence. Also, link width is proportional to the strength of connection between the two terms. Terms that are closely linked to each other form clusters that indicate thematic focus areas.

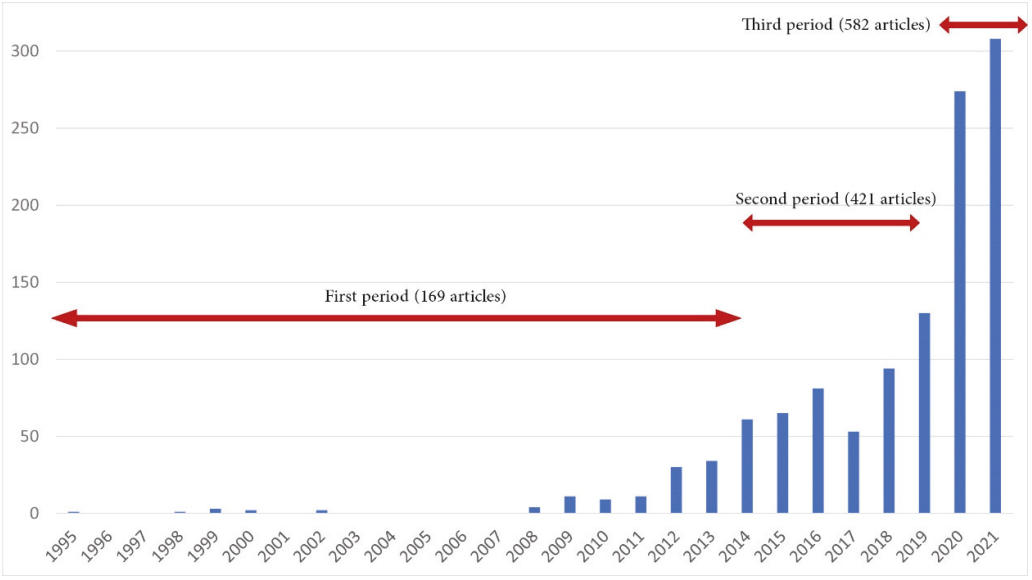

Figure 3. The number of articles published per year. Note that although the literature search was conducted in August 2021, the number of articles in this year is already larger than its previous year. This is a clear indication of increasing interest in this topic and more articles are expected to be published in the rest of 2021 and coming years, especially in view of the impacts of COVID-19 on many economies and the need for prompt recoveries aligning with both economic and sustainability pursuits [57,60,61].

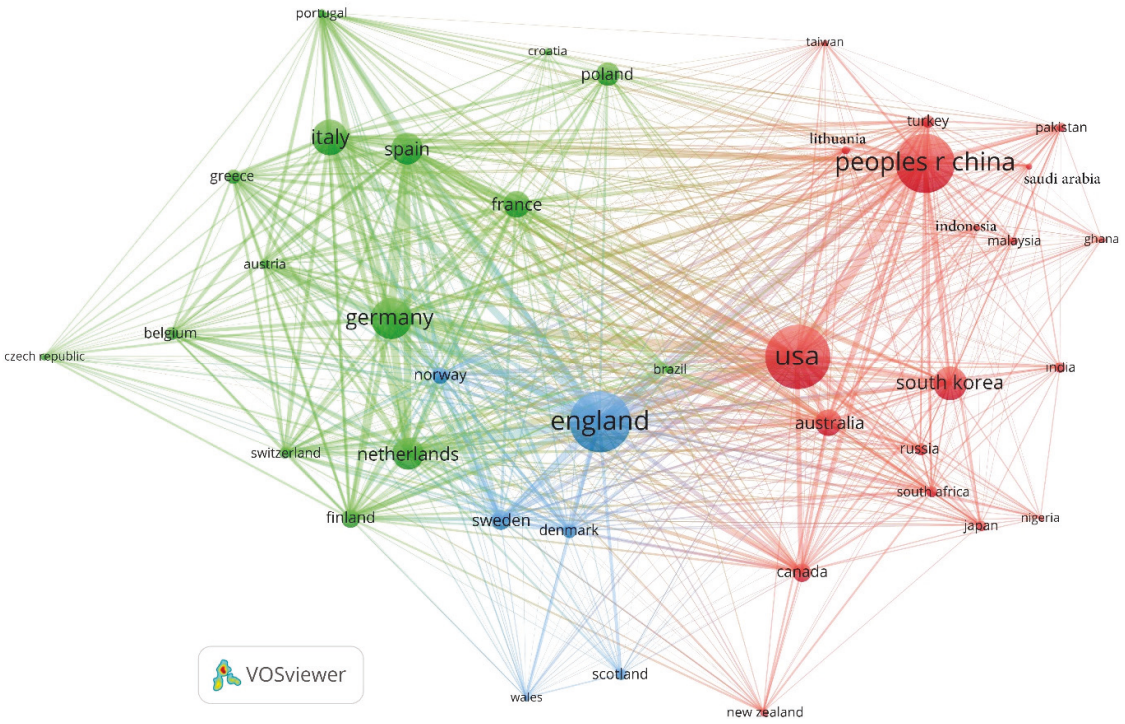

Figure 4. Countries with the most contributions to GND. Illustration by authors.

4. Results and Discussions

4.1. Countries Making the Most Contributions

The analysis supports that, as illustrated in Figure 3 above, the USA, the People's Republic of China, England, and Germany are the most popular contributors to the GND debate with 176, 156, 163, and 99 documents respectively. This is evident by the size of the nodes, which in this case the four countries have the largest (as per the number of documents noted above). The popularity of GND was further observed to be gaining traction in countries such as the Netherlands, France, Italy, South Korea, Australia and Spain and Poland. The green cluster is seen to have received much attention, followed by the red cluster, while the blue cluster comes third.

From the literature, the result obtained in Figure 3 are not surprising as the current global pressures towards the adoption of a Green Deal have been seen to concentrate more in the USA and European zone. For China, as noted by Bradshaw, Ehrlich, Beattie, Ceballos, Crist, Diamond, Dirzo, Ehrlich, Harte, Harte, Pyke, Raven, Ripple, Saltré, Turnbull, Wackernagel, and Blumstein [47], although there is no formal agenda that can be equated to the Green New Deal, there has been an increase in attention toward activities pointing toward a reduction of carbon footprint. The increased attention and research focusing on China may be due to the fact that it is the leading emitter of carbon emissions, accounting for almost 24% of the global emissions [47]. Further, being the leading country in investment on renewable energy may have contributed to increased attention on its focus on matters relating to the adoption of deeper measures, aligning with the Green New Deal. The attention in the USA also maybe multi-pronged. First, since the 1970s (as reported by Conte) [16], there has been numerous calls, proposals, and agitations for the country to adopt climate actions to avert its impacts on the environment, economy and communities. Secondly, as was expressed by Bradshaw et al. [47], it is ranked the second globally in terms of global emissions, and its commitment to global accords such as the Paris Agreement, especially in view of the previous government policies on the same, may have triggered an increased interest. Thirdly, it is the first country to have a realistic Green New Deal formulated and discussed at a congressional level [14], thus drawing global attention. In the case of England, its contribution to the discourse on GND (or Green Deal as it is known in Europe) ranks it top among European countries. From the literature, it is noted that though the Green Deal will impact the entire of European region and beyond, England, would be a major beneficially due to focus on areas such as green spaces and improvement of air quality that was noted to be fairly poor compared to its counterparts in the region [28]. Further, being the main trading partner with its European counterparts, it is understandable that the Green New Deal would impact their trading relationship. Thus, interest in understanding how the deal works would influence policies in the country.

4.2. Most Influential Organisations

Organizations were clustered into three groups depicted in distinctive colors, represented in Figure 5. The red cluster comprise of 12 organizations with larger nodes that are closely linked noting the thickness of their link lines. The blue cluster is located far right, with only three organizations (Vrije University, University Autonoma Barcelona and ICREA with 14, 14, and 11 documents each) therein with each of them having fairly large nodes and close link between themselves. However, this cluster is far linked from the rest of the clusters. The green cluster is comprised of nine organizations that are closely linked to each other but with smaller nodes, indicating that the number of publications from those organisations were fairly few compared to those obtained in other clusters. For instance, INHA University, Macquarie University, Beijing Normal University and University Manchester all had eight documents published.

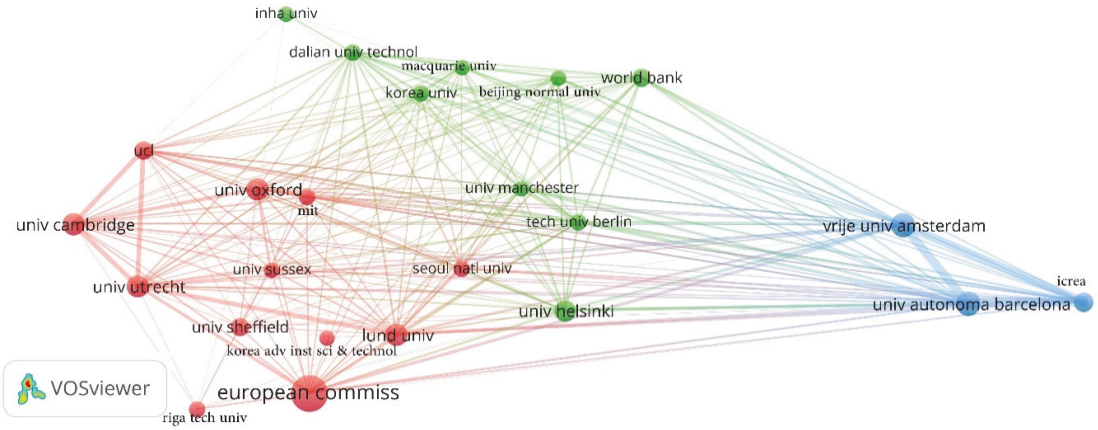

Figure 5. Organizations contributing the most to GND. Illustration by Authors.

From the literature review, the European Commission (EC) has been identified as one of the organizations that eventually managed to bring into fruition the Green Deal agenda in Europe, and from the diagram above, it had very close link with numerous learning institutions. This could explain why most of the documents that could have shaped the GND document emanated from the institution. From the results obtained, the close link between EC and other organizations clustered in red is not surprising as most of these are mostly based in Europe, save for Seoul University. This confirms that the European Green Deal emanated from different environmental knowledge shared, exerted from different quarters in the region, specially from learning institutions. This is true following realization that, indeed, there are notable concerns with issues such as increasing emission levels from the region [47], the unsustainability of the economy due to some sectors still relying on non-renewable energy sources [62], and the increasingly observable cases of social inequalities in the region as document in a report by Bubbico and Freytag [63]. One clear observation from the results above is that most of the organizations are learning institutions drawn from Euro-zone save for the few drawn from Korea, the World Bank, and the European Commission. From the analysis, the U.S. and Europe can be noted as the only two to have clear-cut GNDs. In America, the political class drawn from both the Democrats wing and other smaller parties have been credited for pushing for the realization of GND and this could be due to the fact that other institutions, such as NGOs and learning institutions are not as coordinated in research and policy work, as is the case with Europe. However, the results from Europe highlight the influence the learning institutions can have in shaping and influencing for meaningful changes in the society. Whereas it may be construed that the topic on GND is not widely understood in the public domain, hence, justifying why most organizations pushing for actions to be taken are learning institutions, evidence from the literature show otherwise. On this, youth movements [64,65], UN bodies such as the UNFCCC [66–68] and the IPCC [5,69], and other bodies, have been clear on their position on climate change. However, it is also important to appreciate that adopted GND models do not only concern the environment, but encompasses other cross-cutting issues, that learning organization, the World Bank, the EC and other organizations keenly supporting. This showcases a global consensus on expanding the GND to touch on socio-economic dimensions, hence using the rational for approaching the environment as an underlying foundation to regenerate societies.

4.3. Most Influential Journals

As depicted in Figure 6 below, the influential journals are grouped into three clusters depicted in green, blue, and red colors. The red cluster represent those associated with energy, where journals touching on this topic were popular. For instance, journals 'Energy Policy' and 'Journal of Cleaner Production' had 1810 and 1496 citations, respectively. This cluster contained 20 journals represented by nodes that closely linked, except for the journal

'Energy and Buildings'. The green cluster contained 17 journals, represented by nodes that also fairly closely linked. The most popular journal in this cluster was that of 'Ecological Economics', cited over 1078 times and had over 29,224 links. The blue cluster contain nine journals, with the most popular being 'Energy Economics' with 589 citations and a total of 18,148 links. This cluster had most of the journals with least citations, with most of them seen to be more linked to the green cluster than with the red cluster.

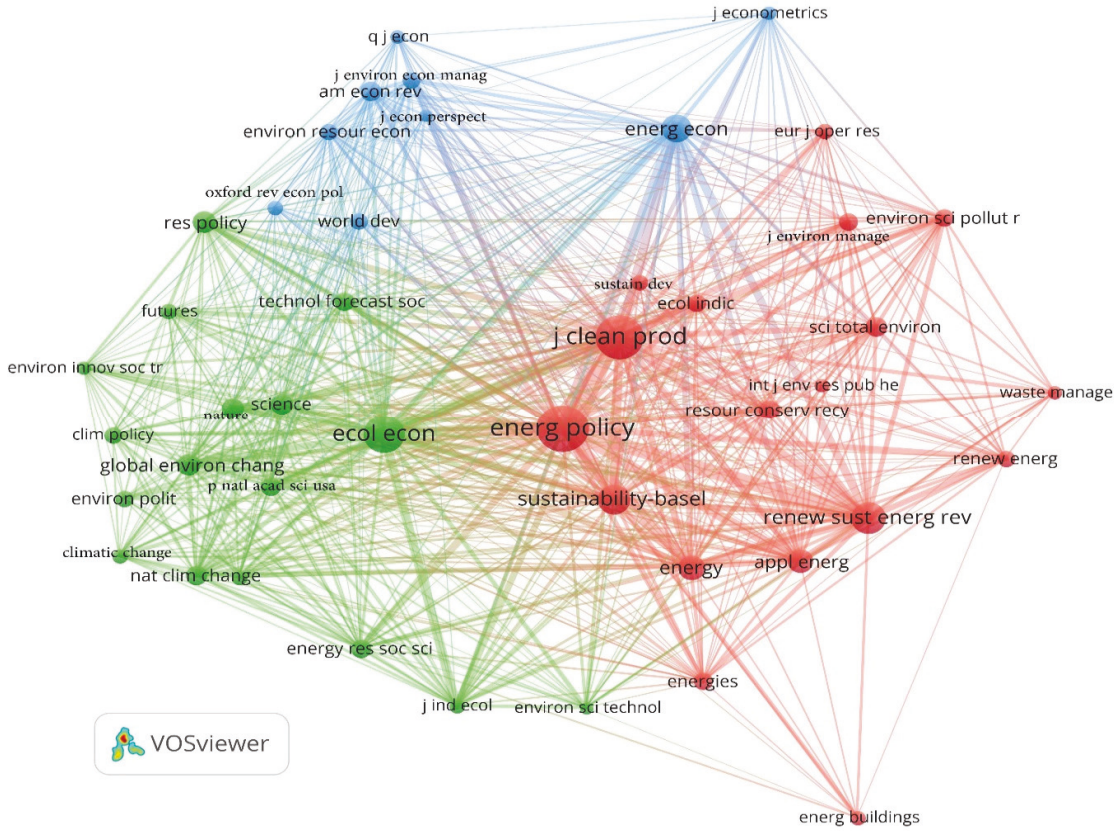

Figure 6. Journals influencing the GDN discourse. Illustration by authors.

The concentration of activities in the journals related to the energy sector is unsurprising considering the amount of effort, mobilization, and resources that have been directed toward a global shift from fossil fuels to renewable energy. In particular, from the literature, it is evident that global efforts are now amassed with energy policies, especially emanating from COP meetings, which started as early as the 1990s, the popular policy frameworks being the Kyoto Protocol (1997) [66] and the Paris Agreement (2015) [67]. These groundbreaking policies are aimed at guiding global economies in their pursuit to addressing climate concerns to ensure that global temperatures do not rise above 2 °C pre-industrial level by 2030 [6]. While the two popular GND models (American and European) covers more than just the energy sector, it is clear than the debates and publication on the energy sector greatly shaped and will further influence policies on existing and emerging Green Deals. The increasing popularity of journals related to energy in terms of citations and linkages shows that over the years, scholars have increased their attention on matters environment more so on the impacts of emissions from the energy sector. What is surprising from the results obtained is the reduced popularity of journals inclined to social and economic aspects, especially noting that Green Deals are also focused on how pursuits of social welfare in areas such as housing, water extraction and consumption and others contribute to sustainable environments. Further, it is evident (as documented in the Circular Economy Action Plan for Europe [13]) that the GND, especially the European Green Deal, is focused on changing the economic model of the region to accommodate a

circular to advance the concept of sustainability, innovation, and technology use in the energy production and others.

4.4. Most Influential References

A total of 38 most influential references were identified and listed for this analysis. The results are presented in Figure 7, which has three clusters identifiable by three colors (red, blue and green), with 15, 10, and 11 references, respectively. Two references, (Dowson, et al. [70] and European Commission [71]) had zero links. Thus, they are not present in the diagram. In terms of influence, documents by the United Nations Environment Programme [72] and the World Bank [73], having a total of 158 and 171 citations respectively, are seen to dominate. All these are identified under the blue cluster just near the center of the diagram due to the extensive relationship that the energy sector (blue cluster) has with themes such as climate change and sustainability (red cluster) and the concept of green growth (green cluster). Table 3 below maps the major references, showcased in Figure 7.

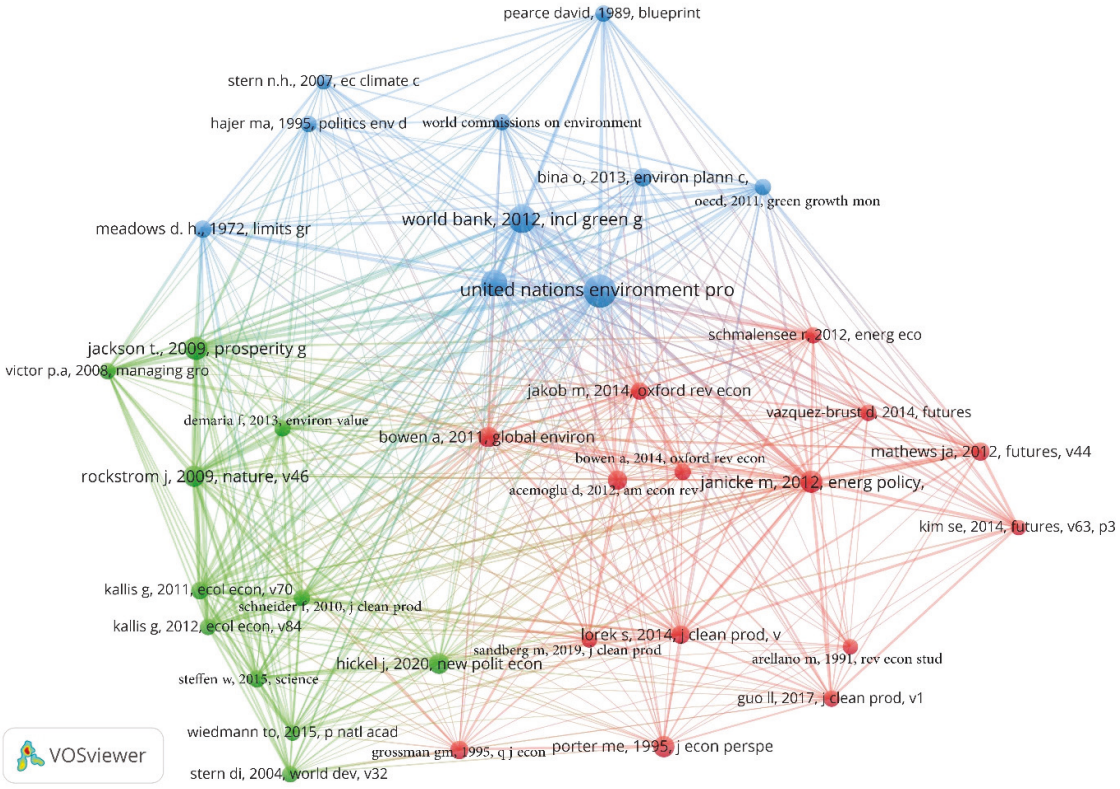

Figure 7. Major references influencing the GDN discourse. Illustration by Authors.

From the literature, it is evident that while themes in sustainability and green growth are gaining in popularity, they are guided by policies and frameworks emanating from bodies such as the United Nations Environment Program (UNEP) and the World Bank, thus justifying their influence in shaping the discourse on GND. In particular, these bodies have been observed to be consistent in advocating for green growth and have been financing diverse programs and projects across the globe aligning with the Green concept. For instance, in the article by the World Bank [73], the clarion call is for an inclusive Green Growth that would ensure that the 9 billion people that will occupy the world by 2050 would not be disadvantaged by agendas of the current generation. Adding to this, is the noticeable need to include the private sector in the common objective of sustainable transitions [74], and to introduce 'Corporate Social Responsibilities' (CSR) as key agendas [75]. To ensure that the objective of having a sustainable future is achieved, those noted organizations are observed to advocate for policies that not only address the environment and climate

issues alone but extend to social and economic dimensions to ensure that prevailing issues such as inequalities, exacerbating unsustainable pursuits are minimized. In support of the discourse advanced by those institutions, many publications touching on sustainability, more so in the energy sector are seen to be increasing; thus, justifying why the red cluster has a substantial number of influential references. From the literature, it is evident that there have been numerous calls, including through global accords such as the Paris Agreement for economies to shift to use of renewable energy as alternative for the fossil fuel to reduce emissions, at least to guarantee that temperatures would not rise beyond 2 °C. This increase on publication on energy, as from 2014, as shown in Figure 7, showcases that as talks about the Paris agreement intensified, researchers worked to complement to policies to potentially influence future directions, such as the formulation of the GND, gaining traction in this dispensation.

Table 3. Major references influencing the GDN discourse, with number of citations and link strength.

Title	Authors	Journal/Organization	No. of Citations	Link Strength
The environment and directed technical change	Daron Acemoglu Philippe Aghion Leonardo Bursztyn David Hemous	American Economic Review	2243	54
Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations	Manuel Rellano Stephen Bond	Review of Economic Studies	11,368	25
The Green Economy and Sustainable Development: An Uneasy Balance?	Olivia Bina	SAGE Journals	293	61
The green growth narrative: Paradigm shift or just spin?	Alex Bowen Samuel Fankhauser	Global Environmental Change	48	117
What is degrowth? From an activist slogan to a social movement	Federico Demaria Francois Schneider Filka Sekulova Joan Martinez-Alier	Environmental Values	693	86
Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal	Mark Dowson Adam Poole David Harrison Gideon Susman	Energy Policy	267	0
European Commission		European Commission	21	0
Economic growth and the environment	Gene M. Grossman Alan B. Krueger	The Quarterly Journal of Economics	8497	47
The interaction effects of environmental regulation and technological innovation on regional green growth performance	Ling Ling Guo Ying Qu Ming-Land Tseng	Journal of Cleaner Production	138	51
The Politics of Environmental Discourse: Ecological Modernisation and the Policy Process.	Maarten A. Hajer	Oxford University Press	9423	47
Is green growth possible?	Jason Hickel Giorgos Kallis	New Political Economy	515	66
Prosperity without growth? The transition to a sustainable economy	Tim Jackson	UK sustainable development commission	1042	134
Green growth, degrowth, and the commons	Michael Jakob Ottmar Edenhofer	Oxford Review of Economic Policy	128	87
"Green growth": From a growing eco-industry to economic sustainability	Martin Jänicke	Energy Policy	319	149
In defence of degrowth	Giorgos Kallis	Ecological Economics	1004	115
The economics of degrowth	Giorgos Kallis Christian Kerschner Joan Martinez-Alier	Ecological Economics	610	99
A new approach to measuring green growth: Application to the OECD and Korea	Satbyul Estella Kim Ho Kim Yeora Chae	Futures	71	58
Sustainable consumption within a sustainable economy–beyond green growth and green economies	Sylvia Lorek Joachim H. Spangenberg	Journal of Cleaner Production	556	106
Green growth strategies—Korean initiatives	John A. Mathews	Futures	129	68
The limits to growth: The 30-year update	Dennis Meadows Jorgan Randers	Taylor and Francis	4577	75
Towards green growth	OECD	OECD	79	171
Towards green growth: Monitoring progress	OECD	OECD	12	87
Blueprint 1: for a green economy	David Pearce Anil Markandya Edward Barbier	Francis and Taylor	4997	67
Toward a New Conception of the Environment-Competitiveness Relatinship	Porte Me	Journal of Economics Perspectives	34	39
A safe operating space for humanity	Johan Rockström, Will Steffen Jonathan A. Foley	Nature	10,911	127
Green growth or degrowth? Assessing the normative justifications for environmental sustainability and economic growth through critical social theory	Maria Sandberg Kristian Klockars KristofferWilén	Journal of Cleaner Production	85	56

Table 3. *Cont.*

Title	Authors	Journal/Organization	No. of Citations	Link Strength
From "Green Growth" to sound policies: An overview	Richard Schmalensee	Energy Economics	107	76
Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue	François Schneider Giorgos Kallis Joan Martinez-Aliera	Journal of Cleaner Production	1116	108
Planetary boundaries: Guiding human development on a changing planet	Will Steffen Katherine Richardson Johan Rockström Sarah E. Cornell Ingo Fetzer Elena M. Bennett Reinette Biggs Stephen R. Carpenter Wim De Vries Cynthia A. De Wit Carl Folke Dieter Gerten Jens Heinke Georgina M. Mace Linn M. Persson Veerabhadran Ramanathan Belinda Reyers Sverker Sörlin	Science	7611	70
The rise and fall of the environmental Kuznets curve	David I Stern	World Development	3587	53
The economics of climate change: the Stern review	Nicholas Stern Nicholas Herbert Stern	Cambridge University Press	1705	36
Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication—A Synthesis for Policy Makers	UNEP	UNEP	259	254
Managing the transition to critical green growth: The 'Green Growth State'	Diego Vazquez-Brust Alastair M. Smith Joseph Sarkis	Futures	60	55
Managing without growth: slower by design, not disaster	Peter A. Victor	Edward Elgar Publishing	1291	76
The material footprint of nations	Thomas O. Wiedmann Heinz Schandl Manfred Lenzen Daniel Moran Sangwon Suh James West Keiichiro Kanemoto	Proceedings The National Academy of Sciences of the United States of America	1235	79

4.5. Most Influential Authors

The authors who have had more influence on the GND discourse are presented in Figure 8 below. These are clustered in four distinctive groups symbolized by red related to sustainability and climate change, blue representing energy themes, green encompassing issues on green growth and yellow on the subject of climate neutrality with direct links to Green New Deals. The results showcase that the most popular authors are institutions such as European Commission, OECD, the World Bank, and UNEP. However, on average, the blue cluster is seen to have larger nodes, that are closely linked, followed by the green cluster and red cluster, respectively. The yellow cluster encompassing only five authors has EC as the most active author. Others in this cluster (CBC, Eurostat, FAO, and UN) are cited only the least, and are also least linked. Individual authors are seen to be more popular in matters of Sustainability, Climate Change, and Green Growth.

The results presented above showcases that the theme of Green New Deal comprises of diverse thematic areas, and those academicians drawn from different fields enrich the discourse on this matter. In particular, authors interested in Green growth, sustainability and climate change are seen to be more popular, than those concentrating on new Green Deals. Probably, the reason for this inclination is due to the fact that the three popular themes are more inclined on impacts, which are well known, unlike the GND, which can be argued to be still new and is yet to gain a widespread recognition by most people, organizations, and institutions. For instance, Steffen, et al. [76] who were exploring matters of planetary boundaries in response to sustainability agendas are seen to have been cited over 7743 times despite their article having been published in 2015. Same case with an article by Guo, et al. [77] who exploring the relationship between technological innovation

and the environmental regulations in influencing green economic growth. The article has been cited over 132 times and linked over 54 times though it was published in 2017. This shows that topics related to sustainability, green growth, climate change and energy are becoming popular, especially in relation to how modern trends such as technological applications are incorporated. This augurs well with the proposals in the GND models, especially in the economic dimension, where the circular economic approach is being pursued [78]. It is evident that circular economy pursuits highly supported an extensive application of technologies in areas such as production, extraction of resources and in recycling processes to ensure an extended lifecycle of products [79], and even though the concept is noted to receive increasing global attention. In view of its merits, there are notable challenges as to its inclusion in vulnerable groups [80].

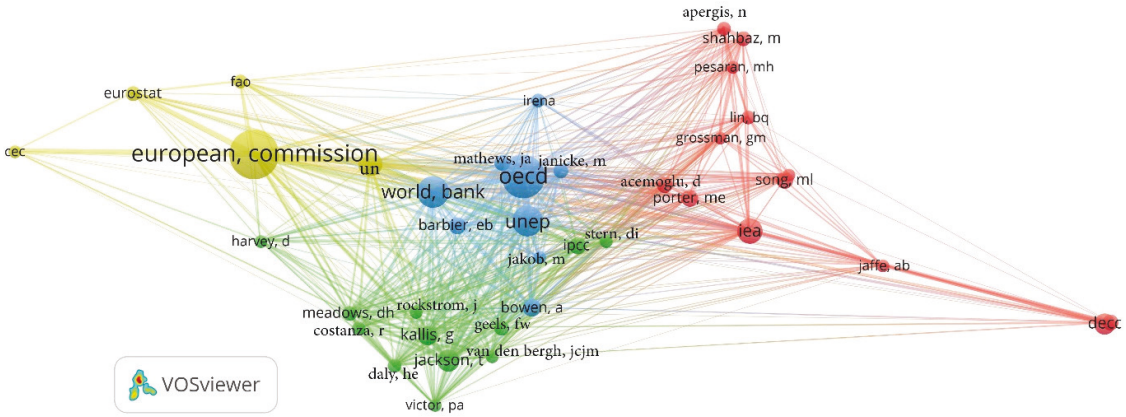

Figure 8. Authors influencing the GDN discourse. Illustration by the authors.

4.6. Term Co-Occurence

4.6.1. All Periods

Results of the term co-occurrence analysis for the whole study period are shown in Figure 9 below. The terms were categorized and clustered into three groups. The red cluster categorizes terms associated with climate change and sustainability, while the blue cluster encompasses terms associated with green growth. The green cluster was dedicated for terms associated with application of technologies and policies to foster economic growth. The red cluster had a total of 25 terms, with key terms (according to size of their node) including sustainability, which deemed to be more closely associated with terms such as green growth and green economy from the blue cluster. The term climate change was almost centrally positioned as shown in Figure 8 and is seen to be associated with terminologies from both the green and blue clusters. The green cluster had a total of 15 terms, with policy, economic growth and efficiency being the main ones and seemed to be closely linked with other terms in this cluster and from the blue and red cluster as well. Other terms that were popular in this category include efficiency, innovation, impact, technology, renewable energy, China, and CO_2. The blue cluster had only six terminologies, with the key one being green growth, which is seen to be closely associated with major terminologies such as sustainability, climate change, energy, Green New Deal and others from the Red cluster. Likewise, it has close links with terms such as Economic Growth, Impacts, Model Performance, Innovation, and Efficiencies from the green cluster.

From the literature, it is not surprising that terms such as green growth, sustainability, climate change, policy, economic growth and energy seem to have been very popular and closely associated over the period in question (1995–2021). It is worth noting that it is within this period that global community had come together to form the COPs with the first meeting happening in March 1995 [81]. Therefore, it is no coincidence that the key terminologies especially in regard to climate change and need for green growth seem to be predominant. Further, the co-occurrence of the terms such as policy, energy eco-

nomic growth, sustainability and climate change may have been influenced by the global discourse that was then focused on the urgent need for introducing policy framework such as the Kyoto Protocol targeting sectors in the economy, such as energy production, sustainable agriculture, equitable economies, with no or minimum market imperfections and others [66]. Successful global meetings, and the introduction of key global agreements such as the Paris Agreement [67], the Sustainable Development Goals [11], New Urban Agenda (NUA) [82], and the Agenda 2030 on Sustainable Development [83] have prompted an emergence of new terms such as mitigations, Green Deal, circular economy and others. The dominance of the co-occurring words such as green growth, sustainability, climate change and energy and others show that the global agendas associated with those are still on course; hence, as more calls continue to stress upon the need to address global climate challenges, those terms will continue to gain in popularity. However, when studying the terms more closely in three distinct periods, we are offered with interesting insights as to their evolution across time. This is expanded in the three sections below.

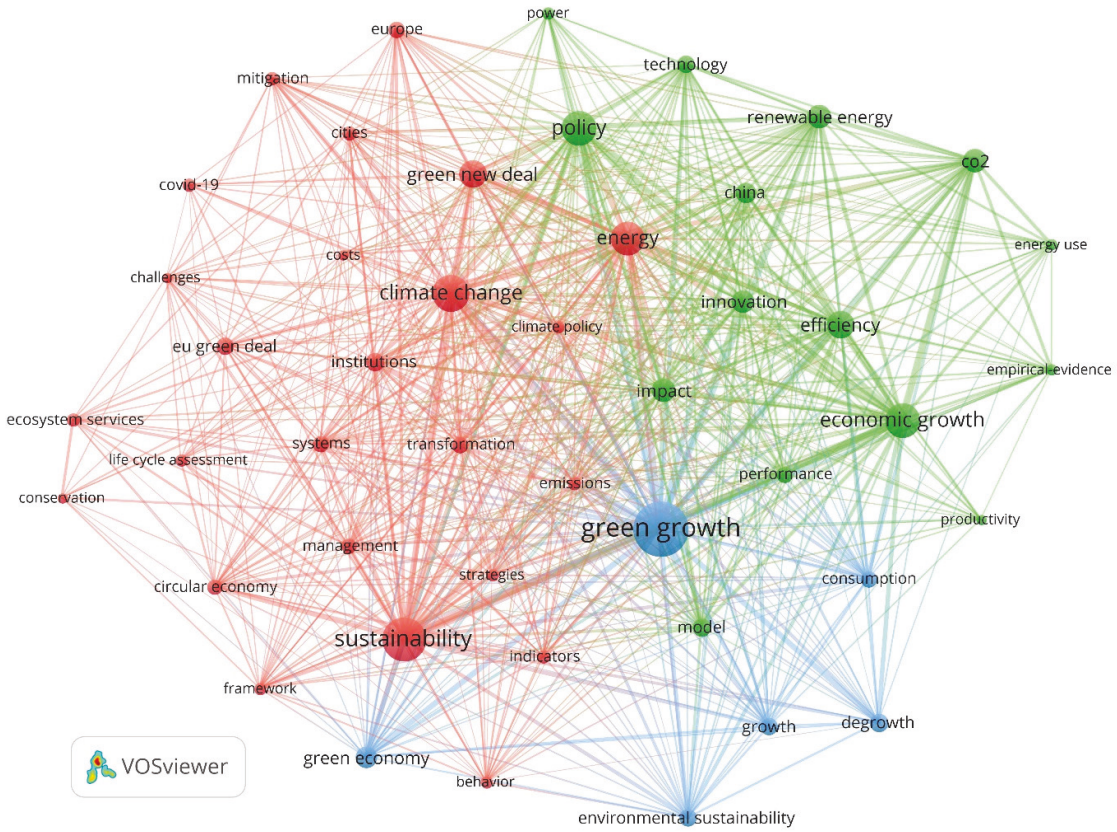

Figure 9. Analysis of terms co-occurrence from 1995 to 2021. Illustration by the authors.

4.6.2. First Period (1995–2014)

During the period 1995–2014, a number of terminologies related to the topic of GND, as shown in Figure 10 below, were already popular with most academicians. A total of 34 key terminologies were identified during this period, classified into three clusters; the red representing sustainability and climate change, the blue encompassing terms such as Green Growth, Developing Countries, and others commonly associated with the economic growth and development. The green cluster with 14 terms is observed to focus on technology, environment and innovations. The key terminologies during this period included Green Growth, Sustainability, Climate Change, Policy and Energy. However, other geographies that had begun attracting substantial attention during this period includes China and South Korea, the latter aligning with the findings of the geographical popularity as represented in Figure 2, where South Korea was noted as being the region attracting the most interest

for GNDs. It is further noted that those two regions showed a particularly high interested in the terms Green Growth, Growth, Technology and Environmental Sustainability. In the sustainability and climate change discourse, terms that gained popularity include Renewable Energy, Institutions, Management, and others. Regarding technology and innovations, terms that were seen to be attraction attention, but were not yet linked to sustainability and economic growth include housing, efficiency, innovations, and others.

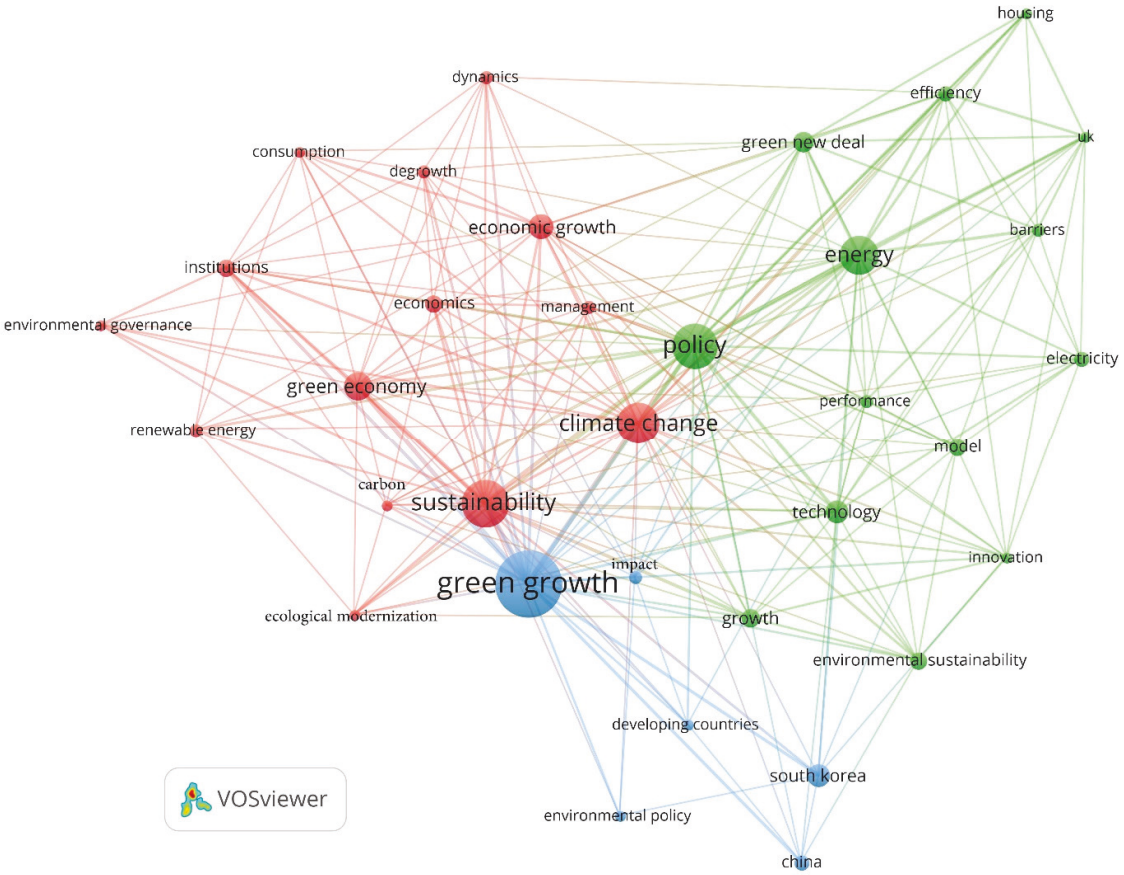

Figure 10. Analysis of terms co-occurrence from 1995 to 2014. Illustration by Authors.

From the analysis, it is not surprising that already, terms such as Climate Change, Green Growth, Sustainability, Policies and Energy were already popular and co-occurring in discourses touching the three thematic areas related to GND. Within this period, as expressed by FAS, countries such as China and South Korea were experiencing unprecedented growth, courtesy of technology and innovations that were popular in those countries. The growth in China begun in the 1970s, and by the 1990s had become a major trade destination, attracting over 445,244 foreign direct investments (FDIs) businesses in the 1990s [84]. The increase in trade was inspired by the deployment of advanced technologies in different sectors. In Korea, which is also seen to have drawn the attention of authors, as from 1995 onwards, its growth is observed to have recovered from an unprecedented decline at the beginning of the 1990s [84]. It is reported that the country had embarked on technological deployment in different sectors, and by 1996, the country had started to grow by 7.1% [85].

Growth was not only being experienced in this region alone, but other countries such as the U.S are also reported to have experienced strong growth. Such economic activities across the globe were prompted by the recovery strategies that countries had embarked on as they tried to recover from the 1990s recession [86]. As a result, coupled with ongoing environmental pressures, usage of non-renewable energy was experienced in countries such as China and the U.S. which had only 7% renewable energy with the rest coming from fossil fuel 24%, coal 23% and natural gas (23%) [87]. As a result, concerns about climate

change intensified, prompting the formulation of the Kyoto Protocol that came into force in 1997 [66]. The economic growth that was being experienced prompted emergence of housing programs, especially low-cost housing in many developing regions, especially in Asia and North America; as disposal income following increase in wages started to rise [88]. Through innovations, affordable housing became the trend, and countries such as the U.S., Canada, Singapore, and others were in a rush to ensure their citizens, whose numbers were also increasing, especially in urban areas were housed [88]. However, in the course of pursuing housing projects, it is noted that concerns arise on energy efficiency and the need for the adoption of alternative clean energy. That being said, it is noted that the concept of 'green' was still not popular during this first period as showcased in the diagram (Figure 10) above.

4.6.3. Second Period (2015–2019)

During this period, as depicted in Figure 11 below, the number of terminologies increased significantly to cover emerging issues. These terms are categorized in three groups, represented by red, blue and green clusters. The red cluster captures all the terminologies directly associated with sustainability and climate change while the blue cluster is dedicated for all terminologies with greater inclination to Energy Production, Consumption, and Impacts. The green cluster encompasses terms focusing on Green Growth, as influenced by factors such as Technology, Policies and Innovations. During this period, it is evident that all the terms recorded in the first period (1995–2014) are still present here and have been reinforced by the emergence of new terms. In the red category, it is evident that new terms such as: Impacts, Cities, Power, Productivities, Transmission and others had become common, and are occurring in document focusing on all three thematic areas. Similarly, in the green cluster which was presented as the Blue cluster in the first period, in addition to the six terms that were recorded then, numerous more terms emerged during this second period. Notable new terms here include Green Economy, Europe, Renewable Energy, Emissions, Scenarios Behaviours, SDGs and others. In the Blue cluster, the number of terms that emerged were not many compared to other clusters. They include Innovation, Buildings, Retrofit and UK. This aligns with the need of not only introducing more sustainable policies for new building stock, but also to retrofit existing ones, so as to ensure a more sustainable built environment [89].

The terms Policy, Efficiency, Innovation, Green New Deal however are seen to have become slightly more popular during this period, and also highly linked with terms such as Energy, Renewable Energy, Technology, Impacts, Green Growth and others.

From the analysis, it is observed that this second period experienced major breakthroughs in the discourse on Sustainability, Equitability and Economic Growth. It is during this period that the Paris Agreement (2015), Sustainable Development Goals (SDGs) 2015, the Agenda 2030 for Sustainable Development (2015), the New Urban Agenda (2016), the Green New Deal (American model) 2019, and others were formulated, and where some are already in force. In fact, there has been numerous meetings on different agendas, especially on environment and sustainability during this period, with a large number of publications published, including notable documents such as the SDGs and the Paris Agreement. During this period still, it became apparent that the world was experiencing increasingly pressures from the (still) unprecedented challenges of climate change, impacting mostly vulnerable economies such as least developed countries (LDCs) and small island developing economies (SIDS) [4]. It is during this period also that sustainability agendas increased more with areas such as urban planning being at the forefront, with urban models such as sustainable smart city models being adopted in numerous geographies, including Songdo, South Korea [90]. Other cities include Singapore [91], Barcelona [92], and other parts of the world that have transformed, courtesy of the proliferation and ubiquity of smart technologies [93–95]. Such activities saw an increase in the academic arena with numerous co-occurring terminologies increasing and covering different aspects of Sustainability, Growth, Economy, Climate Change, Technologies and more. With the global

population increasing at an average of 140 million per year since 2015 as expressed by Roser, et al. [96], substantial changes in different global sectors were observed, especially as demand for services such as energy, transport, manufactured products and other increased. These then prompted the need for policy interventions to ensure that as consumption continued, identified themes such as sustainability, Conservation, and Supply Chain Management were noted, as captured in the Paris Agreement and the New Urban Agenda (NUA) documents [82].

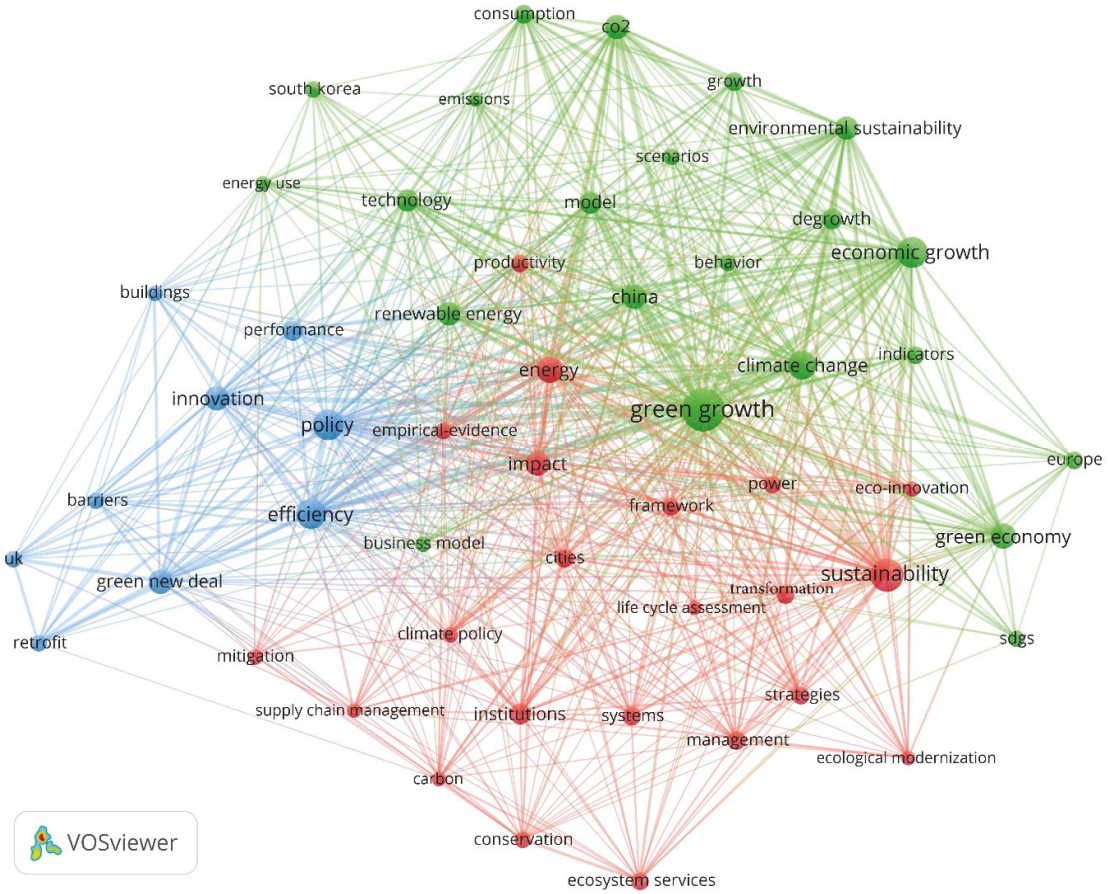

Figure 11. Analysis of terms co-occurrence from 2015 to 2019. Illustration by Authors.

4.6.4. Third Period (2020–2021)

Analysis of the period 2020–2021, as shown in Figure 12 below, further highlighted the consistency of increased terminologies shaping the discourse on GND, within the three thematic areas of sustainability and climate change categorized under the red cluster. The second thematic area is energy and renewable energies highlighted in the blue cluster, while the third thematic area categorized under the green cluster encompassing terms focusing on Green Growth, Economic Development and Technologies. The results here show that like in the previous periods (1995–2014 and 2015–2020), new terms arising from global trends emerged. These include Green Recovery, COVID-19, Agriculture, Biodiversity, Bioeconomy, Circular Economy, EU-Green Deal, Storage, Photovoltaics, Energy Transition, GHGs, LCA, Determinants, Countries, Empirical Evidence, Panel Data, Environmental Kuznets Curve and Decoupling among others. Some other terms that were common in the previous period but were no longer popular include South Korea, Behavior and Productivity.

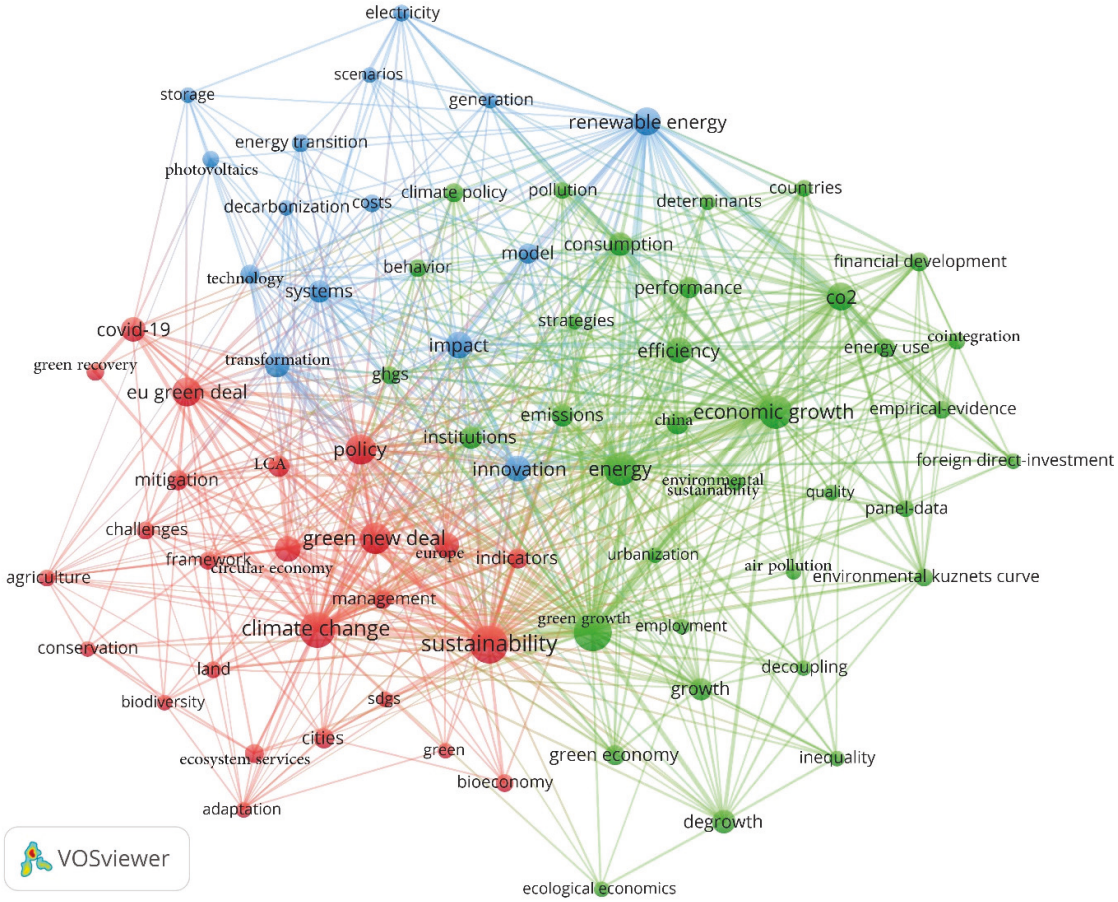

Figure 12. Analysis of terms co-occurrence from 2020 to 2021. Illustration by Authors.

From the analysis, this period portrayed mixed results for the global environment, and the discourse on sustainability, as a result of outbreak of COVID-19 early 2020 [57,60]. On the one hand, measures instituted in different countries and regions saw a reduction of activities in major sectors such as tourism, transport, manufacturing, education, hotels and hospitality industry and in retail among others, resulting into drastic reduction in emissions; by approximately 6.4% equivalent to 2.3 billion tons of CO_2 [97]. However, the pandemic also resulted into unprecedented plummeting of the global economic growth; estimated at around 3.5% by IMF [98], and more so in developed economies. Thereafter, in the third quarter of 2020, countries started to ease COVID-19 restrictions and gradually started to strategize on how to get back their economies into track, thus sparking fears that some would overlook their climate commitments and revert to the use of non-renewable energies. This may explain why terms such as Energy Transition, Decarbonization, Photovoltaic Climate Policy, GHGs, Environmental Sustainability, Panel Data and others have emerged co-concurrently with the existing ones. On this, there has been calls for economies to consider embracing renewable energies in their COVID-19 recovery plans, with solar photovoltaic being championed, especially after notable advancements in the technologies used in making solar panels and other components such as storage batteries helped reduce the prices thereof [99]. During this period also, the EU Green Deal was proposed [15], with proposals of formally adopting the circular economy concept as a means to changing the economic profile of the EU region. According to Dartford [48], this deal impacts the relationship between the EU and its trading partners, more so in respect to the sustainability aspects of raw materials and products exported from and to Europe. The bottom line during this period was for economies to emphasize on green growth, positing as a strong approach for positive impacts even for LCDs and SIDS, observed to be struggling financially due to the debt crisis exacerbated by the impacts of COVID-19 [100,101].

The focus is on implementing policy frameworks that would encourage economies to continue investing in sustainable pathways, as in renewable energy and increased use of technologies in areas such as urban planning. This, as noted by the World Bank [102] will promote a gradual economic recovery, while at the same time ensuring that the global 2030 targets for reduction in emissions are not overlooked. This, as highlighted in Figure 11, could explain why terms such as Impacts, Policies, Green Growth and Innovations are co-occurring almost at the center, showing that issues on Sustainability, Economic Growth, and Social Pursuits are gaining more popularity and co-occurring in cross-cutting in different disciplines.

5. Conclusions

This study, through the performance of a bibliometric analysis, explores the theme of Green New Deals and maps out their theoretical conceptualizations, knowledge structure, and trends across different time scales and publications. One limitation of this approach is that is caters for documents only indexed in academic milieus, in this case Web of Science, and hence omits grey literature. However, this focus on academic literature does not skew the results, as the large sample size of 1174 articles provides a robust dataset which, when analyzed, provided a deeper understanding of the evolution of the concept and can further provide researchers and policy makers with knowledge on how to better craft effective and contextually appropriate GND models. It is noted that GND adoption at a policy level is still in its infancy stage and is expected to keep gaining in popularity in the coming years, especially in view of the challenges brought about by the COVID-19 pandemic, underlining adequate and urgent economic responses aligning with national and international commitments to sustainability policies and agendas, including the Paris Agreement and the 2030 Agenda for Sustainable Development. This subject is thus expected to gain in popularity among academic circles, which will lead to further popularization and adoption. The paper further underlines that while the subject of the Green New Deal varies in interpretation, there is a strong convergence towards universally agreed principles, such as 'green growth' and 'green economy', thereby showcasing foundational precepts to the concept which can then be tailored to varied contexts in accordance with their needs and agendas. As avenues for future research, the mapping of the foundational elements of varied GND models and frameworks could be extremely interesting, and could potentially lead towards a global GND framework and application roadmap, contextualized for implementation in different economies. Finally, in view of global discussions on deep decarbonization needs at the Conference of Parties (COP) 26 at Glasgow in November 2021, aligning with the increasing need for climate financing at both local and regional levels, it could be topical to engage in metanalyses of sustainability transition models along with GND evolutions to try to map and understand what would be the most contextually appropriate GND models (accompanied with financial tools) per geographies and socio-economic groups. The topic of financing sustainability transitions will be made extremely important, and it will provide adequate research attention on this subject, rendering more effective policy outcomes aimed at accelerating much-needed sustainability transitions.

Author Contributions: Conceptualization, Z.A.; methodology, Z.A. and A.S.; validation, D.G. and S.A.S.; formal analysis and data curation, Z.A. and A.S.; writing—original draft preparation, review and editing, Z.A., A.S., D.G., and S.A.S.; supervision, D.G. and S.A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research is supported by an Australian Government Research Training Program Scholarship.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Davies, R. Western Europe—Storms Case Floods in Switzerlnd, Germany and UK. Available online: https://floodlist.com/europe/storms-floods-switzerland-germany-uk-july-2021 (accessed on 10 August 2021).
2. Inman, E.N.; Hobbs, R.J.; Tsvuura, Z. No safety net in the face of climate change: The case of pastoralists in Kunene Region, Namibia. *PLoS ONE* **2020**, *15*, e0238982. [CrossRef] [PubMed]
3. Chiang, F.; Mazdiyasni, O.; AghaKouchak, A. Evidence of anthropogenic impacts on global drought frequency, duration, and intensity. *Nat. Commun.* **2021**, *12*, 2754. [CrossRef] [PubMed]
4. UNEP. *Emerging Issues for Small Island Developing States*; UNEP: Nairobi, Kenya, 2014.
5. IPCC. *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2021; in press.
6. Intergovernmental Panel on Climate Change. Global Warming of 1.5 °C: An IPCC Special Report on the Impacts of Global Warming of 1.5 °C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Intergovernmental Panel on Climate Change. 2018. Available online: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf (accessed on 1 September 2021).
7. UNFCCC. Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat. In Proceedings of the Conference of the Parties Serving as the Meeting of the Parties to the Paris Agreement, Glasgow, Scotland, 17 September 2021.
8. United Nations Framework Convention on Climate Change. Synthesis report on the aggregate effect of the intended nationally determined contributions. In Proceedings of the Report of the Ad Hoc Working Group on the Durban Platform for Enhanced Action, Paris, France, 30 October 2015; p. 66.
9. Shan, Y.; Ou, J.; Wang, D.; Zeng, Z.; Zhang, S.; Guan, D.; Hubacek, K. Impacts of COVID-19 and fiscal stimuli on global emissions and the Paris Agreement. *Nat. Clim. Chang.* **2021**, *11*, 200–206. [CrossRef]
10. UNEP. Are We on Track for A Green Recovery? Not Yet. Available online: https://www.unep.org/news-and-stories/press-release/are-we-track-green-recovery-not-yet (accessed on 20 September 2021).
11. United Nations Development Programme (UNDP). *Sustainable Development Goals*; UNDP: Geneva, Switzerland, 2015; p. 24.
12. Le Quéré, C.; Peters, G.P.; Friedlingstein, P.; Andrew, R.M.; Canadell, J.G.; Davis, S.J.; Jackson, R.B.; Jones, M.W. Fossil CO_2 emissions in the post-COVID-19 era. *Nat. Clim. Chang.* **2021**, *11*, 197–199. [CrossRef]
13. The European Commisision. *Circular Economy Action Plan: For a Cleaner and More Competitive Europe*; European Union: Luxembourg, 2020; p. 28.
14. Congress. 116th Congress 1st Session: H. RES. 109. 2019. Available online: https://www.congress.gov/bill/116th-congress/house-resolution/109 (accessed on 1 September 2021).
15. European Commission. The European Green Deal: Questions & Answers. Available online: https://ec.europa.eu/commission/presscorner/detail/en/QANDA_19_6690 (accessed on 23 February 2021).
16. Conte, N. Green New Deal. Available online: https://wtpartnership.co/green-new-deal/ (accessed on 24 February 2021).
17. UN. Green Economy. Available online: https://sustainabledevelopment.un.org/index.php?menu=1446 (accessed on 2 September 2021).
18. Mastini, R.; Kallis, G.; Hickel, J. A Green New Deal without growth? *Ecol. Econ.* **2021**, *179*, 106832. [CrossRef]
19. Dercon, S. Is Green Growth Good for the Poor? University of Oxford: Oxford, UK, 2011.
20. Daniels, R.; Franklin, D. *Roosevelt: Road to the New Deal, 1882–1939*; University of Illinois Press: Illinois, IL, USA, 2018.
21. Atkin, E. The Democrats Stole the Green Party's Best Idea. Available online: https://newrepublic.com/article/153127/democrats-stole-green-partys-best-idea (accessed on 23 February 2021).
22. Bloomfield, J.; Steward, F. The Politics of the Green New Deal. *Political Q.* **2020**, *91*, 770–779. [CrossRef]
23. Google Trends. Green New Deal: 2004 to 2021. Available online: https://trends.google.com/trends/explore?date=all_2008&gprop=news&q=%27green%20new%20deal%27 (accessed on 29 August 2021).
24. Google Trends. Green New Deal. Available online: https://trends.google.com/trends/explore?date=all_2008&gprop=images&q=green%20new%20deal (accessed on 29 August 2021).
25. Donato, D. The Green New Deal and China's Green Revolution. Available online: https://www.peoplesworld.org/article/the-green-new-deal-and-chinas-green-revolution/ (accessed on 25 August 2021).
26. Chatzky, A.; Siripurapu, A. Envisioning a Green New Deal: A Global Comparison. Available online: https://www.cfr.org/backgrounder/envisioning-green-new-deal-global-comparison (accessed on 25 August 2021).
27. MacArthur, J.L.; Hoicka, C.E.; Castleden, H.; Das, R.; Lieu, J. Canada's Green New Deal: Forging the socio-political foundations of climate resilient infrastructure? *Energy Res. Soc. Sci.* **2020**, *65*, 101442. [CrossRef]
28. London Assembly. A Green New Deal. Available online: https://www.london.gov.uk/coronavirus/londons-recovery-coronavirus-crisis/recovery-context/green-new-deal (accessed on 25 August 2021).
29. Chowdhury, S. South Korea's Green New Dealinthe year of transition. Available online: https://www.undp.org/blogs/south-koreas-green-new-deal-year-transition (accessed on 24 August 2021).
30. Paszak, P. The Chinese Vision of the Green Deal. Available online: https://ec.europa.eu/clima/sites/default/files/international/cooperation/china/docs/zhong_ou_he_zuo_yan_jiu_bao_gao_-20201128_en.pdf (accessed on 24 August 2021).
31. Moreno-Brid, J.C.; Gallagher, K. Mexico's Road to a Green New Deal. *NACLA Rep. Am.* **2020**, *52*, 152–157. [CrossRef]

32. Government of Singapore. Introducing the Green Plan. Available online: https://www.greenplan.gov.sg/key-focus-areas/overview (accessed on 28 August 2021).
33. Gunia, A. Could the World's Largest Green Energy Hub Redefine How Companies Work with Indigenous People? Available online: https://time.com/6080182/australia-green-energy-aboriginal-people/ (accessed on 22 September 2021).
34. Visentin, L. 'Massive Green Deal': NSW Environment Minister Spruiks $2 Billion Energy Package. Available online: https://www.smh.com.au/politics/nsw/massive-green-deal-nsw-environment-minister-spruiks-2-billion-energy-package-20200131-p53wgg.html (accessed on 20 September 2021).
35. The Climate Mobilization. About. Available online: https://www.theclimatemobilization.org/about/ (accessed on 25 August 2021).
36. Green Party. The Green New Deal. Available online: https://www.gp.org/green_new_deal (accessed on 23 August 2021).
37. The Greens/EFA. The Green New Deal: More than a Policy, a Programme for Living. Available online: https://www.greens-efa.eu/en/article/document/the-green-new-deal (accessed on 23 August 2021).
38. DiEM25. The Green New Deal for Europe. Available online: https://diem25.org/campaign/green-new-deal/ (accessed on 23 August 2021).
39. Green Party of the United States. The Green New Deal. Available online: https://gpus.org/organizing-tools/the-green-new-deal/ (accessed on 25 August 2021).
40. French, H.; Renner, M.; Gardner, G. *Toward a Transatlantic Green New Deal: Tackling the Climate and Economic Crises*; Heinrich-Böll-Stiftung: Brussels, Belgium, 2009; Volume 3.
41. League of Conservation Voters (LCV). LCV Supports Green New Deal Resolution. Available online: https://www.lcv.org/article/lcv-supports-green-new-deal-resolution/ (accessed on 22 August 2021).
42. New Economics Foundation. Green New Deal: Cutting Carbon Emissions, Boosting Nature and Creating Good Jobs. Available online: https://neweconomics.org/about/our-missions/green-new-deal (accessed on 23 August 2021).
43. Robinson, E. How are We Doing on a Green New Deal? Available online: https://www.opendemocracy.net/en/transformation/how-are-we-doing-on-green-new-deal/ (accessed on 24 August 2021).
44. UNEP. Global Green New Deal: An Update for the G20 Pittsburgh Summit. Available online: https://wedocs.unep.org/rest/bitstreams/11748/retrieve#:~{}:text=In%20response%20to%20the%20financial,change%2C%20environmental%20degradation%20and%20poverty. (accessed on 25 August 2021).
45. Saha, S.; Subramanian, N.; Menzelos, A. Memo: A Green Marshall Plan—America's Global Climate Compact. Available online: https://www.dataforprogress.org/memos/green-marshall-plan (accessed on 24 August 2021).
46. Ministry of Environment. Green New Deal to Drive Green Recovery in Asia-Pacific Region. Available online: http://eng.me.go.kr/eng/web/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=461&orgCd=&boardId=1415460&boardMasterId=522&boardCategoryId=&decorator= (accessed on 25 August 2021).
47. Bradshaw, C.J.A.; Ehrlich, P.R.; Beattie, A.; Ceballos, G.; Crist, E.; Diamond, J.; Dirzo, R.; Ehrlich, A.H.; Harte, J.; Harte, M.E.; et al. Underestimating the Challenges of Avoiding a Ghastly Future. *Front. Conserv. Sci.* **2021**, *1*, 1–10. [CrossRef]
48. Dartford, K. How can the European Green Deal Avoid "Potential Frictions" with Other Countries? Available online: https://www.euronews.com/green/2021/02/03/how-can-the-european-green-deal-avoid-potential-frictions-with-other-countries (accessed on 28 August 2020).
49. Táíwò, O.m.O. How a Green New Deal Could Exploit Developing Countries. Available online: https://theconversation.com/how-a-green-new-deal-could-exploit-developing-countries-111726 (accessed on 26 August 2021).
50. Doreen, E.M. The Right to Be Free of Fear: Indigeneity and the United Nations. *Wicazo Sa Rev.* **2014**, *29*, 63–87. [CrossRef]
51. Allam, Z.; Jones, D.S. Attracting investment by introducing the city as a special economic zone: A perspective from Mauritius. *Urban Res. Pract.* **2019**, *12*, 201–207. [CrossRef]
52. Allam, Z.; Jones, D.; Thondoo, M. Climate Change Mitigation and Urban Liveability. In *Cities and Climate Change: Climate Policy, Economic Resilience and Urban Sustainability*; Allam, Z., Jones, D., Thondoo, M., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 55–81.
53. Allam, Z.; Jones, D. Climate Change and Economic Resilience through Urban and Cultural Heritage: The Case of Emerging Small Island Developing States Economies. *Economies* **2019**, *7*, 62. [CrossRef]
54. Allam, Z.; Jones, D.; Thondoo, M. *Cities and Climate Change: Climate Policy, Economic Resilience and Urban Sustainability*; Springer International Publishing: Cham, Switzerland, 2020.
55. Chohan, U. A Green New Deal: Discursive Review and Appraisal. SSRN Electron. J. 2019. Available online: https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.10.pdf (accessed on 1 September 2021).
56. Allam, Z.; Jones, D.; Thondoo, M. Economically Incentivizing Urban Sustainability and Resilience. In *Cities and Climate Change: Climate Policy, Economic Resilience and Urban Sustainability*; Allam, Z., Jones, D., Thondoo, M., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 83–106.
57. Allam, Z. *Surveying the Covid-19 Pandemic and Its Implications: Urban Health, Data Technology and Political Economy*; Elsevier Science: Amsterdam, The Netherlands, 2020.
58. Van Eck, N.J.; Waltman, L. VOSviewer manual. *Leiden: Univeristeit Leiden* **2013**, *1*, 1–53.
59. Hartman, H. Milestones in Environmental Protection. Available online: https://www.infoplease.com/math-science/earth-environment/milestones-in-environmental-protection (accessed on 1 September 2021).

60. Allam, Z. Chapter 7—Vital COVID-19 Economic Stimulus Packages Pose a Challenge for Long-Term Environmental Sustainability. In *Surveying the Covid-19 Pandemic and its Implications*; Allam, Z., Ed.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 97–105.
61. Allam, Z.; Jones, D.S. Pandemic stricken cities on lockdown. Where are our planning and design professionals [now, then and into the future]? *Land Use Policy* **2020**, *97*, 104805. [CrossRef] [PubMed]
62. European Environment Agency (EEA). Renewable Energy in Europe: Key for Clilmate Objectives, but Air Pollution Needs Attention. Available online: https://www.eea.europa.eu/themes/energy/renewable-energy/renewable-energy-in-europe-key (accessed on 26 August 2021).
63. Bubbico, R.L.; Freytag, L. *Inequality in Europe*; European Investment Bank: Luxembourg, 2018; pp. 1–50.
64. Fridays For Future. Who we Are. Available online: https://fridaysforfuture.org/what-we-do/who-we-are/ (accessed on 23 February 2021).
65. Frank, M.R.; Sun, L.; Cebrian, M.; Youn, H.; Rahwan, I. Small cities face greater impact from automation. *J. R. Soc. Interface* **2018**, *15*, 20170946. [CrossRef]
66. United Nations Framework Convention on Climate Change. Kyoto Protocol to the United Nations Framework Conventon on Climate Change. Available online: https://unfccc.int/resource/docs/convkp/kpeng.pdf (accessed on 8 August 2021).
67. United Nations Framework Convention on Climate Change. Paris Agreement. Available online: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed on 8 August 2021).
68. UNFCCC. Vulnerability and Adaptation to Climate Change in Small Island Developing States. Available online: https://unfccc.int/files/adaptation/adverse_effects_and_response_measures_art_48/application/pdf/200702_sids_adaptation_bg.pdf (accessed on 8 August 2021).
69. Intergovernmental Panel on Climate Change. *Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Cambridge, UK; New York, NY, USA, 2014.
70. Dowson, M.; Poole, A.; Harrison, D.; Susman, G. Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal. *Energy Policy* **2012**, *50*, 294–305. [CrossRef]
71. European Commission. *Communication from the Commission tothe European Parliament, the European Council, the Council, The European Economic and Social Committee and the Committee of the Regions*; European Commission: Brussels, Belgium, 2019; pp. 1–24.
72. UNEP. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*; UNEP: Nairobi, Kenya, 2011.
73. Fay, M. *Inclusive Green Growth: The Pathway to Sustainable Development*; World Bank Publications: Washington DC, USA, 2012.
74. Beltramello, A.; Haie-Fayle, L.; Pilat, D. *Why New Business Models Matter for Green Growth*; OECD Publishing: Paris, France, 2013.
75. Meseguer-Sánchez, V.; Gálvez-Sánchez, F.J.; López-Martínez, G.; Molina-Moreno, V. Corporate Social Responsibility and Sustainability. A Bibliometric Analysis of Their Interrelations. *Sustainability* **2021**, *13*, 1636. [CrossRef]
76. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; de Vries, W.; de Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. [CrossRef] [PubMed]
77. Guo, L.l.; Qu, Y.; Tseng, M.-L. The interaction effects of environmental regulation and technological innovation on regional green growth performance. *J. Clean. Prod.* **2017**, *162*, 894–902. [CrossRef]
78. Stahel, W.R. The circular economy. *Nature* **2016**, *531*, 435–438. [CrossRef]
79. Di Bartolo, A.; Infurna, G.; Dintcheva, N.T. A Review of Bioplastics and Their Adoption in the Circular Economy. *Polymers* **2021**, *13*, 1229. [CrossRef] [PubMed]
80. Meseguer-Sánchez, V.; Gálvez-Sánchez, F.J.; Molina-Moreno, V.; Wandosell-Fernández-de-Bobadilla, G. The Main Research Characteristics of the Development of the Concept of the Circular Economy Concept: A Global Analysis and the Future Agenda. *Front. Environ. Sci.* **2021**, *9*, 1–16. [CrossRef]
81. United Nations Framework Convention on Climate Change. Documents of the Conference of the Parties COP1 Berlin 1995 (COP1). Available online: https://unfccc.int/cop4/resource/cop1.html (accessed on 8 August 2021).
82. United Nations. *New Urban Agenda*; Habitat III: Nairobi, Kenya, 2017; pp. 1–66.
83. United Nations. *Transforming our World: The 2030 Agenda for Sustainable Development*; A/RES/70/1; Sustainable Development Branch, UN: New York, NY, USA, 2011.
84. Congressional Research Service. *China's Economic Rise: History, Trends, Challenges, and Implications for the United States*; CRS Report: Washington, DC, USA, 2019.
85. Nam, C.W. What Happened to Korea Ten Years Ago? *CESifo* **2008**, *9*, 69–73.
86. Brian, K.; Patrick, L. *OECD Insights from Crisis to Recovery the Causes, Course and Consequences of the Great Recession: The Causes, Course and Consequences of the Great Recession*; OECD Publishing: Paris, France, 2010.
87. Joskow, P.L. U.S. Energy Policy During the 1990s. Available online: https://economics.mit.edu/files/1144 (accessed on 25 August 2021).
88. Evans, D. The History and Evolution of the Affordable Housing Design Advisor: Bringing the Power of Design to Affordable Housing. *Cityscape* **2014**, *16*, 87–102.
89. Pardalis, G.; Mahapatra, K.; Mainali, B. A triple-layered one-stop-shop business model canvas for sustainable house renovations. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *588*, 022060. [CrossRef]
90. Kolotouchkina, O.; Seisdedos, G. Place branding strategies in the context of new smart cities: Songdo IBD, Masdar and Skolkovo. *Place Branding Public Dipl.* **2017**, *14*, 115–124. [CrossRef]

91. Rohaidi, N. Singapore Wins Smart City of 2018 Award. Available online: https://govinsider.asia/smart-gov/singapore-wins-smart-city-of-2018-award/ (accessed on 5 March 2019).
92. Gascó-Hernandez, M. Building a Smart City: Lessons from Barcelona. *Commun. ACM* **2018**, *61*, 50–57. [CrossRef]
93. Samad, M.E.S.; Hawken, S.; Sargolzaei, S.; Foroozanfa, M. Implementing citizen centric technology in developing smart cities: A model for predicting the acceptance of urban technologies. *Technol. Forecast. Soc. Chang.* **2019**, *142*, 105–116. [CrossRef]
94. Chamoso, P.; Gonzalez-Briones, A.; Rodríguez, S.; Corchado, J.M. Tendencies of Technologies and Platforms in Smart Cities: A State-of-the-Art Review. *Wirel. Commun. Mob. Comput.* **2018**, *2018*, 3086854. [CrossRef]
95. To, W.-M.; Lee, P.K.C.; Lam, K.-H. Building professionals' intention to use smart and sustainable building technologies—An empirical study. *PLoS ONE* **2018**, *13*, e0201625. [CrossRef]
96. Roser, M.; Ritchie, H.; Ortiz-Ospina, E. World Population Growth. Available online: https://ourworldindata.org/world-population-growth#citation (accessed on 26 August 2021).
97. Tollefson, J. COVID-19 curbed carbon emissions in 2020—Not by much. *Nature* **2021**, *589*, 343. [CrossRef] [PubMed]
98. Gopinath, G. World Economic Outlook Update: Policy Support and Vaccines Expected to Lift Activity. Available online: https://www.imf.org/en/Publications/WEO/Issues/2021/01/26/2021-world-economic-outlook-update (accessed on 13 June 2021).
99. Marcacci, S. Renewable Energy Prices Hit Record Lows: How Can Utilities Benefit from Unstoppable Solar and Wind? Available online: https://www.forbes.com/sites/energyinnovation/2020/01/21/renewable-energy-prices-hit-record-lows-how-can-utilities-benefit-from-unstoppable-solar-and-wind/?sh=29a8522d2c84 (accessed on 23 February 2021).
100. United Nations. Small Island Developing States Call for Enhanced Support for a Resilient Post COVID-19 Recovery. Available online: https://www.un.org/ohrlls/news/small-island-developing-states-call-enhanced-support-resilient-post-covid-19-recovery (accessed on 7 August 2021).
101. Allam, Z. Chapter 9—Oil, Health Equipment, and Trade: Revisiting Political Economy and International Relations During the COVID-19 Pandemic. In *Surveying the Covid-19 Pandemic and its Implications*; Allam, Z., Ed.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 119–127.
102. World Bank. COVID-19 to Plunge Global Economy into Worst Recession Since World War II. Available online: https://www.worldbank.org/en/news/press-release/2020/06/08/covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii (accessed on 15 April 2021).

resources

MDPI

Perspective

The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption

Zaheer Allam [1,2,*], Simon Elias Bibri [2,3] and Samantha A. Sharpe [1]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney 2007, Australia
[2] Network for Education and Research on Peace and Sustainability, Hiroshima University, Higashi-Hiroshima 739–8530, Japan
[3] The Swiss Federal Institute of Technology Lausanne (EPFL), School of Architecture, Civil and Environmental Engineering (ENAC), Civil Engineering Institute (IIC), Visual Intelligence for Transportation (VITA), GC C1 383 (Bâtiment GC), Station 18, CH-1015 Lausanne, Switzerland
* Correspondence: zaheerallam@gmail.com

Abstract: This perspective paper explores the rising impacts of the COVID-19 and the Russia–Ukraine war from different perspectives, with an emphasis on the role of climate financing in achieving equitable and just transition mechanisms and that of peace in expediting this pursuit and sustaining this drive. It is motivated by the realization that there is an urgent need for accelerating the decarbonisation agenda, as highlighted in pre-COP26 debates and in the resulting Glasgow Climate Pact, through the mitigation measures that can be unpacked at both cost and scale. This is further reiterated in the third instalment of Assessment Report 6 (AR6) the Intergovernmental Panel on Climate Change (IPCC) report, dwelling on Mitigation of Climate Change, underlining the required policy shifts and technology developmental needs. Green technology, however, comes at a green premium, being more expensive to implement in geographies that cannot absorb its cost in the immediate short term. This engenders an inequitable and unjust landscape, as those that require green technology are unable to have access to it but are most often on the frontlines of the impacts of climate change. While it is urgent to review this issue and to encourage more cooperation for technology development and transfer, the COVID-19 pandemic and the Russia–Ukraine war are posing mounting challenges for achieving these objectives. These two crises are causing an unprecedented rise in commodities and labour pricing, with further knock-on impacts on global supply chains for technology. This is in turn rendering green technology unattainable for developing and less developed countries and Small Island Developing States (SIDS).

Keywords: COVID-19 pandemic; Russia–Ukraine war; sustainability; resource management; energy transitions; climate justice; climate change; green premiums; supply chain

Citation: Allam, Z.; Bibri, S.E.; Sharpe, S.A. The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption. *Resources* **2022**, *11*, 99. https://doi.org/10.3390/resources11110099

Academic Editor: Eva Pongrácz

Received: 19 August 2022
Accepted: 25 October 2022
Published: 28 October 2022

1. Introduction

The impacts of climate change in this decade are becoming more apparent, especially in the frequency and intensity of diverse range of climate events and the cascading impacts of these events on socio-economic systems. As expressed in the latest IPCC report (Working Group III of the Sixth Assessment Report), events such as erratic and unpredictable weather are now more frequent [1]. The aftermath of these is a widespread consequence that includes irreversible losses of ecosystems, especially in coastal and low-lying regions and reduced food and water security [2] in many parts of the globe. This is due to issues such as increased desertification, acidification of soils and water [3] and the emergence of vector diseases. Climate change is also contributing to increasing adverse economic effects, resulting from losses in tourism activities, destruction of infrastructures and establishments

that support different businesses and establishments. Such impacts have escalated even on the community levels, leading to forced migration (over 30.7 million climate refugees were estimated in 2020 [4]), and further loss of livelihoods and loss of lives are expected in the forthcoming decade.

The 6th IPCC report calls for cross-sectoral mitigation policies and actions that would help create sufficient capacities for resilience and adaptability for economies, ecosystems, human societies and biodiversity. Among steps that could be adopted include a strong focus on decarbonisation, as was emphasized in 2021 during the COP26 Summit in Glasgow [5]. Further, such actions and policies could draw insights from proposals made in the Sustainable Development Goals (SDGs), highlight 17 fundamental objectives. Further, such policies and actions could be achieved by emphasizing on developing and revamping diverse infrastructural programs as well as investing on technology development. This is particularly important as there already exists a significant imbalance in the scale and geography of climate mitigation investment, where countries in the global north have already taken the initiative to expand their infrastructure networks and invest heavily in modern technologies with capacities to mitigate climate change.

Despite these robust investments, countries from the Global North are responsible for over 75% of the global emissions, which is triggering climate events that are having the greatest impacts in the Global South. This imbalance does not augur well in the quest for climate justice, as most economies in the Global South do not have sufficient financial capacities to adequately invest in expensive climate mitigation infrastructural developments. As a result, a majority of them are forced to risk their public assets in the quest for climate mitigation investment, which can also further derail notable growth due to indebtedness [6,7].

The investment in infrastructure and technology is low in a majority of developing and least developed economies [8], and this has significant ramifications on these economies 'efforts to develop as well as mitigate impacts of climate change. The World Bank notes that these disparities are not good for the global economy, as a majority of these countries also have insufficient capacities for resilience and adaptability; ensuring impacts of climate change events will also have a cascading impact in limiting global economic growth [9]. This calls for a more equitable global landscape in respect to investment, which can only be achieved when attention to terms of financial support, and when the availability of resources and expertise is widespread and rooted in practical policy reforms at regional, local and urban scales. However, these activities have not been forthcoming, with most economies in the Global South experiencing notable financial challenges, to a point of some of them plunging in debt crises, as noted in a report by UNCTAD [10].

Besides financial challenges, there has also been a serious concern regarding global equitability of access to resources and technologies due to ongoing supply chain disruptions. These disruptions are causing price increases and limited availability of certain resources, technologies, and components need for climate mitigation and infrastructure development. In most cases, these are not always seamless, robust and well defined across different geographies, and are having the impact of widening the inequality gap between developed, developing and least developing economies. For instance, Adeoti et al. [11] note that the costs of infrastructure development and maintenance in the Small Island Developing States (SIDS) is greatly affected by the cost of imported goods and the remoteness of these States. Exports of products from these States are also impacted by the current state of the global supply chain, reducing SIDS' access to international markets and trade.

Today, the quest to create a more equitable global landscape in respect to supply chains for different products is expected to encounter two major challenges of scale: the impacts of COVID-19 and the impact of Russia–Ukraine war. The COVID-19 pandemic outbreak in the early 2020 forced almost half (3.9 billion people) of the global population in lockdowns by the second quarter of the year [12], and triggered a worldwide, negative spiral effect on supply chains, specifically due to the restrictions on major transportation modes, border restrictions on a majority of countries, and reduced activities in major sectors such as

manufacturing [13]. Even after the resumption of normalcy in most countries, especially after the introduction of vaccinations, supply chains have not fully recovered [14]. It is now understood that the pandemic is expected to have long-term impacts on global supply chain, especially noting that the virus has continued to mutate prompting new, and occasionally extreme lockdowns call in major export countries, such as China, India, and US which at the time of writing are currently experiencing a fourth wave [15]. The interconnected nature of supply chains is expected to render them even more vulnerable, not only due to long-term impacts but also the cascading impacts of conflict from the ongoing Ukraine and Russian war [16] and related European security and energy issues. Such would also be impacted by the reactionary approach by Russia on the numerous economic sanctions imposed on the country by a number of global economies. For instance, in the recent past months, Russia has been conducting unusual oil pipeline maintenance procedures, affecting supplies in a number of European countries. This is in addition to the 40% reduction on gas flow to most European countries [17].

The long-term impacts of these two global challenges of scale are already being experienced globally with rising prices for basic commodities such as food and fuel [18]. As highlighted in a report by the UNFCCC [18], UNFCCC [19] the impact of the COVID-19 pandemic on the global sustainability agenda will be severe, with most economies failing to meet their Nationally Determined Contributions under Paris Agreement [19]. Coupling this with the complications triggered by Ukraine–Russia war, especially on supply chains for green technology, which now comes at a consequent green premium, is expected to prolong the journey toward sustainability transitions. This is discussed in the succeeding sections below.

2. The Link between Sustainability Transitions and Resource Management

The global sustainability agenda has the potential to benefit and be enriched from collaboration between players drawn from diverse disciplines, including academicians, political class, scientists, civil societies and others based on different parts of the globe. In particular, as expressed by Talens Peiró et al. [20], this is important as most sustainability pursuits are dependent on products and goods that are sourced from diverse geographical locations, thereby underlining the need for a seamless flow in the entire supply chain. That is, there needs to be a coherent understanding between people, manufacturing/production plants and the different systems that allow products (especially) to be moved with minimum delays and at reduced costs. On this note, due to the technological advancement that has been achieved as a result of the emergence of fourth industrial revolution, massive technologically oriented products with capacities to influence positive sustainability practices are being produced [21].

The movement of these products is subsequently benefiting from the supply chain networks that have equally benefitted from the impacts of globalisation as well as the improvements in technology. For instance, in the recent past, numerous countries have embraced the global calls to transition from using non-renewable sources for their energy production, to renewable sources. As a result, there, has been an increase in demand, and economies of scale in development, production and deployment of these technologies; meaning that these technologies and related components can now be produced cheaply and quickly and implemented on a citywide scale (see [22]) for illustrative case studies from Europe). This scaling of production of renewable energy technologies has led to global networks and supply chains of parts manufacture for the energy sector, that navigate complex legislative and fiscal pathways to finished goods, albeit at a high embodied energy weightage [23]. Jelti et al. [24] explain that the ability to move raw materials across different geographical locations has been among the main contributors to the increased penetration of renewable energies in the recent past. This has in part been made possible by manufacturing companies managing to maintain healthy re-order levels due to emergence of concepts such as Just-in-Time (JIT) that promotes efficiency in shipping different products [25].

However, in the quest to respond to resource needs for sustainable technology and related products (PV Panels, Sustainable Wood, Lithium-Ion Batteries, Microchips, Synthetic Cotton, Smart rotors et cetera), there also need to avoid unsustainable practices in acquiring and managing these resources as well as other possibilities for inequalities. On unsustainable practices, Talens Peiró, Martin, Villalba Méndez and Madrid-López [20] note that most of the raw materials used in manufacturing diverse technology products occur naturally in limited quantities and are unequally distributed across different geographical areas. Therefore, they require to be mined, utilized and recycled optimally to avoid unsustainable practices. In addition, their utilisation and supply, including after they are converted into finished products, need to be done in a diligent fashion to avoid bottlenecks and unequal supply chains that has the potential to derail sustainable transition in some economies, especially those in the south. There are also reports that the world is willing to offset the 'dirty' task to China, in the form of pollution intensive manufacturing, which is readily accepting the burden in exchange of economic growth. Lotfi et al. [26], the unsustainable supply chains may be presented in diverse forms including forced labour, child labour, under payment and over-consumption of resources such as water such as in the case of cotton farming.

In 1991, the Den Bosch Declaration was made by government officials drawn from 120 countries all yearning for a sustainable global commodity market. This underlying agenda was aimed at ensuring that there was uniformity and sustainability processes across the entire supply chain, especially in regard to food production and supply [27]. However, this global agenda has not helped to solve the sustainability challenges of supply chains, more so in regard to movement of goods and parts to the markets. This, as noted by Saada [28] explains why there is increased attention toward adoption of Green Supply Chain Management (GSCM). However, the GSCM cannot also hold if the key ingredients, a functional link between producers, suppliers and consumers, is not upheld at all stages, especially in regard to planetary ecological balance. That is, the need to ensure that all stages within the supply chain corresponds with eco-friendly resource management.

While there are numerous sustainability agendas to be pursued, including mitigation of climate change events, the aspect of resource management is urgent and has the capacity to help address many other issues in tandem. For instance, there is a need for all stakeholders within the supply chains to adopt best practices emerging in global markets aimed at promoting optimal resource consumption as envisioned in the SDG12. Such include the circular economy concept where emphasis is on extending the lifecycle of a product or its parts to the maximum by adopting practices such as re-using, repairing, refurbishing, leasing, up-cycling and recycling [29], hence reducing its carbon footprint. The circular economy concept would help the pursuit of resource management by (i) help minimize wastage and pollution, (ii) ensure consumers get the highest value from products and materials and (iii) allow nature to regenerate. Circular economy programmes would further help to stimulate the emergence of new alternatives via eco-innovations that would eventually reduce excessive resource consumption.

Other best practices include emphasizing on using renewable energy in all stages of the supply chain, including mining, production, manufacturing, transportation, storage and during consumption of products. On this, Yu et al. [30] note that the use of non-renewable sources in different stages of the supply chain does not only contribute to climate change but compromises the integrity of natural resources and jeopardizes the quest for sustainability in the supply chain. It also contributes to defeating all other actions that are set in place to address challenges such as climate change, high price of commodities, food insecurity, and so on. It is key in this respect to look at supply chains not only at local level, but to also include challenges linked at regional and global levels, including the need to reduce friction flows when moving products.

3. Impacts on Global Supply Chains

3.1. The Case of the COVID-19 Pandemic

The outbreak of COVID-19 'caught' the global community unprepared, and as outlined by Allam [31], most of the policies, actions and frameworks to contain the pandemic were not in place. As a result, Meyer et al. [32] noted that the pandemic exposed the vulnerability and lack of resilience of the global supply chains. In particular, the supply chain networks showcased their inability to respond effectively to the unprecedented demand-supply pressures. Such pressure was exerted by factors such as the abnormal demands and consumption of medical supplies in different parts of the world. It was also catalysed by enormous demand for consumer goods encouraged by factors such as panic buying, successive waves of the pandemic, and restricted movement of goods and people due to global lockdowns [33,34].

The simultaneous, widespread outbreak of the pandemic in different parts of the globe elicited numerous challenges on diverse sectors such as mining, manufacturing, and transport. For instance, as a majority of people retreated to confinement, most factories and manufacturing industries were experiencing labour shortages as well as scarcity of raw materials. A case in point is the airline industry which, as a critical component in seamless supply chain networks, was short staffed by approximately 4.8 million people as a result of the global containment measures [35], prompting a 7.7%, reduction in air cargo capacities [36]. In the shipping industry, a report by the United Nations Conference on Trade and Development (UNCTAD) highlights these challenges, such as shortages of raw material, prolonged lead time, ocean blank sailings and port closures, among others, intensified during the height of COVID-19 pandemic [37].

For factories and manufacturing plants with raw materials needs, border restrictions and grounding of different modes of transport triggered issues such as labour shortages, transport capacity constraints, and surplus supplies—since it was not possible to move finished products to the consumers, among other obstacles, that eventually compromised smooth supply chain operations and trade flows. According to Freight Right [38], as of October 2021, there were approximately 353 container ships still stranded outsides different ports spread across the globe. The congestions were occasioned by the containment measures that had been instituted almost a year earlier (2020). The impacts of COVID-19 continue to be felt with the backlog for stranded cargo ships continuing even in 2022, where, as of January, there were over 82 container ships that were waiting outside ports in China ready to take cargo, while Hong Kong had 61 and Long Beach, Los Angeles had 61 [39].

The stranding of those ships translated to container shortages in the millions. For instance, as of September 2021, it is reported that there was a global shortage of over 2.4 million 20ft containers, which amplified that congestion in ports [40]. Coupled with these challenges were fuel shortages and increased prices of petroleum products which eventually translated to increased shipping freight rates. For instance, between 2020 and 2021, freight rates from China to South America are reported to have increased by approximately 443%. Between China and other Asia countries and North America, the costs had increased by approximately 63% [41]. Even with the increased charges, the Just in Time (JIT) that had previous helped activities at sea to move seamlessly and flawlessly became inefficient, as normal operations had been greatly disrupted because attention had shifted to containing the pandemic [42].

The impact of this supply chain disruption includes relatively high (compared to pre-pandemic) costs of final products, prolonged transportation time, reduced access to raw materials and increased inequalities in the supply chains. According to Carrière-Swallow et al. [43] of International Monetary Fund (IMF), with the average shipping costs increasing by more than double the previous cost, final consumers have had to put up with not only high costs of products, but also increasing inflation. For instance, in 2021, in a study covering about 143 countries, it was established that the inflation rose by an average of 7% and by 2022, as the challenges in the sea continued to manifest, inflation is

expected to increase by another 1.5% [43]. In particular, the high rates of inflation are being experienced in many western countries, reminiscent to situation in the 1970s.

While the war is still unfolding, and impacts are expected to perdue in time and across sectors, a first set of global challenges are already observed. Figure 1 below highlights some of the global crises that have arose and continue to escalate due to the outbreak of the COVID-19 pandemic as well as the continuing Ukraine–Russia conflict.

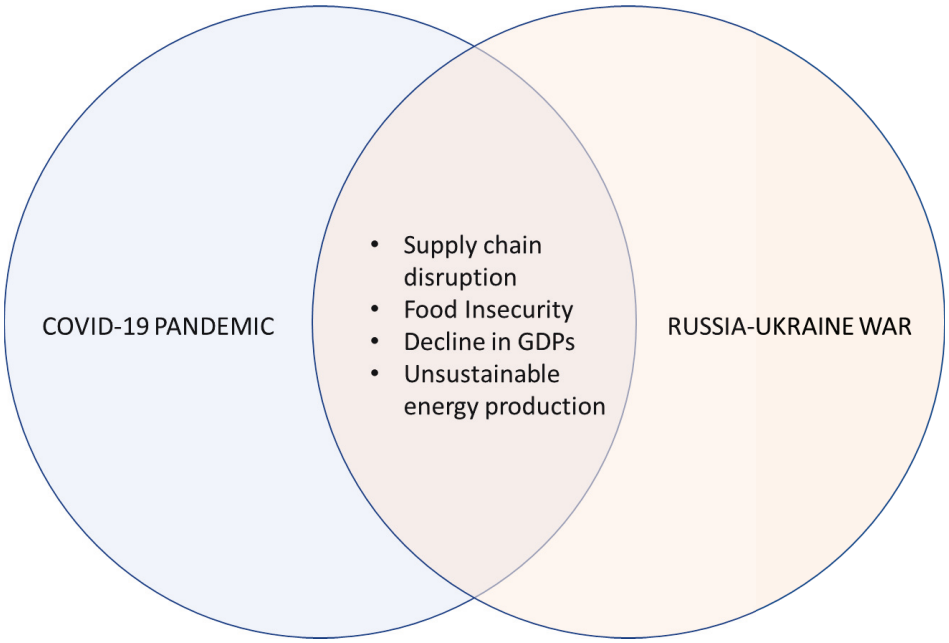

Figure 1. Venn Diagram describing some emerging global crises arising from the COVID-19 Pandemic and the Russia–Ukraine war.

3.2. The Case of the Russia–Ukraine War

The current conflict between Ukraine and Russia that escalated into full blown war, prompted abrupt impacts on the global community, leading to unprecedented challenges. For instance, as a result of the war, there has been an increase in oil prices, global food shortages and uncertainties on the supply chain leading to from the two countries and their neighbours [44]. While the hostility between the two neighbouring countries began in 2014, the situation had not precipitated into the current situation where most of the global communities have resulted into instituting harsh sanctions on Russia. The sanctions by the USA, the European Union (EU), Australia and other regions targeted the financial sectors (capital market, Banking system), real estates, imports and exports of different products and services, technology and others [45]. Though a majority of these economies, especially in Europe, have not yet stopped completely trading with Russia regarding oil and energy, there are plans to gradually detach from the country in terms of reliance on such resources [46]. However, the USA, which was one of the main oil trade partners with Russia, completely banned trade in all energy-related products (Oil, Liquefied Natural Gas and Coal) through an Executive Order signed by President Biden on 8 March [47].

Despite standing with Ukraine, most European countries still rely heavily on oil and related products from Russia, not only for fuelling automobiles, but also for heating, manufacturing industries, and so on. From a report by Eurostat [48], it is evident that Russia has been the largest supplier of Crude oil to the EU. In 2020 alone, the EU imported approximately 25.5% of petroleum oil from Russia and 24.7% in the first semester of 2021 as per the Eurostat database. Further, in terms of entire energy products, between 2017 and 2021, it was reported that Europe increased their imports from between 45% and 48% [48].

With these major importers of oil from Russia banning any importation, this has left other competitors straining to meet the global energy demands. In a report by the

International Energy Agency (IEA) on EU, following the boycott on Russian oil, IEA members had agreed on the 1 March 2022 to release 62.7 million barrels of emergency oil reserves, but the demand pressure escalated such that by the 1st of April, they were forced to announce another 120 million barrels from their emergency stock [49]. This however did not suffice to stabilize the oil supply chain, leading to global markets reacting accordingly, with prices soaring to unprecedented levels globally. For instance, by March 2022, the price of oil per barrel increased by approximately 15% to reach approximately USD 130. Whereas the prices reduced in the following months, to approximately USD 95 by September, the overall impacts are still high especially regarding electricity generation [49].

Besides the oil market, the Russia–Ukraine war has also impacted the global market for consumer products especially food supplies such as wheat, corn and edible oils (sunflower oil). Both Ukraine and Russia are among the major exporters of global wheat, which accounts to approximately a quarter of the total exports from the region [50]. These two economies supply approximately 70% of grain requirements for countries such as Turkey and Egypt, while Ukraine alone is the top supplier of corn to China. Ukraine is also reported to be the global top export of sunflower oil; accounting for approximately 50% of the total global export [51].

The trickle-down effect of scarcity of these products in the global market is the unprecedented increase in their prices and those of other agricultural products that rely on those products as raw materials. For example, in a short-term outlook report published by the European Commission, it is highlighted that most EU countries in particular are bracing for an escalated strain on agri-food sectors. It is expected that the production of milk in the region, for example, is expected to be reduced by approximately 1.5% in the short term, prompting a reduction in products such as cheese, butter and other daily products [52]. The poultry farming is also expected to be impacted as some raw materials for feeds production are sourced from both Ukraine and Russia. According to the UN Food and Agriculture Organisation (FAO) [53], there are possibilities that the overall global prices of food supplies will increase by between 8% and 22% by end of 2022 and 2023, before other alternative sources are established, or the conflict is contained.

Scarcity and high prices for basic products are further expected to trigger an upward adjustment on labour prices in some of the affected countries, as citizenry try to cope with the rising costs of living. For instance, in the United Kingdom, the regular wages have already increased by approximately 4% since the start of this year [54], and with the impacts of war, the demand for wage rises is expected to continue growing [55]. According to the Ratha and Kim [56], the conflict has also prompted a reduction in remittances in most Central Asian countries that have a majority of their residents, especially in Russia. It is projected that remittances from Russia to the Kyrgyz Republic for instance will plummet from 83% recorded in 2021 to approximately 33% this year. Such impacts will then prompt an increase in the domestic labour market as many people will require additional regular income to keep up with rising prices. Overall, the conflated impacts on labour and commodity prices will have substantial ripple effects on other sectors and drive unsustainable prices for various goods and manufactured products, including technology and tech products required for sustainability transitions.

The ripple effects will be felt in sectors such as transport, which, as noted in this paper, is already experiencing notable consequences such as increased freight charges. The agricultural sector in most countries is already experiencing supply chain disruptions, especially for basic farm inputs such as fertilisers, impacting on estimated food production [57]. It is expected that this would have serious ramifications, especially in Africa and other regions that are already strained by reduced food availability prompted by ranging impacts of climate change [58]. In addition, the war has had serious land degradation impacts, including natural resource destruction, pollution, fires et cetera. Sizeable number of farming fields have also become derelict and would take time before they are reclaimed back for agricultural activities [59]. Furthermore, in other scenarios, irrigation systems and agricultural infrastructures have been destroyed. Compounded, all these impacts of the

war would have serious, long-term influence on food production, not only locally, but at the global sphere. Already, months of full-scale aggression has had significant impacts on the global food supply [57], and if a lasting peace solution is not reached urgently, the outcome on food security will be momentous.

4. The Challenges of Green Premiums Additionally, Access to Green Technology

The calls for deep decarbonisation and subsequent, diverse commitments made at COP26 in Glasgow are expected to echo across policy frameworks in countries worldwide. They are anticipated to spark positive outcomes in regard to different countries 'and stakeholders' ambitions for climate action in the pursuit of reaching net-zero emissions by mid-century [5] In recent years, the world has witnessed a plethora of policies, actions and innovations that are expediting sustainability transitions, especially in the energy sector away from fossil fuels towards zero-carbon energy production. To secure a sustainable future, the energy sector needs to rapidly transform from its dependency on fossil fuels to relying on renewable energy sources and smart energy solutions—under the framework of sustainable energy systems. Therefore, energy transition and environmental innovations are high on the agenda of many countries, supranational unions, and international organizations.

The above relates to the Sustainable Development Goal (SDG) 13—Climate Action, which aims to take urgent actions and implement innovative approaches to combatting climate change and thus mitigating its impacts. The energy sector is crucial for transitioning to low-carbon economies and ultimately fossil fuel-free societies through integrating large shares of green energy with smart energy through additional flexibility and decarbonizing other key emitting sectors, notably manufacturing, industry, transport, and buildings. In this respect, one of the key challenges to address and overcome is how to accelerate the transition to low-carbon economies through sustainable energy technologies as a socio-technical system, and what this entails in terms of changes or transitions to the underlying socio-technical processes and their management. Here, more effective policy and governance approaches, coupled with applied new technology solutions, are of crucial importance to enable this purposive transition and spur innovation [60].

The corresponding aim of rapid and deep decarbonization will affect major economic sectors. In this light, innovative but available technologies are regarded by the United Nation's 2030 Agenda as a means to protect the environment, increase resource efficiency, upgrade legacy infrastructure, and retrofit industries (United Nations 2015). A large body of work on transition pathways towards zero-carbon energy or zero-emissions innovations emphasises the role of science, technology and innovation [61] With respect to the latter, the COVID-19 pandemic has accelerated and intensified the digital transformation of the world [62], opening up new windows of opportunity for mainstreaming the adoption and use of science-based technologies across all economic sectors and hopefully for more meaningful innovations in the energy sector.

However, transitions toward sustainable socio-technical systems are associated with complex and multi-dimensional shifts (e.g., [63,64]) increasingly requiring sophisticated approaches. These are necessary to adapt economies and societies to sustainable modes of whole chains of production and consumption. These changes involve a large number of actors, complex relationship, and dynamic networks that need to be orchestrated as part of management transitions and evolved technological innovation systems. Energy transitions involve "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" [65], p. 956). The geographical context for sustainability transitions, policy and governance is a critical dimension to understand. Indeed, as sustainability transitions are constituted spatially, unpacking this configuration is crucial to better understand the underlying socio-technical processes that give rise to these patterns [66]. Many studies of urban transitions have homed in on spatial factors conditioning energy transitions [67]. One of the key research strands in energy transitions is their geographies and the mean-

ingfulness of the analysis of their spatial aspects. Generally, in order for the geography of sustainability transitions to capture the distribution of different transition processes across space [68], it requires analysis of the particular settings in which transitions are embedded and evolve while focusing on spatial relations in terms of geographical connections and interactions [66].

In addition, policies stimulate industrial development of clean/green tech industries [69,70] and facilitate the integration of renewable energy and smart energy technologies as strategic innovative niches [71]. In this area, clean-tech clusters can be mapped and supported through research and development support, training programmes, and funding schemes [72]. This should be based on evidence-based regional innovation policy design using the knowledge of and available research on place specific conditions and their ability to fine-tune policies. What policies should take into account and reflect on in this regard is the difference between the innovation potential and the potential for sustainability transitions due to industrial and technological specialisations [66]. Additionally, the ability to innovate through new knowledge combinations [73], which can be enabled by advanced technologies, is key to smart specialisations based on related sectors with different complementary capabilities.

Several questions are still below the radar in the emerging work on energy transitions. These questions particularly pertain to how policy is analysed and designed, how governance is implemented, and how new technological niches are stimulated and formed based on emerging technologies as part of the socio-technical processes underlying sustainable energy transitions. These are geographical processes that happen in actual locations and through spatial relations and evolve within the spatial configurations and dynamics of networks. The importance of place specificity for sustainability transitions has been extensively examined by geographers [74]. A place-based perspective is, as argued by Coenen, Hansen, Glasmeier and Hassink [67], critical to the understanding of the multifaceted nature of contemporary energy transitions, as well as instrumental to the development of effective policies. The importance of policies reflects the necessity to mobilise the heterogeneous group of local actors of relevance to sustainability transitions and its aims [75]. Governance of sustainability transitions increasingly becomes a collaborative effort involving public and private actors with varied interests and incentives [76]. This results in highly complex processes with, as noted by Hodson and Marvin [77], many disagreements and struggles in terms of ambitions and development of initiatives promoting sustainability transitions. For instance, such disagreements could be in form of pricing of final products, especially in countries further positioned in the supply chain, and also in relation to ensuring that those products are accessible in substantial quantities especially in global south countries. Interestingly, during the process of sourcing raw materials, prices are relatively lower, but after being processed and converted to final products (mostly in countries in the global north), they are marketed at relatively higher prices compared to the cost of production. Therefore, countries especially in the global south with lower purchasing powers are forced to bear those high prices despite the fact that they are key constituents, via the sourcing of raw materials, being a key element in the production cycles.

While the above challenges pertain to the global south, they also have to put up with widespread financial and technological capabilities challenges. In this regard, as rightly acknowledged by the new Global Energy Alliance for People and Planet (GEAPP) that was launched at COP26 [78], access to finances and technology, especially for developing countries, more so those in the global south, will remain an issue that equally require to be addressed urgently. To put this into perspective, it has been reported that currently the compounded CO_2 emissions for energy-poor countries is only 25% of the total global emissions [55]. However, within these economies, there are already at least 243 Gigawatts of coal power plants that are at different stages of completion (planning, being permitted and some being constructed) and expected to operation before mid-term (2041–2060) [79] When complete, such will increase emission capacities for those countries to 75% (equivalent to 38 billion tons of CO_2 emissions) [1]. This will be catastrophic and as has been

captured in the April 2022 IPCC report on mitigation of climate change [1], this means we will not achieve net-zero emissions by mid-century. However, as expressed in a report by the African Development Bank [78], it is not the desire for developing economies to generate their energy from non-renewable sources; however, they have been financially and technologically constrained, promoting them to continue consuming the aforesaid products. This could be changed by initiatives such as the proposed USD 100 billion fund from developed countries, pledged under the Paris Agreement, and anticipated to be in place by 2020, to help developing and less-developed countries in their mitigation programs. The promised USD 100 billion was not achieved, to date it is reported that developing economies have only received approximately 13% of the promised total clean energy financing [78], rendering the fund insufficient in supporting green energy transitions in these countries.

The limited financial resources have made it impossible for countries on the global south to develop their own climate action-oriented technologies. Therefore, they rely on technologies, whose Intellectual Property (IP) is largely owned by the global north [80]. This makes it relatively expensive for developing and least-developed economies to prioritize green solutions, particularly in the energy sector due to costs of accessing different green technologies. Whereas it is important to recognize and appreciate the IP rights protection to promote innovations and creativity, this however should not come at the expense of a global crisis such as climate change, which indeed does not discriminate even against developed economies.

The challenge with expensive green energy solutions is that such attracts relatively higher price margins for green products, making them unattractive compared to products developed through unsustainable alternatives. This margin, or the difference between the cost of a product borne of green technologies and one borne of unsustainable conventional technologies is known as the 'Green Premium'. That is, the extra cost that is incurred for choosing presumably cleaner technologies. Whereas green technologies are important in allowing for a gradual progress toward the net-zero agenda, the green premium could however lead to inequitable outcomes, especially for those without express access to the technologies. The green premium for a technology therefore remains active until a technology achieves a scale that could warrant it to be mass manufactured globally and in all geographies. As such, this means that until such a scale is achieved, green technology would continue to remain 'elusive' as noted in the book *How to Avoid a Climate Disaster* by Bill Gates [81]. There is an urgent need to lower the cost of green premiums, and this can be achieved by promoting equitable access to knowledge (human mobility), raw materials, and finished products in an effective manner. The alternative to this, as proposed by Gates [58], is to charge for all the hidden costs of pollution in products and services. However, the most optimal vanguard for achieving a net-zero agenda is lowering the cost of premiums, especially by streamlining supply chain networks for diverse products. The cost of premiums could also be lowered by providing financial support to less developed and vulnerable regions to help them build their capacities to transition to greener options.

According to Cheney [82], the quest to reduce the green premium is further impacted by the financial systems and availability of financial resources. Whereas there has been quests to make financial resources available, including in form of grants (e.g., Green Climate Fund and others) and loans, these have not been sufficient or in some instances not forthcoming (such as in the case of the proposed USD 100 billion for developing economies proposed in the Paris Agreement). Due to the global economic situations in the recent past, the financial systems are seen to focus more on supporting technology developments, which are majorly based in the global north. In most cases, it has not been possible to expand such developments in the global south. Therefore, most developing and least developed countries are forced to pay high costs for those technologies in their pursuits to implement climate change mitigation programs. This then means that most of the products pushed to market have a relatively higher green premium, and this has the potential to derail their uptake. However, as noted by Oyedokun [83], green products are very critical

for most of the developing and least-developed economies, as they are relatively vulnerable to climate change events despite not being the highest emitters.

For global justice and universal achievement of equitable climate change mitigation, there is a need for urgent consideration to reduce green premiums globally to facilitate social and economic growth equity across the board, as highlighted in different New Green Deals (GND) agendas [84–88]. Further, there is also a need to increase financial support in the global south to unlock the development and manufacturing capacities for increased green energy solutions, as emphasized during the COP26 and also in the latest report by the IPCC. It would also be important to address the shortcomings in supply chains by addressing the structural inequalities that exist, making it hard for most countries, especially in the global south, to access clean technologies that would help in addressing climate vulnerabilities. However, doing this will demand a well-functioning supply chain, which is unfortunately stressed with the pandemic and the war in Europe. The next section engages in a discussion on the subject.

5. Discussions

The need for deep decarbonisation has been apparent even before the United Nations Framework Convention on Climate Change (UNFCCC) was instituted in 1992 [89], as the Intergovernmental Panel on Climate Change (IPCC) was established in 1988. Over the period, supported by scores of global international treaties and agreements such as the Kyoto Protocol of 1997 [90], the Paris Climate Action Agreement of 2015 [90,91] and the Glasgow Climate Pact of 2021 [5] among many others, the quest for climate neutrality has not wavered. The increased attention is particularly driven by recent climate change events that are increasing both in frequency and intensity, prompting serious impacts on the global communities. The outbreak of COVID-19 and the subsequent impacts it has had, coupled with the unravelling impacts of the war between Ukraine and Russia, are further catalysing the need for climate neutrality. These two crises have the potential to prompt a return to unsustainable practices as economies increase their pace to return to pre-war and pre-COVID-19 economic levels [92]. One major challenge with these is the return by economies to the use of non-renewable sources, as was observed by Heubl [92], to be the case in 2021. The two crises would be a major hindrance to the achievement of the SDGs, especially 7, 11, 12, 13, 16 and 17.

On taking charge the impact of climate change, it is evident that many countries, including those on the global north where substantial investments on climate mitigation infrastructure development have been done, are facing increased erratic weather patterns, with consequences such as flooding, heatwaves, prolonged seasons, droughts et cetera [93]. Further, the impacts of climate change events are causing irreversible damages to the global economy, including destruction of infrastructure and properties, loss of livelihoods especially in sectors such as tourism and loss of cultural heritage and culture [94,95].

In Europe as a result of climate-related events, it has been reported that between 1980 and 2020, the region experienced an accumulated loss of between 450 million and 520 billion Euros [96]. In North America, it is reported that the impacts of climate change resulted in a USD 99 billion dollars loss in the USA alone in 2020, despite reduced economic activities as a result of COVID-19 [97]. Going into the future, it is estimated that the global economic loss will be equivalent to around USD 23 trillion, this is equivalent to approximately 18% loss on the global Gross Domestic Product (GDP) [98] The challenges of climate change are then as much economic as environmental, hence bridging polarisation gaps for climate action. With the realities of the COVID-19, and the subsequent impacts of the Russia–Ukraine conflict, it is anticipated that the losses might increase even further, more so due to challenges such as untamed inflation, food scarcity, increased pollution and destruction of natural resources among others [44,59]. For instance, due to the Russian-Ukraine war, the global inflation in advanced economies is reported to have risen to an average of 5.7% by April 2022. In emerging and developing economies, the inflation rose to 8.7% with anticipation that if the situation would be contained in this year, the inflation might reduce to 6.5% and to (2.5% in

advanced economies), since it is also being influenced by the impacts of the COVID-19 [99]. With the ranging inflation, as noted in the previous section, food prices globally are on the rise, with estimation that wheat and maize prices increased by over 35% with average global food prices increasing by over 5 points [44].

The diverse negative impacts of climate change coupled with emerging challenges such as the COVID-19 and the Ukraine–Russia conflict on the global scale have prompted calls for increased attention for green transitions, with the ultimate objective target for net-zero scenarios by the mid-century. However, as was revealed in the wake of COP26 when different countries submitted their Nationally Determined Contributions (NDCs) under the Paris Agreement [18,19] there is much that needs to be done. Indeed, despite most countries having made pledges to reduce emissions, the submissions and communications made in 2021 showcased that a majority were far below their 2030 climate action targets. This then prompts the need to re-look the whole aspect of 'green premiums', which has the potential to derail optimal adoption of green technologies (products) [81].

The green premiums [81] are particularly counterproductive in the global south and developing economies that urgently need to increase their investments in development programs that warrant and guarantee climate mitigation. The negative impacts of green premiums on green transitions ranges from increased costs of technology to the fact that they cannot be effectively measured. These are further expected to be compounded by the impacts of the COVID-19 pandemic that continue to inflict serious economic and social challenges globally, with particular impacts on economies on the global south. The current crisis between Ukraine and Russia is further expected to escalate challenges, especially in relation to market imbalances for different products, which will in turn trigger a further re-emergence of unsustainable practices in different economies.

During the height of COVID-19, the global supply chains for diverse products, including those that support green transitions were greatly affected and even after the resumption of activities in different freight nodes such as ports and airports, there were notable disparities with countries on the global north gaining substantial advantages of their counterparts on the global south. Such disparities are expected to escalate due to the dynamics of the Ukraine–Russia war and the subsequent shortages and scarcity of diverse products, especially consumer goods, food supplies and oil and energy products. As highlighted in the previous section, the war in Ukraine is expected to encourage further escalation of the cost of living globally and these might have a bearing in the financing of green transition programs. Additionally, the war is expected to increase unsustainable practices such as the destruction of natural resources as people explore alternative ways to compensate for scarce fuels and related products. According to Dennison [100], the war has shifted the attention of many European governments in pursuing EU climate goals which include among the important need to transition to clean and sustainable energy.

The two crises—COVID-19 pandemic and Ukraine–Russia war—have prompted challenges of scale in the supply chains networks globally, which in turn are expected to further escalate the disparities in access to green technology due to the ever-increasing issue of green premiums. This gap in development and deployment of green technology is also impacted by disparities in financing, especially with the giant share of climate finance being invested in the global north. However, it is worth noting that despite sharing over 87% of the clean energy financing, developed countries only account for 16% of the global population [78]. The majority of the global population (nearly 60%) living in the global south only receives 13% of the global clean energy financing. However, a majority of these are in the frontline of the climate change events despite contributing less than 15% of the total global emissions [101]. For instance, the SIDS are reported to bear the greatest risks from climate change incidences, yet their contribution is only less than 1% of the global CO_2 emissions [102].

In regard to receiving supplies from global markets, economies in the global south face almost an equal share of inequalities. The remoteness of most of their transportation routes and hub, the increasing freight charges and scarcity of products being part of the many

factors that exacerbates this challenge. All these challenges expose the prevailing climate injustices and global inequality on global climate change support, and this landscape reverberates on supply chain networks being key to develop green technology. The most ideal situation would be to reform, refocus and develop new governance arrangements for financial markets, supply chain networks, and the manufacturing and production systems to promote resilient and more affordable solutions for all players, in a decentralised fashion.

6. Conclusions

The unprecedented impacts of the COVID-19 pandemic, compounded by the Russia–Ukraine war, are expected to continue shaping the global discourse as well as directing it for certain economic and political purposes, especially around sustainability, environmental justice, supply chain management, energy reliability, and food security, among others. This may have serious ramifications on the achievement of the SDGs, which are targeted to be achieved by 2030. Therefore, there is a need to rethink the methodologies deployed for remaining on course to achieve global agendas, including climate change mitigation strategies and goals. In this respect, achieving the numerous global objectives, especially those related to clean energy, supply chain, equality and justice can be done by adopting a raft of strategic pathways and approaches, including legislation (via fiscal mechanisms), and through the formulation of policies that would guide regional and nation-scale development, or by encouraging a set of collaborative paths (shared IP, Knowledge transfer, tech transfer, etc.).

These endeavors would in turn help countries and even possibly regions to consider adopting development models with the potential to spur economic developments, akin to the post WW2 period, which witnessed countries such as Japan and South Korea gaining substantial economic growth. There also is a need for the developed economies to accelerate their supportive role, especially in financial pledges, to ensure that the targeted USD 100 billion aimed at helping developing and the least developed economies are achieved. Further, there will be a need to concentrate on best practices such as the adoption of the circular economy, New Green Deals and others that would ensure that there is some level of decoupling resources from development programs, thereby guaranteeing sustainability transitions in an equitable and just fashion. Further, policy interventions by major global economies, targeting the de-escalation of the Russia–Ukraine war, need to be re-evaluated to encourage the resumption of the exportation of critical components for the production of renewable energy products, such as solar panels and wind turbines.

Author Contributions: Conceptualization, investigation, writing—review and editing by Z.A., S.E.B. and S.A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability; Intergovernmental Panel on Climate Change: 2022. Available online: https://www.ipcc.ch/report/ar6/wg2/ (accessed on 1 September 2022).
2. Ray, D.K.; West, P.C.; Clark, M.; Gerber, J.S.; Prishchepov, A.V.; Chatterjee, S. Climate change has likely already affected global food production. *PLoS ONE* **2019**, *14*, e0217148. [CrossRef]
3. Burrell, A.L.; Evans, J.P.; De Kauwe, M.G. Anthropogenic climate change has driven over 5 million km2 of drylands towards desertification. *Nat. Commun.* **2020**, *11*, 3853. [CrossRef] [PubMed]
4. Behlert, B.; Diekjobst, R.; Felgentreff, C.; Manandhar, T.; Mucket, P.; Pries, L.; Radtke, K.; Welle, D. World Riks Report 2020. Focus: Forced Displacement and Migration; Relief Web: 2020. Available online: https://reliefweb.int/attachments/30ab4c7d-59bc-327d-87da-8d86f265ebcc/WorldRiskReport-2020.pdf (accessed on 1 September 2022).
5. UNFCCC. Glasgow Climate Pact; UNFCCC: 2021; pp. 1–10. Available online: https://unfccc.int/sites/default/files/resource/cma2021_10_add1_adv.pdf (accessed on 1 September 2022).
6. Kling, G.; Lo, Y.; Murinde, V.; Volz, U. Climate Vulnerability and the Cost of Debt. *SSRN Electron. J.* **2018**, 1–30. [CrossRef]

7. Were, A. Debt Trap? Chinese Loans and Africa's Development Options. *S. Afr. Insittute Int. Aff. Policy Insights* **2018**, *66*, 1–13.
8. Gurara, D.; Klyuev, V.; Mwase, N.; Presbitero, A.; Xu, X.C.; Bannister, G. *Trends and Challenges in Infrastructure Investment in Low-Income Developing Countries*; WP/17/233; International Monetary Fund: Washington, DC, USA, 2017.
9. The World Bank. Unprecedented Impacts of Climate Change Disproportionately Burdening Developing Countries, Delegate Stresses, as Second Committee Concludes General Debate. Available online: https://www.un.org/press/en/2019/gaef3516.doc.htm (accessed on 20 April 2022).
10. UNCTAD. Developing Country External Debt: From Growing Sustainability Concerns to Potential Crisis in the Time of COVID-19. Available online: https://sdgpulse.unctad.org/debt-sustainability/ (accessed on 2 November 2021).
11. Adeoti, T.; Fantini, C.; Morgan, G.; Thacker, S.; Ceppi, P.; Bhikhoo, N.; Kumar, S.; Crosskey, S.; O'Regan, N. *Infrastructure for Small Island Developing States: The Role of Infrastructure in Enabling Sustainable, Resilient and Inclusive Development in SIDS*; UNOPS: Copenhagen, Denmark, 2020; pp. 1–39.
12. Sandford, A. Coronavirus: Half of Humanity Now on Lockdown as 90 Countries Call for Confinement. Available online: https://www.euronews.com/2020/04/02/coronavirus-in-europe-spain-s-death-toll-hits-10-000-after-record-950-new-deaths-in-24-hou (accessed on 15 April 2020).
13. Guan, D.; Wang, D.; Hallegatte, S.; Davis, S.J.; Huo, J.; Li, S.; Bai, Y.; Lei, T.; Xue, Q.; Coffman, D.M.; et al. Global supply-chain effects of COVID-19 control measures. *Nat. Hum. Behav.* **2020**, *4*, 577–587. [CrossRef] [PubMed]
14. DHL. Understanding the "New Normal" Supply Chain Risks in 2022 and Beyond. Available online: https://www.dhl.com/global-en/delivered/globalization/supply-chain-risks-in-2022.html (accessed on 18 April 2022).
15. Goshwami, S. 4th Wave of COVID-19 in USA, India, China and Other Countries. Available online: https://dmerharyana.org/4th-wave-of-covid-19/ (accessed on 19 April 2022).
16. Bond, I.; Cornago, E.; Mortera-Martinez, C.; Scazzieri, L. Russia's War on Ukraine: There is Worse to Come (for the West as Well). Available online: https://www.cer.eu/insights/russias-war-ukraine-worse-west (accessed on 26 March 2022).
17. Connolly, K. Nord Stream 1: Russia Switches off Gas Pipeline Citing Maintenance. Available online: https://www.theguardian.com/business/2022/aug/31/nord-stream-1-russia-switches-off-gas-pipeline-citing-maintenance (accessed on 18 October 2022).
18. United Nations. *Global Impact of War in Ukraine on Food, Energy and Finance Systems*; United Nations: New York, NY, USA, 2022; pp. 1–22.
19. UNFCCC. Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat. In Proceedings of the Conference of the Parties Serving as the Meeting of the Parties to the Paris Agreement, Glasgow, UK, 17 September 2021.
20. Talens Peiró, L.; Martin, N.; Villalba Méndez, G.; Madrid-López, C. Integration of raw materials indicators of energy technologies into energy system models. *Appl. Energy* **2022**, *307*, 118150. [CrossRef]
21. Palmer, M.; Truong, Y. The Impact of Technological Green New Product Introductions on Firm Profitability. *Ecol. Econ.* **2017**, *136*, 86–93. [CrossRef]
22. Bibri, S.E. Data-driven smart eco-cities of the future: An empirically informed integrated model for strategic sustainable urban development. *World Futur.* **2021**, 1–44. [CrossRef]
23. Deloitte. *Sustainable Manufacturing: From Vision to Action*; Deloitte: London, UK, 2021; p. 28.
24. Jelti, F.; Allouhi, A.; Büker, M.S.; Saadani, R.; Jamil, A. Renewable Power Generation: A Supply Chain Perspective. *Sustainability* **2021**, *13*, 1271. [CrossRef]
25. Kong, L.; Li, H.; Luo, H.; Ding, L.; Zhang, X. Sustainable performance of just-in-time (JIT) management in time-dependent batch delivery scheduling of precast construction. *J. Clean. Prod.* **2018**, *193*, 684–701. [CrossRef]
26. Lotfi, M.; Walker, H.; Rendon-Sanchez, J. Supply Chains' Failure in Workers' Rights with Regards to the SDG Compass: A Doughnut Theory Perspective. *Sustainability* **2021**, *13*, 2526. [CrossRef]
27. FAO. The Den Bosch Declaration and Agenda for Action on Sustainable Agriculture and Rural Development: Report of the Conference. In Proceedings of the FAO Netherlands Conference on Agriculture and the Environment, S'Hertogenbosch, The Netherlands, 15–19 April 1991.
28. Saada, R. Green Transportation in Green Supply Chain Management. In *Green Supply Chain-Competitiveness and Sustainability*; Bányai, T., Kaczmar, I., Eds.; IntechOpen, 2020. [CrossRef]
29. Andersen, I. The Circularity Transition: Leaving No One Behind. Available online: https://www.unep.org/news-and-stories/speech/circularity-transition-leaving-no-one-behind (accessed on 25 August 2021).
30. Yu, Y.; Zhu, W.; Tian, Y. Green Supply Chain Management, Environmental Degradation, and Energy: Evidence from Asian Countries. *Discret. Dyn. Nat. Soc.* **2021**, *2021*, 5179964. [CrossRef]
31. Allam, Z. *The first 50 days of COVID-19: A detailed chronological timeline and extensive review of literature documenting the pandemic. Surveying the COVID-19 Pandemic and Its Implications: Urban Health, Data Technology and Political Economy*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 41–69.
32. Meyer, A.; Walter, W.; Seuring, S. The Impact of the Coronavirus Pandemic on Supply Chains and Their Sustainability: A Text Mining Approach. *Front. Sustain.* **2021**, *2*. [CrossRef]
33. Allam, Z. Chapter 9—Oil, Health Equipment, and Trade: Revisiting Political Economy and International Relations During the COVID-19 Pandemic. In *Surveying the Covid-19 Pandemic and Its Implications*; Allam, Z., Ed.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 119–127.

34. Allam, Z.; Jones, D.S. Pandemic stricken cities on lockdown. Where are our planning and design professionals [now, then and into the future]? *Land Use Policy* **2020**, *97*, 104805. [CrossRef] [PubMed]
35. IATA. The Impact of COVID-19 on Aviation. Available online: https://airlines.iata.org/news/the-impact-of-covid-19-on-aviation (accessed on 19 April 2022).
36. WTW. COVID-19 Impact on the Air Cargo Industry. Available online: https://www.wtwco.com/en-VN/Insights/2021/01/covid-19-impact-on-the-air-cargo-industry (accessed on 19 April 2022).
37. Pallis, A.A. *COVID-19 and Maritime Transport: Impact and Responses*; UNCTAD: Geneva, Switzerland, 2021.
38. Freight Right. Congestion All Around, from COVID in China to Gridlocks in L.A. Available online: https://www.freightright.com/news/congestion-all-around-from-covid-in-china-to-gridlocks-in-la (accessed on 19 April 2022).
39. Morris, C. Warning Shipping Delay Problems to Continue This Year. Available online: https://www.bbc.com/news/business-60131947 (accessed on 19 April 2022).
40. Van der Merwe, B. Weekly Data: How COVID-19 Disrupted Global Shipping. Available online: https://www.investmentmonitor.ai/analysis/covid-global-shipping-container-shortage (accessed on 19 April 2022).
41. UNCTAD. Shipping during COVID-19: Why Container Freight Rates Have Surged. Available online: https://unctad.org/news/shipping-during-covid-19-why-container-freight-rates-have-surged (accessed on 19 April 2022).
42. Business Wire. Just-in-Time Made the World Tardy: COVID-19 Revealed Manufacturing Cost Cutting Strategies May Have Gone Too Far. Available online: https://www.businesswire.com/news/home/20210628005038/en/Just-In-Time-Made-the-World-Tardy-COVID-19-Revealed-Manufacturing-Cost-Cutting-Strategies-May-Have-Gone-Too-Far-According-to-Pricefx (accessed on 19 April 2022).
43. Carrière-Swallow, Y.; Deb, P.; Furceri, D.; Jiménez, D.; Ostry, J.D. How Soaring Shipping Costs Raise Prices Around the World. Available online: https://blogs.imf.org/2022/03/28/how-soaring-shipping-costs-raise-prices-around-the-world/ (accessed on 19 April 2022).
44. Ben Hassen, T.; El Bilali, H. Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems? *Foods* **2022**, *11*, 2301. [CrossRef]
45. Kadosh, O.; Milhalter, G.; Ochoa, A. A Summary of the Latest Sanctions Against Russia. Available online: https://www.pearlcohen.com/a-summary-of-the-latest-sanctions-against-russia-2/ (accessed on 20 April 2022).
46. European Commission. REPowerEU: Joint European Action for More Affordable, Secure and Sustainable Energy. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1511 (accessed on 20 April 2022).
47. White House. FACT SHEET: United States Bans Imports of Russian Oil, Liquefied Natural Gas, and Coal. Available online: https://www.whitehouse.gov/briefing-room/statements-releases/2022/03/08/fact-sheet-united-states-bans-imports-of-russian-oil-liquefied-natural-gas-and-coal/ (accessed on 20 April 2022).
48. Eurostat. EU Imports of Energy Products—Recent Developments. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_imports_of_energy_products_-_recent_developments&oldid=558719#Overview (accessed on 20 April 2022).
49. International Energy Agency (IEA). Russia's War on Ukraine: Analysing the Impacts of Russia's Invasion of Ukraine on Global Energy Markets and International Energy Security. Available online: https://www.iea.org/topics/russia-s-war-on-ukraine (accessed on 20 April 2022).
50. Duggal, H.; Haddad, M. Infographic: Russia, Ukraine and the Global Wheat Supply. Available online: https://www.aljazeera.com/news/2022/2/17/infographic-russia-ukraine-and-the-global-wheat-supply-interactive (accessed on 21 April 2022).
51. Schiffling, S.; Kanellos, N.V. Five Essential Commodities That Will Be Hit by War in Ukraine. Available online: https://theconversation.com/five-essential-commodities-that-will-be-hit-by-war-in-ukraine-177845 (accessed on 20 April 2022).
52. European Commission. Supply Shock Caused by Russian Invasion of Ukraine Puts Strain on Various EU Agri-Food Sectors. Available online: https://ec.europa.eu/info/news/supply-shock-caused-russian-invasion-ukraine-puts-strain-various-eu-agri-food-sectors-2022-apr-05_en (accessed on 21 April 2022).
53. UN Food and Agriculture Organisation (FAO). FAO Food Price Index Rises to Record High in February. Available online: https://www.fao.org/newsroom/detail/fao-food-price-index-rises-to-record-high-in-february/en (accessed on 21 April 2022).
54. Office for National Statistics. Average Weekly Earnings in Great Britain: March 2022. Available online: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/averageweeklyearningsingreatbritain/march2022 (accessed on 21 April 2022).
55. Office for National Statistics. Average Weekly Earnings in Great Britain: April 2022. Available online: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/averageweeklyearningsingreatbritain/april2022 (accessed on 21 April 2022).
56. Ratha, D.; Kim, E.J. Russia-Ukraine Conflict: Implications for Remittance Flows to Ukraine and Central Asia. Available online: https://blogs.worldbank.org/peoplemove/russia-ukraine-conflict-implications-remittance-flows-ukraine-and-central-asia (accessed on 21 April 2022).
57. Behnassi, M.; El Haiba, M. Implications of the Russia–Ukraine war for global food security. *Nat. Hum. Behav.* **2022**, *6*, 754–755. [CrossRef] [PubMed]
58. Pickson, R.B.; Boateng, E. Climate change: A friend or foe to food security in Africa? *Environ. Dev. Sustain.* **2022**, *24*, 4387–4412. [CrossRef] [PubMed]

59. Clapp, J. Concentration and crises: Exploring the deep roots of vulnerability in the global industrial food system. *J. Peasant Stud.* **2022**, 1–25. [CrossRef]
60. Bibri, S.E.; Krogstie, J. Environmentally data-driven smart sustainable cities: Applied innovative solutions for energy efficiency, pollution reduction, and urban metabolism. *Energy Inform.* **2020**, *3*, 29. [CrossRef]
61. Hess, D.J.; Sovacool, B.K. Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science. *Energy Res. Soc. Sci.* **2020**, *65*, 101462. [CrossRef]
62. Bibri, S.E.; Allam, Z. The Metaverse as a Virtual Form of Data-Driven Smart Urbanism: On Post-Pandemic Governance through the Prism of the Logic of Surveillance Capitalism. *Smart Cities* 2022, *in press*. [CrossRef]
63. Geels, F.W. *Technological Transitions and System Innovations: Aco-Evolutionary and Socio-Technical Analysis*; Edward Elgar: Cheltenham, UK, 2005.
64. Smith, A. Transforming technological regimes for sustainable development: A role for alternative technology niches? *Sci. Public Policy* **2003**, *30*, 127–135. [CrossRef]
65. Markard, J.; Raven, R.; Truffer, B. Sustainability transitions: An emerging field of research and its prospects. *Res. Policy* **2012**, *41*, 955–967. [CrossRef]
66. Hansen, T.; Coenen, L. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environ. Innov. Soc. Transit.* **2015**, *17*, 92–109. [CrossRef]
67. Coenen, L.; Hansen, T.; Glasmeier, A.; Hassink, R. Regional foundations of energy transitions. *Camb. J. Reg. Econ. Soc.* **2021**, *14*, 219–233. [CrossRef]
68. Bridge, G.; Bourzarovski, S.; Bradshaw, M.; Eyre, N. Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy* **2013**, *53*, 331–340. [CrossRef]
69. Carvalho, L.; Mingardo, G.; Van Haaren, J. Green Urban Transport Policies and Cleantech Innovations: Evidence from Curitiba, Göteborg and Hamburg. *Eur. Plan. Stud.* **2012**, *20*, 375–396. [CrossRef]
70. McCauley, S.M.; Stephens, J.C. Green energy clusters and socio-technical transitions: Analysis of a sustainable energy cluster for regional economic development in Central Massachusetts, USA. *Sustain. Sci.* **2012**, *7*, 213–225. [CrossRef]
71. Bibri, S.E. Introduction: The rise of sustainability, ICT, and urbanization and the materialization of smart sustainable cities. In *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context–Aware Computing for Advancing Sustainability*; Springer: Berlin/Heidelberg, Germany, 2018. [CrossRef]
72. Smith, A. Green Niches in Sustainable Development: The Case of Organic Food in the United Kingdom. *Environ. Plan. C Gov. Policy* **2006**, *24*, 439–458. [CrossRef]
73. McCann, P.; Ortega-Argilés, R. Smart Specialization, Regional Growth and Applications to European Union Cohesion Policy. *Reg. Stud.* **2015**, *49*, 1291–1302. [CrossRef]
74. Lawhon, M.; Murphy, J.T. Socio-technical regimes and sustainability transitions: Insights from political ecology. *Prog. Hum. Geogr.* **2011**, *36*, 354–378. [CrossRef]
75. Bibri, S.E.; Krogstie, J. Towards A Novel Model for Smart Sustainable City Planning and Development: A Scholarly Backcasting Approach. *J. Futures Stu.* **2019**, *24*, 45–62. [CrossRef]
76. Lagendijk, A.; Boertjes, S. Light Rail: All change please! A post-structural perspective on the global mushrooming of a transport concept. *Plan. Theory* **2012**, *12*, 290–310. [CrossRef]
77. Hodson, M.; Marvin, S. Mediating Low-Carbon Urban Transitions? Forms of Organization, Knowledge and Action. *Eur. Plan. Stud.* **2012**, *20*, 421–439. [CrossRef]
78. African Development Bank. Historic Alliance Launches at COP26 to Accelerate a Transition to Renewable Energy, Access to Energy for All, and Jobs. Available online: https://www.afdb.org/en/news-and-events/historic-alliance-launches-cop26-accelerate-transition-renewable-energy-access-energy-all-and-jobs-46557 (accessed on 20 April 2022).
79. Rockefeller Foundation. Transforming the Power System in Energy-Poor Countries; The Global Energy Alliance for People and Planet (GEAPP): 2022. Available online: https://www.rockefellerfoundation.org/initiative/global-energy-alliance-for-people-and-planet-geapp/ (accessed on 1 September 2022).
80. Allam, Z.; Jones, D.S.; Roös, P. Addressing Knowledge Gaps for Global Climate Justice. *Geographies* **2022**, *2*, 14. [CrossRef]
81. Gates, B. *How to Avoid a Climate Disaster*; Knopf: New York, NY, USA, 2021.
82. Cheney, C. How Blended Finance Might Help Low 'the Green Premium'. Available online: https://www.devex.com/news/how-blended-finance-might-help-lower-the-green-premium-101997 (accessed on 20 April 2021).
83. Oyedokun, T.B. Green premium as a driver of green-labelled commercial buildings in the developing countries: Lessons from the UK and US. *Int. J. Sustain. Built Environ.* **2017**, *6*, 723–733. [CrossRef]
84. Conte, N. Green New Deal. Available online: https://wtpartnership.co/green-new-deal/ (accessed on 24 February 2021).
85. London Assembly. A Green New Deal. Available online: https://www.london.gov.uk/coronavirus/londons-recovery-coronavirus-crisis/recovery-context/green-new-deal (accessed on 25 August 2021).
86. Filatoff, N. A Green New Deal for Australia? Available online: https://www.pv-magazine.com/2020/01/06/a-green-new-deal-for-australia/ (accessed on 25 August 2021).
87. Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. Green new deals could be the answer to COP26's deep decarbonisation needs. *Sustain. Horiz.* **2022**, *1*, 100006. [CrossRef]

88. Allam, Z.; Sharifi, A.; Giurco, D.; Sharpe, S.A. On the Theoretical Conceptualisations, Knowledge Structures and Trends of Green New Deals. *Sustainability* **2021**, *13*, 12529. [CrossRef]
89. United Nations Framework Convention on Climate Change. Status of Ratification of the Convention. Available online: https://unfccc.int/process-and-meetings/the-convention/status-of-ratification/status-of-ratification-of-the-convention (accessed on 8 August 2021).
90. United Nations Framework Convention on Climate Change. Kyoto Protocol to the United Nations Framework Conventon on Climate Change. Available online: https://unfccc.int/resource/docs/convkp/kpeng.pdf (accessed on 8 August 2021).
91. United Nations Framework Convention on Climate Change. Paris Agreement. Available online: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed on 8 August 2021).
92. Heubl, B. Global Carbon Emissions: The World Keeps Polluting after COVID-19. Available online: https://eandt.theiet.org/content/articles/2021/06/global-carbon-emissions-the-world-keeps-polluting-after-covid-19/ (accessed on 24 September 2021).
93. UN Environment. Cities and Climate Change. Available online: https://www.unenvironment.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change (accessed on 3 September 2019).
94. Kim, H.-e. Changing Climate, Changing Culture: Adding the Climate Change Dimension to the Protection of Intangible Cultural Heritage. *Int. J. Cult. Prop.* **2011**, *28*, 259–290. [CrossRef]
95. Leal Filho, W. Will climate change disrupt the tourism sector? *Int. J. Clim. Chang. Strateg. Manag.* **2022**, *14*, 212–217. [CrossRef]
96. European Environment Agency (EEA). Economic Losses and Fatalities from Weather-and Climate-Related Events in Europe. Available online: https://www.eea.europa.eu/publications/economic-losses-and-fatalities-from (accessed on 20 April 2022).
97. So, K.; Hardin, S.; Extreme Weather Cost U.S. Taxpayers $99 Billion Last Year, and It Is Getting Worse. Available online: https://www.americanprogress.org/article/extreme-weather-cost-u-s-taxpayers-99-billion-last-year-getting-worse/ (accessed on 20 April 2022).
98. Flavelle, C. Climate Change Could Cut World Economy by $23 Trillion in 2050, Insurance Giant Warns. Available online: https://www.nytimes.com/2021/04/22/climate/climate-change-economy.html#:~{}:text=the%20main%20story-,Climate%20Change%20Could%20Cut%20World%20Economy%20by%20%2423%20Trillion%20in,and%20invests%20its%20mammoth%20portfolios (accessed on 1 May 2022).
99. Ahmed, K. Inflation Bites Hardest in Developing World as Ukraine War Raises Prices. Available online: https://www.theguardian.com/global-development/2022/apr/29/inflation-bites-hardest-in-developing-world-as-ukraine-war-raises-prices (accessed on 15 October 2022).
100. Dennison, S. Green Peace: How Europe's Climate Policy Can Survice the War in Ukraine. Available online: https://ecfr.eu/publication/green-peace-how-europes-climate-policy-can-survive-the-war-in-ukraine/ (accessed on 15 October 2022).
101. Guivarch, C.; Taconet, N.; Méjean, A. Linking Climate and Inequality. Available online: https://www.imf.org/Publications/fandd/issues/2021/09/climate-change-and-inequality-guivarch-mejean-taconet (accessed on 20 April 2022).
102. UNEP. *Emerging Issues for Small Island Developing States*; UNEP: Nairobi, Kenya, 2014.

frontiers | Frontiers in Climate

OPINION
published: 02 June 2022
doi: 10.3389/fclim.2022.918790

Pandemic and Conflict Could Undermine Climate Action

Zaheer Allam[1,2,3]*, *David S. Jones*[4,5] *and Ayyoob Sharifi*[6]

[1] Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW, Australia, [2] Chaire Entrepreneuriat Territoire Innovation (ETI), Groupe de Recherche en Gestion des Organisations (GREGOR), IAE Paris—Sorbonne Business School, Université Paris 1 Panthéon-Sorbonne, Paris, France, [3] Live+Smart Research Lab, School of Architecture and Built Environment, Deakin University, Geelong, VIC, Australia, [4] Wadawurrung Traditional Owners Aboriginal Corporation, Geelong, VIC, Australia, [5] Cities Research Institute, Griffith University, Nathan, QLD, Australia, [6] Graduate School of Humanities and Social Sciences and Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Hiroshima, Japan

Keywords: climate action, conflict, climate geopolitics, Ukraine-Russia conflict, sustainable transitions

OPEN ACCESS

Edited by:
Bao-Jie He,
Chongqing University, China

Reviewed by:
Junsong Wang,
South China University of Technology, China
Wei Wang,
Chongqing University, China

***Correspondence:**
Zaheer Allam
zaheerallam@gmail.com

Specialty section:
This article was submitted to Climate Adaptation, a section of the journal Frontiers in Climate

Received: *12 April 2022*
Accepted: *19 May 2022*
Published: *02 June 2022*

Citation:
Allam Z, Jones DS and Sharifi A (2022) Pandemic and Conflict Could Undermine Climate Action. Front. Clim. 4:918790. doi: 10.3389/fclim.2022.918790

Two wars are raging in Ukraine and Russia: the pandemic and the conflict. The former called for the necessary redirection of funding for resilience and preparedness, and the latter is leading to the further redirection of financial flows from community resilience and climate action to military. Combined, both wars lead to a lack of funding for sustainable development at national and local levels post-war in Russia and Ukraine, as well as NATO members. Additionally, current and future economic sanctions on Russia will impoverish communities and businesses, and reduce Russia's capacity to invest in internally sustainable transitions. Concurrently Ukraine (or the re-invented "Ukraine") will need to redirect further financing for re-building and economic development.

Such a landscape will make it near impossible for both Russia and Ukraine to realize their COP26 pledges to achieve deep decarbonization and net-zero targets (Duggal, 2021), leading to their continued high dependence upon the sustenance of fossil fuels for many years into the future. The increasingly vast and diverse imposed economic and business sanctions upon Russia will substantially delimit their future debt-funded infrastructures. A possible argument may be geared toward lifecycle extensions of fossil fuel power plants, as those offer lower upfront investment costs when compared to the erection of new renewable power plants and or nuclear complexes—even if they have faster Return on Investment (ROI) prospects (Castro, 2022). The need for funding can be bridged but will demand deeper commitments for green transitions, a re-structured societal system for more engaged citizen involvement, and renewed trading partnerships where the latter will unfortunately rely upon a sustenance of fossil resources trading. Ensuring sustainable, and long term stable infrastructure, will be particularly key for liveability of cities and communities, as ensuring the functioning of those territories not only ensures human processes, but power economic engines. On the climate side, addressing sustainable policies will allow for more sensible longer-term prospects for developing sustainable cities, and for accessing developmental funds provided for this effect.

On the Ukrainian side, a challenge of scale will present itself to its allies, particularly geared on how to distribute aid and climate financing. This includes tapping into the USD$100 billion climate fund pledged at COP26 (Ares and Loft, 2021) [or broken pledge (Timperley, 2021)], for urgent retrofits in essential infrastructures for both immediate liveability needs and post-war developments. The two avenues, however, must be structured in a way to avoid the reduction of financial flows to the Global South, Least Developing Countries (LDCs) and Small Islands Developing States [SIDS; (UN, 2022)], which are on the frontline of climate change. A global discourse will soon emerge on how funding flows need to be channeled, where, on one side, some

will advocate that human liveability is key in climate discourses and thus needs to be funded in priority, and the other stating that loss and damage caused by climate change must take precedence in its disbursements.

The Ukraine-Russian conflict provides us with a need to ponder on how to revitalize communities in- and -post, conflict to fight a third war, that of climate change. The difficulty at present is that the former is deflecting our attention from the latter, to its detriment, while in other geographies, like in Australia (BBC, 2022), sirens of climate emergencies are being heard.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

Ares, E., and Loft, P. (2021). *COP26: Delivering on $100 Billion Climate Finance*. Available online at: https://commonslibrary.parliament.uk/cop26-delivering-on-100-billion-climate-finance/ (accessed March 12, 2022).

BBC (2022). *Australia Floods: PM Morrison to Declare a National Emergency*. Available online at: https://www.bbc.com/news/world-australia-60672065 (accessed March 12, 2022).

Castro, R. (2022). "Economic assessment of renewable energy projects," in *Electricity Production From Renewables*, ed R. Castro (Cham: Springer International Publishing), 105–123.

Duggal, H. (2021). *Infographic: What has Your Country Pledged at COP26?*. Available online at: https://www.aljazeera.com/news/2021/11/14/infographic-what-has-your-country-pledged-at-cop26 (accessed March 1, 2022).

Timperley, J. (2021). The broken $100-billion promise of climate finance—and how to fix it. *Nature* 598, 400–402. doi: 10.1038/d41586-021-02846-3

UN (2022) *About Small Island Developing States*. Available online at: https://www.un.org/ohrlls/content/about-small-island-developing-states (accessed March 12, 2022).

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.