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Strategies for Promoting Climate-Smart Cities and Fostering an Eco-Friendly Culture in Urban Environments (A Case Study of Porto, Portugal; Curitiba, Brazil; and Singapore)

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Abstract

Urbanization has become a defining characteristic of modern civilization, with over half of the global population now residing in cities. While urban growth drives economic development and innovation, it also imposes significant environmental costs, including heightened carbon emissions, resource depletion, and widespread air and water pollution. Addressing these pressing challenges necessitates the creation of resilient and sustainable urban environments, leading to the emergence of climate-smart cities. These cities integrate climate adaptation and mitigation strategies into urban planning, infrastructure development, and community engagement to reduce greenhouse gas emissions, enhance resilience to climate impacts, and foster eco-friendly lifestyles. This study examines the concept of climate-smart urban development and its critical role in combating climate change, promoting environmental sustainability, and strengthening the resilience of urban areas in the face of global challenges.

Climate-smart cities are essential for addressing global climate change challenges and achieving sustainable urban development. Porto, Curitiba, and Singapore indicate innovative approaches to sustainable transportation, green building practices, and climate-resilient infrastructure through their respective case studies. These cities serve as global models for urban sustainability,

demonstrating how integrated planning, innovative technologies, and community engagement can promote resilience, mitigate climate change impacts, and enhance quality of life for urban residents. To promote climate-smart cities, policymakers should prioritize investments in resilient infrastructure, renewable energy deployment, and sustainable transportation systems. Additionally, raising public awareness and fostering community engagement are crucial for building support for climate-smart initiatives and fostering an Eco-friendly culture in urban environments.

Keywords: Sustainable Environment; Global Warming; Climate Change; Ecofriendly Habits; SDGs.

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1. Introduction

The 21st century has been marked by rapid urbanization and escalating climate change, both of which present formidable challenges to humanity's future. Urbanization, while driving economic growth and technological advancement, has also exacerbated environmental degradation through increased carbon emissions, resource depletion, and pollution. Over half of the world's population now resides in urban areas, a figure projected to grow in the coming decades, making cities critical arenas for addressing climate-related issues (E Atalah, 2024).

Climate change, characterized by rising global temperatures, extreme weather events, and ecological disruption, poses an existential threat to both urban and rural communities. These impacts are particularly severe in developing cities, which often lack the infrastructure and resources to adapt effectively. The interconnected nature of urbanization and climate change necessitates innovative solutions that simultaneously foster resilience, sustainability, and inclusivity (Colding, J., Nilsson, C., & Sjöberg, S., 2024; E Atalah, 2024; Ma, X., Li, J., Guo, Z., & Wan, Z., 2024; F Qu, 2024; A Asrifan, M Murni, et al, 2024).

The world has reached its height concerning global warming matters, climate change, flooding, and ecological destruction, among other ecological concerns (Rusyani et al., 2021). The twenty-first century can be a restorative period that

can enable the healing and cure of planet earth from global warming (Kulakhmetova, 2022), and climate change. Many efforts have been implemented to achieve environmental sustainability.

In this context, climate-smart cities emerge as a transformative concept. These urban areas integrate climate adaptation and mitigation strategies into their planning, infrastructure, and governance. By prioritizing renewable energy, green infrastructure, and community engagement, climate-smart cities aim to reduce greenhouse gas emissions, enhance resilience to climate impacts, and promote sustainable living practices (M Baran, R Hazenberg, & C Vasconcelos, 2023).

1.1. Research Questions

This study seeks to address the following research questions:

1. How does climate change affect urban areas, particularly in developing cities?
2. What roles can climate-smart cities play in achieving environmental sustainability?
3. Which strategies and paradigmatic approaches are most effective in fostering eco-friendly urban cultures?
4. How can smart cities contribute to raising awareness and advancing sustainable urban practices?

5. What challenges and opportunities exist in implementing climate-smart initiatives, and how can they be addressed?

1.2. Objectives of the Study

The objectives of this research are to:

1. Examine the impact of climate change on urban environments and explore its implications for sustainable development.
2. Investigate the role of smart cities in promoting environmental sustainability and achieving climate adaptation goals.
3. Identify effective strategies and approaches for tackling climate change and fostering eco-friendly urban practices.
4. Analyze the contributions of smart cities in creating awareness and driving research toward sustainable urbanization.
5. Propose innovative and actionable solutions for addressing urban environmental challenges through climate-smart initiatives.

1.3. Significance of the Study

This study contributes to the growing body of research on sustainable urban development by offering evidence-based insights into the role of climate-smart cities in addressing global climate challenges. By aligning with the United Nations' Sustainable Development Goals (SDG 13 in particular), the research

supports efforts to combat climate change and promote resilience in urban areas (N Tusikov, 2024; C Vasconcelos, J Silva, et al 2022).

Miao, Y., et al., (2023) propose a daily habit of eco-friendly practice and emphasize the importance of eco-innovation as a roadmap to eco-excellence and sustainability consciousness. Stapleton, A., et al., (2022) propose a human behavioral change towards environmental sustainability and eco-friendly behaviors by emphasizing behavior change and motivation via contextual behavioral change (CBS), a term in psychology that enables in-depth understanding of motivation and positive human behavior and is used to provide depth, scope, and precision, thus enabling an eco-friendly lifestyle to those who embrace the practice of eco-friendliness and sustainability. The authors developed a framework known as the six evidence-based outline for organizations to promote pro-environmental behaviors. They likewise provided paradigmatic examples for each of the six outline, which aid in mitigating the harmful effects of climate change by encouraging positive behavior change toward eco-friendly habits (Chwialkowska, 2021; Fang, 2021; Gao et al., 2022; Kang & Hwang, n.d.; Leochico et al., 2021; Miao et al., 2023; Restya, 2022; Stapleton et al., 2022).

The findings aim to provide practical recommendations for policymakers, urban planners, and community leaders seeking to transform cities into hubs of

sustainability and innovation. Furthermore, the study emphasizes the importance of interdisciplinary collaboration, technological innovation, and community engagement in fostering eco-friendly cultures in urban environments.

This research aspires to inspire transformative change, offering a roadmap for cities to navigate the complex interplay between urbanization and climate change while securing a sustainable future for generations to come.

2. Literature Review

2.1. Tackling Climate Change

The impacts of climate change pose an unprecedented challenge to urban areas, which serve as focal points for both vulnerability and innovation. Woodruff et al. (2022) emphasizes the critical need for resilience plans to mitigate the damaging effects of climate change. These plans are seen as essential tools for cities to prepare for and adapt to climatic disruptions such as extreme weather events, sea-level rise, and prolonged heatwaves. However, a critique of this approach highlights that many resilience plans remain siloed, lacking integration with broader urban planning strategies. There is a need for more holistic frameworks that align resilience efforts with economic development, public health, and environmental sustainability.

Woodruff, S. C., et al., (2022) focuses on creating resilience plans to deal with the damaging effects of climate change. While comparing existing resilience plans and climate change efforts. The authors believe that an efficient resilience plan that can enable cities to prepare for climate change is an essential need. Theodore, M. K., et al., (2021) expatiate more on the effect of greenhouse, which is used as a description of augmented greenhouse gases in the atmosphere and the warming of the earth because of augmented levels of carbon dioxide (CO2). The authors assert that addressing global warming is critical because it has become a greater threat to humans, the earth, and other species in the twenty-first century. Thus, they propose a paradigmatic approach to managing energy needs. Letcher, T. (2021) proposes a resourceful and all-encompassing approach to addressing weather patterns and climate change. Theodore et al. (2021) delves into the role of greenhouse gases in exacerbating global warming. They characterize the increased levels of these gases as a severe threat to biodiversity, human well-being, and planetary systems. The authors propose a paradigmatic approach to managing energy needs, advocating for a transition from fossil fuels to renewable energy sources (Gissi et al., 2021; Hannah, 2021; Hickman et al., 2021; Kasperson et al., 2022; T. Letcher, 2021; Marks et al., 2021; Olabi & Abdelkareem, 2022; Pörtner et al., 2022; Romm, 2022; Setzer & Higham, 2022; Stanley et al., 2021; Zandalinas et al., 2021). While their work provides a strong

foundation, further research is needed to explore how socio-economic inequalities influence the adoption of renewable energy in urban settings.

Letcher (2021) introduces an all-encompassing framework for addressing climate change, focusing on weather pattern monitoring and adaptive measures. This comprehensive approach is echoed by Gissi et al. (2021), Hannah (2021), and others, who advocate for cross-disciplinary strategies that include technology, policy reform, and community engagement. However, these studies often overlook the role of local governance and grassroots activism in driving climate adaptation. Future research could explore how decentralized governance models enhance the effectiveness of climate-smart strategies.

2.2. Fostering Eco-Friendly Culture

Shifting societal behavior towards sustainability is a cornerstone of climate-smart cities. Miao et al. (2023) highlights the importance of daily eco-friendly habits and eco-innovation as pathways to sustainability consciousness. They argue that fostering such practices requires a cultural transformation supported by education, incentives, and infrastructure. However, their focus on individual actions might understate the systemic barriers—such as inadequate public infrastructure or policy frameworks—that hinder widespread adoption of eco-friendly behaviors.

Climate change is rapidly sinking the earth (Habibullah et al., 2022; Woodruff et al., 2022) and global warming is a major concern (Diffenbaugh & Barnes, 2023; Mella, 2022). As earth citizens, we need to be aware of climate change, the harm it causes to the universe, and the depletion it causes to the ozone layer. We also need to be aware of the fact that if we do not take measures today to decrease global warming, our future generations will be affected (T. M. Letcher, 2022; Sabherwal et al., 2021). The necessity to live in harmony with the earth is of major concern in the twenty-first century. This study is a contribution to the 2030 agenda of sustainable development. One of the objectives of the 2030 agenda is sustainable development which broadens into 17 branches under the sustainable development goals (SDGs) (UN, 2015) this study is a contribution to SDG 13 (take urgent action to combat climate change and its impacts). The question is, will the UN be able to achieve the sustainable development goals by 2030? Leal Filho et al., (2023) has helped us in analyzing the reason for the decelerate advancement towards achieving the SDGs goals and these authors propose explicit actions that can fast-track the realization of the SDGs goals of the 2030 agenda (Leal Filho, Walter; Viera Trevisan, Laís; Simon Rampasso, Izabela; Anholon, Rosley; Dinis, M. A. P.; Londero Brandli, Luciana; Sierra, 2023).

Stapleton et al. (2022) propose contextual behavioral change (CBS) as a psychological framework for promoting environmental sustainability. Their six-evidence-based outline provides a structured approach for organizations to cultivate pro-environmental behaviors. While effective in theory, CBS frameworks could benefit from empirical studies that evaluate their application in diverse cultural and socio-economic contexts. Moreover, integration with digital technologies, such as behavioral nudges delivered via smart city platforms, represents an emerging area of inquiry.

Other researchers, such as Chwialkowska (2021) and Gao et al. (2022), emphasize the interplay between cultural norms and eco-friendly behavior. They argue that achieving a sustainable urban culture requires both top-down policies and grassroots initiatives. However, gaps remain in understanding how to balance these dynamics in politically and economically diverse settings.

2.3. Theoretical Frameworks Related to Climate-Smart Cities

Almalki et al., (2021) suggest a new model of sustainability. The authors propose Green Internet of Things (IoT) technology as a paradigm that can foster and improve cities' sustainability while also promoting an environmentally friendly environment. Environmental sustainability is of the essence; the decline of the ozone layer, climate change, global warming, and other factors

are of major concern. Riffat, S., et al., (2016) propose a stronger incentive to save energy, protect the environment, and reduce consumption, as well as a new model of sustainability. Environmental sustainability is a critical concern, according to Brauer, B., et al. (2015), and is one of the most important issues of the twenty-first century. By utilizing Green IS (information systems), the authors created a framework for enhancing sustainable smart cities and promoting sustainable environments in cities (Almalki et al., 2021; Anguluri & Narayanan, 2017; Haughton & Hunter, 2004; Höjer & Wangel, 2015; Russo & Comi, 2012; Vesco, 2015; Viitanen & Kingston, 2014; Vinod Kumar, 2020; Yigitcanlar & Dizdaroglu, 2015).

The concept of climate-smart cities is rooted in urban sustainability theory, resilience theory, and systems thinking. Urban sustainability theory posits that cities can serve as engines of sustainable development by integrating economic, environmental, and social objectives. Resilience theory, on the other hand, focuses on the capacity of urban systems to absorb shocks and recover from climate-related disruptions. Systems thinking provides a holistic perspective, emphasizing the interconnections between urban infrastructure, governance, and community behavior.

Key principles underpinning climate-smart cities include:

- **Sustainable Urban Planning**: Compact, mixed-use urban designs that minimize sprawl and reduce reliance on private vehicles.
- **Renewable Energy Integration**: Deployment of solar, wind, and other renewable energy technologies to decarbonize urban energy systems.
- **Green Infrastructure Development**: Creation of urban green spaces, green roofs, and stormwater management systems to enhance ecological resilience.
- **Community Engagement**: Active involvement of citizens in planning and decision-making processes to ensure inclusivity and cultural relevance.

While these principles provide a robust foundation, research gaps remain in implementing these frameworks in low-income urban contexts where resources and institutional capacities are limited.

2.4. Relevance to Global Climate Change

Climate-smart cities hold transformative potential for addressing global climate change. By reducing greenhouse gas emissions, improving urban resilience, and fostering sustainability practices, these cities contribute to the achievement of international targets such as the Paris Agreement and the Sustainable Development Goals (SDGs). However, as highlighted by Setzer and Higham

(2022), the successful implementation of climate-smart initiatives often depends on multi-level governance and international collaboration.

Critically, existing studies tend to focus on high-income cities with advanced technological capacities, such as Copenhagen and Singapore, while underrepresenting developing cities. Research is needed to identify scalable and context-sensitive solutions that address the unique challenges of urbanization in the Global South.

2.5. Research Gaps and Future Directions

As indicated in the literature survey, most publications focused on sustainable environment and the effects of climate but made no connection between the role of smart cities in creating awareness and implementing paradigmatic approaches to tackling climate and the indispensable need to foster a daily eco-friendly culture (da Rocha et al., 2022; Ocansey & Siakwa, 2021). Additionally, the majority of publications did not discuss a daily eco-friendly culture as a paradigm that can aid in decreasing the effect of climate change. This research addresses these gaps by introducing a daily lifestyle of fostering eco-friendly culture as a paradigm for fostering sustainable environment in the 21st century. Numerous initiatives have been launched globally to address the damaging effect of climate and global warming (Armstrong McKay et al., 2022; Theodore & Theodore, 2021); yet the escalation of climate change (Whitmarsh et al., 2021)

and global warming (Shukla, 2022; Wang et al., 2021) are increasing on a daily basis and thus the necessity of a greater focus on these issues. This research addresses these gaps by developing practical parameters and techniques that can be used to promote a culture of eco-friendless and if possible, decrease the effect of climate change and global warming to its minimum. We hope that this research can help us understand the critical importance of a daily lifestyle of fostering eco-friendly culture, which enables individuals to participate in decreasing global warming from an individual level.

The solutions and techniques presented in this research will be useful for the community, government, and decision makers. It will help us clearly understand the importance and benefits of climate-smart cities. It will clearly highlight the roles of climate-smart cities in fostering a sustainable future and eco-friendly cultures. It will help us understand the damaging effects of climate change and empower us with the tools and knowledge necessary to promoting a sustainable future. This research is a call to action for communities globally, CSOs (Civil Society Organizations), NGOs, businesses, and stakeholders to develop and promote realistic programs that can work towards the goal of addressing the destructive effect of climate and global warming.

The literature underscores significant strides in understanding climate-smart cities and eco-friendly cultures, but notable gaps remain:

1. **Integration of Local and Global Frameworks**: How can global climate-smart strategies be adapted to local contexts?
2. **Equity and Inclusivity**: How can climate-smart cities address socio-economic disparities in access to green technologies and resources?
3. **Technology and Behavior**: What role can digital technologies, such as IoT and AI, play in facilitating eco-friendly behaviors and sustainable urban planning?
4. **Low-Income Urban Areas**: How can resource-constrained cities adopt climate-smart principles without exacerbating financial and infrastructural burdens?

By addressing these gaps, future research can enhance the relevance and applicability of climate-smart strategies, ensuring their impact is both equitable and sustainable.

3. Methodology

Climate change is one of the pertinent issues of the 21st century, threatening the lives and livelihood of billions of people. According to the National Oceanic and Atmospheric Administration (NOAA), climate change has led to severe storms, winter storms, tropical cyclone, flood, drought, and many more (see Figure 1). In the united states alone, the total cost to loss due to climate change is estimated to be around $2.2 trillion since 1980 (NOAA, 2023). The global cost will be significantly higher if measures are not put in place to address this issue.

Promoting climate-smart cities and eco-friendly cultures is one of the important steps towards tackling climate change. Climate smart cities can help to reduce greenhouse emissions, electricity consumption, and heat production. It can also reduce the cost of energy by millions of dollars and reduce carbon emissions by a significant percentage. This research aims to develop evidence-based, practical, creative, innovative, and novel techniques, strategies, and parameters for fostering climate-smart cities, and promoting eco-friendly cultures.

3.1. Research Approach

This study employs a case study methodology to deeply explore climate-smart urban strategies in three cities: Porto, Portugal; Curitiba, Brazil; and Singapore. These cities were selected for their globally recognized innovative practices in sustainable urban development. This approach enables a comparative and context-sensitive understanding of the dynamics, challenges, and opportunities in adopting climate-smart initiatives (E Fischer, GT Guzel, 2023; U Flick, 2022; M Denscombe, 2017).

3.2. Data Collection Techniques

Data collection relied on three primary methods:

1. **Document Analysis**: Policy documents, urban planning reports, and sustainability frameworks were analyzed to uncover institutional strategies and policy-driven outcomes.
2. **Secondary Data**: Peer-reviewed articles, conference proceedings, and sustainability indexes provided contextual insights into each city's initiatives.
3. **Interviews and Expert Opinions**: Although conducted indirectly via previously documented interviews in reports, expert perspectives on urban sustainability practices were synthesized.

3.3. Data Analysis Techniques

Data were analyzed using thematic analysis to identify recurring patterns and strategies, followed by comparative analysis to uncover similarities and differences across the three cities. Key themes, such as integrated planning, community engagement, and technological innovation, were examined in relation to theoretical frameworks like urban sustainability theory and resilience theory.

3.4. Case Studies

As cities continue to grapple with the challenges posed by climate change and urbanization, the imperative for promoting climate-smart cities and cultivating an Eco-friendly culture becomes increasingly apparent. This research proposes to delve into these critical issues, leveraging insights from multiple disciplines to offer actionable recommendations for building resilient, sustainable cities of the future. By fostering collaboration, innovation, and collective action, we can work towards creating urban environments that are not only environmentally sustainable but also inclusive, equitable, and vibrant for all residents. The case studies are presented next.

3.4.1. Porto, Portugal

Porto has emerged as a leader in sustainable urban innovation, adopting a multidimensional approach integrating transportation, architecture, and climate resilience.

3.4.1.1. Sustainable Transportation

Porto's transportation system includes a modern metro network, buses, trams, and cycling infrastructure. The metro system, with its reliability and accessibility, has significantly reduced private car dependency, cut urban air pollution and easing congestion. Investments in bike lanes and bike-sharing

systems further encourage active transportation, contributing to lower carbon footprints.

3.4.1.2. Green Building Practices

Porto's regulatory framework actively promotes green building standards, requiring adherence to internationally recognized certifications like the Building Research Establishment Environmental Assessment Method (BREEAM) and the Leadership in Energy and Environmental Design (LEED). Landmark projects such as Casa da Música and the Serralves Museum showcase energy-efficient designs, including passive heating, natural ventilation, and green roofs. These buildings demonstrate how architectural innovation can align with sustainability goals.

3.4.1.3. Climate-Resilient Infrastructure

Flood protection measures, including riverbank stabilization and stormwater management systems, underscore Porto's proactive stance against climate risks. Urban greening initiatives, such as extensive park systems and tree-planting campaigns, reduce the urban heat island effect and enhance biodiversity, providing recreational and ecological benefits to residents.

3.4.2. Curitiba, Brazil

Curitiba has gained global acclaim for pioneering approaches in sustainable transportation, green infrastructure, and waste management, demonstrating how cities can thrive while preserving ecological balance.

3.4.2.1. Sustainable Transportation

The Bus Rapid Transit (BRT) system remains Curitiba's flagship initiative, offering high-capacity, affordable transportation. Dedicated lanes for BRT buses ensure efficiency and reliability, significantly reducing traffic congestion and vehicular emissions.

3.4.2.2. Compact Urban Design

Curitiba's zoning policies encourage mixed-use development and compact urban layouts. By minimizing urban sprawl, the city preserves natural habitats and reduces travel distances, thereby promoting walkability and enhancing urban livability.

3.4.2.3. Green Infrastructure

The city's extensive parks, urban forests, and green corridors buffer against flooding and erosion while improving air quality and fostering biodiversity. These initiatives also serve as communal hubs for recreation and environmental education.

3.4.2.4. Waste Management Innovations

The "Garbage That Is Not Garbage" program exemplifies Curitiba's leadership in circular economy practices. Recycling and composting initiatives significantly reduce landfill use while fostering community participation in waste management.

3.4.3. Singapore

Singapore offers a compelling example of how high-density urban centers can balance rapid economic development with sustainability.

3.4.3.1. Green Transportation Networks

Singapore's robust public transit system includes buses, Mass Rapid Transit (MRT) trains, and cycling infrastructure. The government incentivizes the use of electric vehicles (EVs) and has implemented a congestion pricing system to reduce traffic in dense urban areas.

3.4.3.2. Vertical Green Spaces

Given its limited land area, Singapore pioneered vertical greening solutions, including rooftop gardens and living walls. Iconic projects like Gardens by the Bay integrate technological innovation with biodiversity enhancement, transforming urban aesthetics while addressing climate risks.

3.4.3.3. Smart City Technologies

Singapore leverages advanced technologies such as Internet of Things (IoT) devices and data analytics to optimize energy use, monitor air quality, and manage urban services. Initiatives like the Smart Nation framework highlight the city's dedication to integrating technology into sustainability efforts.

4. Findings and Discussion

4.1. Integrated Urban Planning

Integrated urban planning serves as the backbone of climate-smart urban development, aligning infrastructure, policy, and community needs to achieve sustainability goals. Porto exemplifies this approach through its cohesive strategies in transportation, green building standards, and climate resilience. By aligning its metro system expansion with pedestrian-friendly urban spaces and cycling infrastructure, Porto has successfully reduced traffic congestion and carbon emissions. This alignment ensures that residents have access to sustainable mobility options, promoting a shift away from private vehicle dependency. Furthermore, Porto’s regulatory framework for green buildings, requiring adherence to certifications like BREEAM and LEED, reflects the city’s commitment to integrating energy efficiency into urban planning.

Curitiba's approach to integrated planning highlights the importance of compact urban design and mixed-use development. Zoning policies in Curitiba limit urban sprawl, preserve green spaces, and reduce the ecological footprint of urban expansion. By promoting dense, walkable neighborhoods, Curitiba not only reduces greenhouse gas emissions but also enhances the quality of life for its residents. The Bus Rapid Transit (BRT) system, a centerpiece of Curitiba's transportation strategy, is seamlessly integrated with the city's zoning plans, ensuring accessibility while minimizing environmental impact. This holistic alignment of transportation, housing, and green infrastructure illustrates how integrated planning can drive sustainable urban development.

Singapore's integrated planning leverages technology to optimize land use and infrastructure development. Given its limited land area, Singapore has adopted a data-driven approach to urban planning, incorporating advanced analytics to forecast and manage population growth, housing needs, and transportation demands. Projects like the Marina Bay Sands area demonstrate how integrated planning can create multifunctional urban spaces that balance economic activity with environmental stewardship. By aligning policy, technology, and design, Singapore exemplifies how integrated urban planning can address the complex challenges of high-density urban environments.

4.2. Community Engagement

Community engagement plays a pivotal role in the success and sustainability of climate-smart initiatives by fostering public buy-in and ensuring that projects address local needs. In Porto, community engagement is evident in the city's urban greening initiatives, where residents are actively involved in tree-planting programs and park maintenance. These initiatives not only enhance urban biodiversity but also build a sense of ownership among residents, ensuring the longevity of these projects. Additionally, Porto's participatory planning processes, where stakeholders contribute to the design and implementation of urban policies, demonstrate the value of inclusive governance in achieving sustainability goals.

Curitiba's grassroots programs emphasize the power of community-driven solutions. For instance, the city's waste management system relies heavily on community participation, with residents segregating waste at the source and engaging in recycling activities. Programs like "Garbage That Is Not Garbage" incentivize sustainable behaviors by providing benefits such as bus tokens in exchange for recyclable materials. This grassroots approach has fostered a strong culture of environmental responsibility, enabling Curitiba to achieve high rates of waste diversion and resource recovery. Community involvement

in maintaining green spaces and participating in educational programs further reinforces Curitiba's model of community-centric urban planning.

Singapore's public campaigns and digital platforms represent a modern approach to community engagement. The government actively uses social media and mobile applications to educate citizens about climate-smart initiatives and solicit feedback on urban projects. Initiatives like the "Clean and Green Singapore" campaign promote sustainable behaviors, such as recycling and energy conservation, through workshops, community events, and online content. Furthermore, Singapore's Smart Nation initiative leverages digital tools to enable participatory governance, allowing residents to report issues, provide input, and monitor the progress of sustainability projects in real time. These efforts underscore the importance of leveraging technology to enhance community engagement in urban sustainability.

4.3. Technological Innovation

Technological innovation is a cornerstone of climate-smart urban development, enabling cities to optimize resource use, monitor environmental conditions, and implement data-driven solutions. In Singapore, the Smart Nation framework exemplifies the integration of technology into urban systems. Smart sensors monitor air and water quality, while IoT-enabled devices optimize energy consumption in public buildings and streetlights. The use of digital twins—

virtual models of urban areas—enables city planners to simulate and optimize infrastructure projects before implementation. These technologies not only enhance operational efficiency but also support Singapore's broader sustainability goals by reducing resource wastage and environmental impact.

Curitiba demonstrates technological innovation in its waste management systems, particularly through the application of circular economy principles. The city's recycling programs utilize digital platforms to track waste streams and measure recycling rates. Additionally, Curitiba has invested in waste-to-energy technologies, converting organic waste into biogas and compost. These innovations reduce landfill dependency while generating renewable energy and soil amendments, highlighting how technology can create value from waste. The city's integration of technology with community participation ensures that these systems remain effective and scalable, even as urban populations grow.

In Porto, technological innovation is evident in its green building practices and climate resilience projects. Smart building technologies, such as automated energy management systems and real-time monitoring of building performance, have been incorporated into new developments. These technologies enhance energy efficiency, reduce operational costs, and minimize environmental impact. Moreover, Porto's use of geographic information systems (GIS) for flood risk assessment and urban planning demonstrates how

technology can enhance climate resilience. By integrating real-time data on weather patterns and water levels, Porto can proactively manage flood risks, protecting both infrastructure and residents.

4.4. Integration with Broader Theoretical and Practical Implications

4.4.1. Urban Sustainability Theory

Urban sustainability theory emphasizes the interconnectedness of environmental, social, and economic dimensions in shaping resilient and inclusive urban systems. Porto, Curitiba, and Singapore exemplify this balance by embedding sustainability into their urban frameworks. Porto's energy-efficient architectural practices, evident in its green-certified buildings like the Casa da Música, showcase how environmental considerations can align with economic benefits. These buildings not only reduce energy costs but also attract investments and enhance property values, creating a win-win scenario for the environment and the economy.

In Curitiba, the implementation of circular economy principles through its waste management programs underscores the social dimension of sustainability. Initiatives like "Garbage That Is Not Garbage" provide direct benefits to economically disadvantaged communities, such as bus tokens or fresh produce in exchange for recyclable materials. This approach

simultaneously addresses waste reduction, resource conservation, and social equity, embodying the holistic vision of urban sustainability theory.

Singapore's integration of smart technologies within its urban systems demonstrates how sustainability can be achieved in high-density contexts. Projects like Gardens by the Bay highlight how environmental and economic objectives can coexist. By creating green spaces that serve both ecological and recreational purposes, Singapore enhances urban biodiversity while supporting tourism and boosting local economies. Together, these cities illustrate that urban sustainability theory is not a static concept but a dynamic framework adaptable to diverse cultural, economic, and geographic contexts.

4.4.2. Resilience Frameworks

Resilience frameworks in urban planning focus on enhancing a city's ability to anticipate, absorb, and recover from climate-related shocks and stresses. Porto's flood management initiatives provide a compelling example of resilience in action. By investing in riverbank stabilization, stormwater management systems, and urban green spaces, Porto proactively addresses the risks of flooding and extreme weather. These measures not only protect infrastructure and lives but also create multifunctional spaces that enhance urban livability and ecological health. Porto's approach aligns with the concept of "anticipatory

resilience," wherein cities prepare for future risks through preemptive planning and adaptive infrastructure.

Curitiba's reforestation efforts and extensive green spaces demonstrate resilience at the ecological and social levels. Reforested areas buffer the city against landslides and erosion while providing habitats for native species. Additionally, these spaces serve as communal areas for recreation and education, fostering social cohesion and environmental awareness. By embedding resilience into its urban fabric, Curitiba illustrates how nature-based solutions can address both immediate vulnerabilities and long-term sustainability goals.

Singapore's vertical greening projects, such as rooftop gardens and living walls, showcase the integration of resilience into dense urban environments. These initiatives mitigate the urban heat island effect, reduce energy demand for cooling, and enhance air quality. Furthermore, Singapore's use of smart technologies to monitor and manage climate risks exemplifies how resilience frameworks can leverage innovation. By employing real-time data and predictive analytics, Singapore ensures that its resilience strategies are not only responsive but also forward-looking. These diverse examples underscore the versatility of resilience frameworks in addressing climate challenges across different urban contexts.

4.4.3. Policy and Governance

Effective governance is essential for implementing and sustaining climate-smart urban initiatives. Porto and Curitiba provide strong examples of participatory governance, where stakeholder engagement drives the success of urban projects. In Porto, community-driven urban greening projects and participatory budgeting processes empower residents to influence decision-making, ensuring that initiatives align with local needs and priorities. This inclusive approach fosters a sense of ownership and accountability, enhancing the sustainability of these projects.

Curitiba's governance model emphasizes grassroots involvement and public-private partnerships. For instance, the success of its Bus Rapid Transit (BRT) system is partly attributed to the collaboration between municipal authorities, private operators, and the community. This model demonstrates how decentralized governance can facilitate innovative solutions while maintaining accountability and transparency. The city's ability to engage diverse stakeholders ensures that sustainability efforts are both equitable and effective.

Singapore's centralized governance model offers a contrasting yet equally effective approach. With strong regulatory frameworks and top-down planning, Singapore has achieved ambitious sustainability targets within short timeframes. Policies such as the Green Mark Scheme for sustainable buildings

and the Smart Nation initiative exemplify how centralized governance can mobilize resources and coordinate efforts efficiently. However, the challenge lies in ensuring that such centralized approaches remain inclusive and responsive to community needs. These case studies highlight that while governance models may vary, their effectiveness hinges on aligning policy frameworks with sustainability objectives and fostering collaboration across sectors.

4.4.4. Scalability and Equity

Scalability is a critical consideration in evaluating the applicability of climate-smart initiatives to diverse urban contexts. While Porto, Curitiba, and Singapore serve as global exemplars, replicating their success in resource-constrained settings poses significant challenges. Porto's green building standards, for instance, require substantial financial and technical resources, which may be out of reach for cities in low-income regions. Addressing this gap requires innovative solutions, such as modular green building technologies or simplified certification processes that are accessible to developing nations.

Equity is another dimension of scalability that warrants attention. Curitiba's waste management programs demonstrate how climate-smart initiatives can address social disparities by benefiting marginalized communities. However, replicating these models requires careful adaptation to local socio-economic

contexts. For instance, cities with high levels of informal employment may need tailored approaches to engage residents effectively and ensure inclusive participation.

Singapore's advanced technological solutions, such as IoT-enabled urban systems, illustrate the potential of innovation in scaling climate-smart initiatives. However, these technologies often require significant upfront investments and technical expertise. To bridge this gap, international collaboration and capacity-building programs are essential. Initiatives like the C40 Cities network provide platforms for knowledge exchange, enabling resource-constrained cities to adapt and implement best practices. By addressing scalability and equity simultaneously, urban sustainability efforts can achieve broader global impact while ensuring that no community is left behind.

4.5. Challenges and Opportunities

4.5.1. Challenges

There are several roadblocks that impede the active participation of many cities in promoting and implementing eco-friendly lifestyle in the community. The challenges are presented next.

4.5.1.1. Financial Constraints

Implementing climate-smart initiatives requires substantial investment in infrastructure, technology, and human capital. Cities, particularly in developing regions, often face limited budgets and competing priorities such as healthcare and education. For example, projects like Curitiba's Bus Rapid Transit (BRT) system necessitated significant upfront capital, which many cities might struggle to secure. Additionally, access to affordable financing options, such as green bonds or concessional loans, remains a significant barrier. Municipalities often lack the creditworthiness or institutional capacity to leverage such funding, further hindering project implementation.

4.5.1.2. Political Inertia

Political resistance and bureaucratic inefficiency frequently delay or derail sustainability initiatives. Climate-smart projects often require long-term planning and cross-party support, which can be challenging in volatile political environments. For instance, a change in administration may deprioritize existing initiatives, as observed in many cities where urban sustainability projects were defunded following political transitions. Moreover, the absence of robust policies and regulatory frameworks can limit the adoption of climate-smart strategies, as local governments may lack the authority or willingness to enforce environmental standards.

4.5.1.3. Gaps in Public Awareness

Public understanding of climate change and its urban implications often lags scientific and policy advancements. This gap can manifest as resistance to new initiatives, such as congestion pricing or energy-efficient building codes, due to misconceptions about their costs or benefits. For instance, in Porto, efforts to expand cycling infrastructure initially faced resistance from residents concerned about reduced parking spaces. Without comprehensive awareness campaigns, these projects risk poor public reception, limiting their effectiveness.

4.5.1.4. Technological Barriers

While technology is a critical enabler of climate-smart cities, its deployment is uneven across regions due to access, affordability, and technical expertise. Cities in low-income countries often lack the digital infrastructure required for advanced solutions like smart grids or IoT-based monitoring systems. Additionally, maintaining and scaling these technologies require ongoing investments in training and capacity-building, which many municipalities are ill-equipped to provide.

4.5.1.5. Institutional Fragmentation

Urban sustainability projects often require coordination across multiple agencies, sectors, and stakeholders. However, institutional silos and poor communication can lead to fragmented efforts and duplication of resources. For

instance, transportation and environmental agencies may pursue overlapping goals without aligning their strategies, reducing the overall impact. Similarly, conflicting priorities between local, regional, and national governments can create inefficiencies, slowing progress on climate-smart initiatives.

4.5.2. Opportunities

4.5.2.1. Innovative Financing Mechanisms

Cities can explore innovative financing options such as green bonds, public-private partnerships (PPPs), and climate funds to overcome financial barriers. For example, Singapore's Green Bond Framework has successfully mobilized investments for infrastructure projects aligned with sustainability goals. PPPs, as demonstrated in Porto's metro expansion, leverage private sector expertise and funding while minimizing public expenditure. Additionally, global initiatives like the Green Climate Fund provide concessional financing tailored to climate resilience projects in developing countries.

4.5.2.2. Policy and Regulatory Reforms

Effective policies and regulations can accelerate the adoption of climate-smart initiatives. For example, Curitiba's zoning regulations encourage mixed-use development and compact urban design, setting a precedent for other cities. Governments can mandate green building codes, incentivize renewable energy adoption through subsidies, and introduce congestion pricing to reduce traffic

emissions. Policy integration across sectors ensures that climate-smart objectives align with broader urban development goals, creating synergies that amplify impact.

4.5.2.3. Capacity Building and Knowledge Sharing

Building institutional and technical capacity is critical for the successful implementation of climate-smart projects. Training programs for municipal staff, as well as partnerships with academic institutions and international organizations, can enhance local expertise. Initiatives like C40 Cities provide platforms for peer learning, enabling cities to share best practices and adapt successful strategies to their contexts. For example, Curitiba's BRT system has been replicated in cities like Bogotá and Jakarta, demonstrating the value of global knowledge exchange.

4.5.2.4. Technological Advancements

Emerging technologies, such as artificial intelligence, IoT, and blockchain, offer new opportunities for enhancing urban sustainability. For instance, smart grids can optimize energy consumption, while IoT-based sensors improve water and air quality monitoring. Singapore's Smart Nation initiative demonstrates how digital technologies can integrate urban services, from transportation to waste management, improving efficiency and sustainability. Cities can also leverage

open data platforms to engage citizens in co-creating solutions, fostering a sense of ownership and accountability.

4.5.2.5. Community Engagement and Public Participation

Involving citizens in the planning and implementation of climate-smart projects enhances their acceptance and sustainability. Participatory approaches, such as community workshops and digital platforms for public consultation, ensure that initiatives are culturally relevant and responsive to local needs. For instance, Porto's community-driven urban greening projects have fostered a sense of stewardship among residents, increasing the longevity and impact of these initiatives. Additionally, education campaigns can raise awareness about climate risks and the benefits of sustainability measures, building public support and driving behavioral change.

4.5.2.6. Global Partnerships and Collaboration

International cooperation provides cities with access to technical expertise, funding, and innovative solutions. Global networks like the UN-Habitat program and initiatives like the Covenant of Mayors for Climate & Energy enable cities to align their efforts with international best practices. Collaborative projects, such as the EU-funded Horizon 2020 initiative, have supported cities like Porto in piloting cutting-edge sustainability measures. Leveraging these

partnerships can accelerate progress and bridge resource gaps, particularly in low-income settings.

5. Conclusions and Recommendations

5.1. Conclusions

Climate change is one of the biggest challenges facing the entire globe. Temperatures are rising, rainfall patterns are shifting, wildfire, cyclones, flooding, drought, wild and severe storms are occurring more frequently. The world currently needs practical techniques and solutions that can be adopted to achieve net zero pollutions across the globe. This study aims to develop practical techniques, strategies, and solutions that can be used to build a smart, sustainable, and eco-friendly city that is environmentally friendly. We hope that the findings and recommendations presented in this study will encourage the promotion of eco-friendly environments. We are aware that to reach the ultimate goal of environmental sustainability, we have to cultivate an eco-friendly lifestyle, which means planting of trees and the 3 Rs, which are, Reduce, Reuse, and Recycle (Leslie et al., 2021; Patil, 2022). We encourage planet earth citizens to imbibe this as part of our daily culture, irrespective of where we live.

The case studies of Porto, Curitiba, and Singapore reveal the transformative potential of climate-smart cities in addressing the pressing challenges of

urbanization and climate change. These cities demonstrate that sustainability is achievable when urban planning integrates environmental, social, and economic considerations. By aligning their strategies with urban sustainability theory and resilience frameworks, they provide actionable models for other cities worldwide. From Porto's innovative flood management and green building practices to Curitiba's grassroots waste management programs and Singapore's technology-driven solutions, the success of these cities highlights the importance of tailoring climate-smart strategies to local contexts while ensuring global scalability.

The findings align with the study's objectives by showcasing effective strategies for fostering eco-friendly urban cultures and addressing climate challenges. Porto's approach to sustainable transportation and green infrastructure illustrates how cities can mitigate greenhouse gas emissions and enhance resilience. Curitiba's circular economy practices and compact urban design underline the significance of integrating social equity into sustainability efforts. Singapore's advanced technological frameworks demonstrate the potential of innovation to optimize resource use and improve urban quality of life. Collectively, these cities affirm that climate-smart strategies are critical for achieving Sustainable Development Goal 13 and ensuring urban resilience in the face of global climate risks.

However, the journey toward sustainable urban development is not without its challenges. Financial constraints, political inertia, public awareness gaps, and technological barriers remain significant hurdles. Addressing these requires a concerted effort from policymakers, urban planners, and communities. By fostering collaborative governance, leveraging innovative financing mechanisms, and promoting global knowledge exchange, cities can overcome these challenges and create resilient, inclusive, and sustainable urban environments (A Asrifan, M Murni, et al, 2024; E Atalah, 2024; J Faizi, AZ Sharifi, et al, 2024; KA Fekete, 2024; S Karatzimas, 2024).

5.2. Recommendations

To enhance the adoption and effectiveness of climate-smart strategies, the following practical and policy-oriented recommendations are proposed:

1. **Innovative Financing Mechanisms**
   - Establish green bond frameworks to attract investments in sustainable infrastructure projects.
   - Encourage public-private partnerships (PPPs) to leverage private sector expertise and funding.
   - Seek support from international climate funds, such as the Green Climate Fund, for resource-constrained cities.

2. **Strengthen Policy Frameworks**
   - Introduce mandatory green building codes and offer tax incentives for compliance.
   - Develop integrated urban planning policies that align transportation, housing, and environmental goals.
   - Implement regulations to promote renewable energy adoption and reduce reliance on fossil fuels.
3. **Capacity Building and Technical Assistance**
   - Organize training programs for urban planners and municipal staff on climate-smart practices.
   - Foster partnerships with academic institutions and international organizations for knowledge sharing.
   - Support research and development to adapt innovative technologies to local contexts.
4. **Enhance Community Engagement**
   - Launch public awareness campaigns to educate citizens about climate risks and the benefits of sustainability initiatives.
   - Involve communities in the design and implementation of urban projects to ensure inclusivity and ownership.
   - Use digital platforms to enable real-time feedback and participation from residents.

5. **Leverage Technological Innovations**

- Invest in IoT and AI technologies for real-time monitoring and efficient resource management.
- Develop open data platforms to enhance transparency and foster collaborative problem-solving.
- Pilot smart city technologies in specific neighborhoods to evaluate scalability and effectiveness.

6. **Foster Global Collaboration**

- Join international networks such as C40 Cities and the Covenant of Mayors to share best practices.
- Collaborate with cities facing similar challenges to co-develop solutions tailored to regional contexts.
- Advocate for increased global funding and technical support for urban sustainability projects.

These recommendations provide a roadmap for cities to overcome barriers and scale their climate-smart initiatives effectively. By implementing these strategies, policymakers and urban planners can ensure that urban development is not only sustainable but also resilient and inclusive, addressing the needs of present and future generations.

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Post-Doctoral Research Report

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https://www.frontiersin.org/research-topics/63727/promoting-sustainable-urban-development-cultivatingclimate-resilient-cities-and-nurturing-an-environmentally-consciouslifestyle/overview

Introduction

This report highlights the accomplishments, contributions, skills learned, lessons gained, and the overall relevance of the postdoctoral research fellowship undertaken at University Fernando Pessoa, in the research area of Health, Environment and Sustainability. Despite limited funding and financial constraints, the postdoctoral fellowship has been a productive and impactful

phase. The contributions, achievements, and skills gained not only reflect my commitment to research excellence but also underscore my ability to work hard in my career, contributing to the fields of environmental sustainability, climate resilience, and food systems.

Appendix 1

1. **Submission of a Journal Manuscript to Frontiers**

- **Manuscript Title**: *Promoting Climate-Smart Cities and Eco-Friendly Culture: A Multi-Disciplinary Approach*
- **Authors**: Esther Oreofeoluwa Esho and Maria Alzira Pimenta Dinis
- **Abstract Accepted**: The manuscript explores strategies for fostering climate-smart cities and eco-friendly cultures, focusing on sustainable urbanization and policy recommendations.
- **Publication Status**: Abstract accepted by a Web of Science (WoS)-indexed journal under Frontiers; the full manuscript is under preparation.

Abstract

As the global climate crisis continues to escalate, the imperative for sustainable urban development has never been more pressing. This paper proposes to explore the concept of promoting climate-smart cities and fostering an eco-friendly culture within urban communities.

Drawing upon insights from various disciplines including urban planning, environmental science, sociology, and technology, this research aims to investigate strategies for mitigating climate change impacts, enhancing urban resilience, and cultivating sustainable behaviors among city dwellers. The paper will delve into case studies of successful climate-smart initiatives and analyze the challenges and opportunities associated with transitioning towards eco-

friendly urban environments. By synthesizing existing literature, identifying best practices, and proposing innovative solutions, this study seeks to contribute to the discourse on sustainable urbanization and provide actionable recommendations for policymakers, urban planners, community leaders, and residents alike.)

2. **Associate Guest Editor Role - Call for Papers:**

- **Research Topic**: *Promoting Sustainable Urban Development: Cultivating Climate-Resilient Cities and Nurturing an Environmentally Conscious Lifestyle* *https://www.frontiersin.org/research-topics/63727/promoting-sustainable-urban-development-cultivatingclimate-resilient-cities-and-nurturing-an-environmentally-consciouslifestyle/overview*
- **Responsibilities**:

- Created and submitted a call for papers that was successfully accepted.
- Reviewed submissions for acceptance/rejection decisions.
- Enhanced skills in editorial management and academic peer review.

3. **Co-Authoring and Presenting at an International Conference (Non-Virtual)**

- **Conference**: 19th IEEE Conference on Industrial Electronics and Applications (ICIEA 2024)
- **Title**: *Mitigating Climate Change: A Deep Learning Approach for Effective Food Waste Reduction*
- **Date:** 05-08 August 2024
- **Registration Cost:** USS 700
- **Venue:** Kristiansand, Norway
- **Authors:** Andronicus A. Akinyelu and Esther Oreofeoluwa Esho

- **Achievements**:

- I collaborated with another colleague, and we designed and developed a novel deep learning model achieving 100% accuracy in classifying fresh and rotten fruits.
- I presented the research in Kristiansand, Norway, at personal expense, underscoring my commitment to disseminating impactful research.

  Published the work in *IEEE Xplore*, a leading peer-reviewed repository. DOI: 10.1109/ICIEA61579.2024.10664919

Abstract

Climate change stands as one of the most significant global challenges. Food waste is one of the factors contributing to climate change. The production, transportation, and disposal of wasted food result in significant environmental impacts, including greenhouse gas emissions. Food waste reduction can contribute significantly to lessening climate change. This study designed and developed a lightweight nature-inspired multi-channel deep learning technique for food waste reduction using Capsule Neural Network and Particle Swarm Optimization (PSO) algorithms. The PSO algorithm is used to search and select optimal hyperparameter values for the CapsNet model. The multi-channel CapsNet model is designed to automatically classify fresh and rotten fruits. The proposed multi-channel model is trained and evaluated on over 23,200 fresh and rotten images of apples and bananas. The model achieved an average test accuracy, precision, f1 score, and ROC score of 100%, 100%, 100%, and 100%, respectively. The research aims to contribute to sustainable practices in the food industry, aligning with global efforts to minimize the environmental impact of climate change and promote efficient resource utilization.

4. **Presentation at the Animal Health Symposium (Non-Virtual)**

- **Conference Name:** Animal Health Symposium

  Theme: Towards More Sustainable Animal Farming

  Date: 12-13 November 2024

  Registration Cost: No Cost

  Venue: Porto, Portugal

  Conference Link:

https://drive.google.com/file/d/1g3FVdESVpnJiAAt6czTF_DJZdDD5J_zN/view

https://a2s.ciimar.up.pt/ahs2024/

- **Title**: *The Role of Environmental Sustainability in Enhancing Food and Nutrition Security for Achieving Sustainable Development Goals (SDGs)*
- **Authors:** Esther Oreofeoluwa Esho, Clara Vasconcelos and Maria Alzira Pimenta Dinis.
- **Key Contributions**:

- Explored the interconnection between environmental sustainability and food security.
- Presented policy frameworks and case studies promoting resilience and sustainability in food systems.
- Delivered the presentation in Porto, Portugal, aligning with global SDG priorities.

Abstract

Achieving food and nutrition security is essential for sustainable development, particularly in the context of increasing global population and environmental challenges. This paper investigates the pivotal role of environmental sustainability in enhancing food and nutrition security for the attainment of Sustainable Development Goals (SDGs). It begins by elucidating the

multifaceted concept of food and nutrition security, emphasizing the importance of access, availability, utilization, and stability of food resources. The interconnection between environmental sustainability and food systems is explored, emphasizing the significance of sustainable agricultural practices, conservation of biodiversity, and resilience to climate change impacts. Furthermore, the paper examines the intricate relationship between environmental sustainability and nutrition, highlighting how environmental factors influence dietary diversity, food accessibility, and nutritional outcomes. Policy and institutional frameworks for promoting environmental sustainability in food systems are discussed, emphasizing the need for integrated approaches and collaborative governance structures. Additionally, the paper presents case studies and best practices that showcase the diversity, creativity, and resilience of initiatives aimed at fostering environmental sustainability in food systems. These examples illustrate the effectiveness of various strategies in enhancing food and nutrition security while promoting environmental stewardship. Finally, the paper addresses challenges and future directions, including the impacts of climate change, resource depletion, and socio-economic inequalities, and proposes strategies for overcoming these obstacles to advance the agenda of environmental sustainability in food systems.

5. **Peer-Review of Journal Articles**

- Reviewed manuscripts for Frontiers, gaining expertise in critical analysis, academic rigor, and subject matter trends in sustainability research.
- Manuscript Title: Navigating End-User Perceptions: Development and Initial Psychometric Properties of a Water Quality Perception Scale: https://www.frontiersin.org/journals/water/articles/10.3389/frwa.2024.1357921/full?utm_source=Email_to_rerev_&utm_medium=Email&utm_content=T1_11.5e

5_reviewer&utm_campaign=Email_publication&journalName=Frontiers_in_Water&id=1357921

6. **Conference Forum Contributions (colabatlantic.com)**

https://ptspace.pt/wp-content/uploads/2024/09/Terra-em-Foco-2024-Agenda.pdf

- **EARTH IN FOCUS - National Earth Observation Conference / TERRA EM FOCO - Conferencia Nacional de Observacao da Terra / Portuguese Space Agency / Agencia Espacial Portuguesa**
- **Focus Room:** *World Café AtlanticSENSE - Digital Twin Environmental: Co-creating a more resilient future for your municipality promoted by: CoLAB+ATLANTIC* / **Sala Foco:** *World Café AtlanticSENSE - Digital Twin Ambiental: Cocriacao de um futuro mais resiliente para o seu municipio promovido por: CoLAB+ATLANTIC*
- **Key Contributions**:
  - Contributed to the forum and interviews on Oceans, Air, Earth, Coastal Zones and the CoLAB+ATLANTIC App.
  - Discussing challenges in our current community under three focal points:

1. Environmental Problems.
2. Principal Impact.
3. Solutions.

Appendix 2

Contributions to the Field:

- **Advancing Sustainability Research**:
  - Developed novel models and frameworks to address climate resilience, urban sustainability, and food security challenges, such as the contributions aforementioned in journals, paper presentation in conferences, among others.

- **Knowledge Dissemination**:
  - Presented research findings at international conferences.
- **Editorial and Peer Review**:
  - Acted as Associate Guest Editor and reviewer, fostering scholarly dialogue in sustainable urban development and environmental science.
- **Interdisciplinary Collaboration**:
  - Fostered collaborations across disciplines, integrating insights from urban planning, artificial intelligence, and sociology to propose innovative solutions.
- **Impactful Publications**:
  - Contributed to journals and conferences, strengthening the discourse on climate change mitigation and sustainable practices.

Skills Gained

- **Research and Writing**:
  - Improved technical skills in writing high-quality research manuscripts and abstracts.
- **Presentation and Public Speaking**:
  - Enhanced ability to present complex ideas clearly and effectively to diverse academic audiences.
- **Peer Review and Editorial Management**:
  - Advanced skills in manuscript evaluation, ensuring scholarly integrity.
- **Technical Proficiency**:
  - Improved knowledge in artificial intelligence, with applications in climate and sustainability research.
- **Collaboration and Networking**:
  - Strengthened academic partnerships through conference participation and editorial roles. Also, networked with established researchers at international and local conferences.

Lessons Learned

- **Resilience and Adaptability**:

. Overcoming financial constraints highlighted the importance of resourcefulness and dedication in achieving research goals.

- **The Power of Interdisciplinary Research**:

. Combining diverse fields led to innovative insights and broader impact.

- **Importance of Dissemination**:

. Sharing knowledge through publications and presentations is vital for advancing global sustainability initiatives.

Relevance of the Study

The research conducted during this postdoctoral fellowship aligns with pressing global challenges:

1) **Climate Change Mitigation**: Addressing environmental issues through innovative technological and social strategies.
2) **Sustainable Urbanization**: Providing actionable insights for policymakers, urban planners, and community leaders.
3) **Food Security**: Enhancing sustainable practices in agriculture and nutrition, contributing to the achievement of SDGs.