Leveraging Smart City Technologies Solutions for Climate Change in Ghana: Implications for Urban Planning and Policy

Christian Kofi Sarpong [a] and Prince Attakora [a*]

[a] Department of Land Economy, Kwame Nkrumah University of Science and Technology, Ghana.

Authors' contributions

This work was carried out in collaboration between both authors. Authors CKS and PA reviewed and agreed to the final manuscript. Both authors read and approved the final manuscript.

Review Article

ABSTRACT

Ghana's urban centres are increasingly vulnerable to the effects of climate change, including rising temperatures and erratic rainfall patterns, as well as recurrent flooding. Addressing these issues requires innovative, technology-based solutions. This paper examines the role of smart city technologies in mitigating and adapting to climate change within the Ghanaian space economy through a systematic review of papers published from 2009-2025. The paper identifies nine priority domains: carbon emissions reduction, resource optimization, environmental monitoring, urban mobility, community engagement, renewable energy integration, sustainable infrastructure, climate resilience, and policy support, where smart technologies can make significant contributions. The finding revealed that through the integration of intelligent systems in transportation, energy, and urban planning, smart cities are capable of reducing climate impacts and enhancing citizens' quality

Corresponding author: Email: pattakora@st.knust.edu.gh;

of life. By contextualizing global experiences within Ghana's unique socio-political and infrastructural setting, this paper contributes novel, localized insights into the potential and challenges of these technologies for inclusive, sustainable urban transformation. The paper proposes coordinated policy frameworks, targeted investment, and inclusive governance to leverage digital innovations for climate action in Ghanaian cities.

1. INTRODUCTION

Climate change poses an unparalleled menace to environmental and economic sustainability worldwide, thus requiring innovative and technologically driven solutions to reduce its effects (Adewnmi et al, 2024). Urban cities, as the focal points of economic activities and human settlements, account for more than 70% of global greenhouse gas emissions (United Nations, 2022). As the rate of urbanization is high, especially in developing economies, smart city technologies have become a strategic response to climate change mitigation and adaptation (Sui, 2014). Smart cities exploit digital technologies, data analysis, and networked infrastructure to promote efficiency in energy use, transportation, waste management, and urban planning (Caragliu et al., 2011). The concept has received global attention, and Singapore, Amsterdam, and Copenhagen are leading the way in implementing smart initiatives that drastically minimize carbon footprints (Yigitcanlar et al., 2019).

Urbanization in Sub-Saharan Africa is progressing at an unprecedented level, while climate change is intensifying pre-existing socio-economic vulnerabilities like energy insecurity, water shortages, and weather extremes (UN-Habitat, 2021). The cities alone in this region will be home to more than 50% of the population by 2050, thus calling for climate-resilient urban plans (World Bank, 2020). Nonetheless, although smart city technologies can increase urban sustainability, their implementation in Africa is confronted with obstacles of inadequate infrastructure, low digital literacy, and financial constraints (Kamana et al., 2024). Notwithstanding these obstacles, nations such as Rwanda, Kenya, and South Africa have embarked on smart city initiatives that incorporate renewable energy, intelligent transport networks, and climate-resilient urban planning to adapt to environmental risks (Kiribou et al., 2024).

Urban areas in Ghana are on the frontline of climate impacts, facing increasing temperatures, erratic rainfall, and frequent flooding events (Morlu, 2024). These challenges underscore the urgent need for innovative solutions that promote environmental sustainability, enhance resource efficiency, and strengthen climate resilience. Smart city technologies, comprising sensor-based environmental monitoring, intelligent transportation systems, renewable energy integration, and community engagement platforms, offer promising tools to address these urban vulnerabilities (Bittencourt et al., 2024).

However, Ghana's unique socio-economic context, marked by gaps in digital infrastructure and limited institutional coordination, requires that these technologies be implemented in a manner that is inclusive and tailored to local realities (Omweri et al., 2024). Bridging digital divides to ensure marginalized urban populations benefit from climate-smart technologies is critical. Additionally, a coordinated governance framework that aligns with national development priorities is essential to maximize the impact and sustainability of smart city initiatives (Kutty et al., 2020). By adopting a comprehensive, multi-domain approach combining technological innovation with social inclusion and governance reform, Ghana can leverage smart technologies not only to mitigate climate change impacts but also to foster sustainable urban development that improves the quality of life for all residents. This paper addresses these gaps by examining the potential of smart city technologies in mitigating and adapting to climate change within Ghana's urban economy. Specifically, the study aims to: (i) analyze how smart technologies contribute to climate action; (ii) evaluate the feasibility of deploying such technologies in Ghana; and (iii) propose actionable policy recommendations to support digital and environmental transformation.

2. LITERATURE REVIEW

2.1 Overview of Smart City's Technologies

Smart cities use cutting-edge technology to improve urban living, streamline municipal

processes, and encourage sustainable growth (Jalal, 2023). By integrating technology seamlessly, they hope to improve quality of life, maximize resources, and boost public service efficiency. The Internet of Things (IoT), data analytics, and information and communication technologies (ICT) are all crucial elements of smart cities because they enable real-time decision-making and enhance citizen participation (Chaurasia et al., 2020; Mohanty, 2016). Smart cities offer answers to complicated urban problems, including pollution, traffic congestion, and energy management, hence fostering sustainable urban expansion as urbanization picks up speed worldwide (Umamaheswari et al., 2021).

2.1.1 Internet of Things (IoT)

The Internet of Things (IoT) is the foundation of smart city projects because it makes it possible to connect different sensors, devices, and systems that gather and exchange information (Jiang, 2020). IoT applications include intelligent energy management systems that optimize energy use, public safety systems that improve emergency response, and smart transportation systems that offer real-time traffic information (Hammi et al., 2018). Through interactive services, IoT integration improves urban infrastructure and increases public involvement (Whaiduzzaman et al., 2022).

2.1.2 Big data and data analytics

Advanced data analytics technologies are needed to process and analyze the massive volumes of data produced by smart city systems (Osman, 2019). Big data analytics gives city planners and administrators the ability to make well-informed decisions based on up-to-date knowledge about urban dynamics, including environmental conditions, population trends, and patterns of energy usage (Bibri, 2019). Taking proactive steps to resolve problems before they worsen improves service delivery (Gupta et al., 2021).

2.1.3 Machine learning and artificial intelligence

Data patterns are analyzed and predictions are made using AI technologies and machine learning algorithms (Sarker, 2021). These technologies can help increase efficiency and save operating costs by automating activities in areas like garbage disposal, energy use, and traffic control. Because AI-powered chatbots can instantly respond to questions and concerns, they can also enhance citizen contact (Umamaheswari et al., 2021).

2.1.4 Blockchain technology

Blockchain technology provides transparent and safe ways to handle the data flows that are a part of smart city infrastructures (Li, 2018). In a variety of smart city applications, its decentralized structure can improve trust and security by enabling safe transactions in domains like as identity verification, supply chain management, and land registration (Chaurasia et al., 2020).

2.1.5 Cloud computing

Smart cities can store and analyze vast amounts of data more effectively and economically thanks to cloud computing (Khan et al., 2013). It lessens the requirement for actual hardware by enabling scalable infrastructure that can support a range of applications. Cities can quickly implement services and promote cooperation between many stakeholders, such as public and private organizations, by utilizing cloud platforms (Ahad et al., 2020).

2.1.6 Geographic Information Systems (GIS)

GIS technology's mapping and spatial analytic skills are essential to urban planning (Tao, 2013). The tool's ability to depict intricate data sets about environmental conditions, infrastructure, and demographics helps planners and policymakers make well-informed decisions on urban growth and resource allocation (Whaiduzzaman et al., 2022). Cities can function more effectively, and inhabitants can enjoy a better quality of life in a networked environment created by the integration of these technologies into smart city efforts (Yeh, 2017). According to Umamaheswari et al. (2021) and Abdulsattar et al. (2022), smart cities have to tackle persistent issues of data privacy, cybersecurity, and system interoperability to fully achieve their promise for sustainable urban development.

2.2 Climate Change in Ghana

Climate change poses a significant risk to various sectors in Ghana, affecting agriculture, health, energy, and national welfare (Mensah et al., 2022). The impacts of climate change are multifaceted and intricate, and a multifactorial

approach is needed to understand and mitigate its adverse impacts (Bandh et al., 2021). Indications are that Ghana is experiencing notable climatic changes, including a rise in temperatures by approximately 1°C over the past four decades and a corresponding rise in sea level (Ankrah, 2020). These changes are expected to reduce agricultural production, especially in vulnerable regions. The agricultural sector is very vulnerable to climatic changes. Maize yield can decrease by 55% by 2050 due to rising temperatures and erratic rainfall (Doso Jnr, 2014). Cocoa cultivation zones are decreasing in suitability, endangering crops and food insecurity (Asante & Amuakwa-Mensah, 2014). Rising sea temperature is a threat to fisheries that are vital to Ghanaian livelihood and food (Ankrah, 2018). Destabilized ecosystems can reduce fish stocks, impacting subsistence and commercial fishing (Asante & Amuakwa-Mensah, 2014).

Climate change targets Ghana's most vulnerable and poorest, specifically the urban and northern Savannah areas (Armah et al, 2011). These populations will suffer from more poverty and reduced livelihoods as the conditions get worse (Arndt et al. 2015). There is a need to invest in agricultural research, adaptation, and infrastructure in order to fight these problems. These initiatives can reduce the impacts of climate change and enhance resilience in affected communities. Adjustment in agriculture and transport can enhance food security and economic stability (Arndt et al. 2015). The Ghana government has initiated interventions to mitigate the impacts of climate change and build resilience in various sectors. Poor funding prevents proper implementation of such strategies (Awuni et al. 2023). Sustainability in funding and policy consistency are vital to ensuring success. Besides, climate change awareness, knowledge enhancement on adaptive strategies, and stimulating community engagement are essential for building grassroots resilience. The majority in Ghana have a partial understanding of climate change, hence successful adaptation is hindered (Odonkor et al. 2020 & Addaney et al. 2021). Climate change is a big challenge facing Ghana as it impacts its economy, environment, and society (Awuni et al., 2023). A multifaceted approach of research, mobilization of communities, and investment in mitigation and adaptation is necessary in a sustainable response to climate change (Suhaeb et al., 2024). A combination of efforts by the government, NGOs, and local communities is the way forward in solving these issues and guiding Ghana towards resilience (Arhin, 2018).

2.3 Smart Cities Technologies and Climate Change

Carbon emissions reduction through intelligent transportation systems can reduce commute times by 20-30%, cutting greenhouse gases accordingly. Incorporating carbon-neutral zones and pedestrianized areas complements technological solutions, emphasizing that integrated urban planning is essential to maximize impacts. The effectiveness of these interventions hinges on alignment with local urban design and policies. Therefore, a combined approach fusing smart technologies with robust urban governance and policy frameworks holds the greatest promise for measurable climate benefits in Ghanaian cities. Resource optimization through IoT-enabled water management and dynamic energy systems directly addresses pressing challenges in Ghana, such as water scarcity and energy demand fluctuations, supporting more sustainable urban resource use (Matemilola et al. 2022; Paskaleva & Curwell, 2009).

2.3.1 Reduction of carbon emissions

The reduction of carbon emissions is a paramount objective for smart cities, contributing directly to the mitigation of climate change. Smart city technologies utilize sensors, data analytics, and autonomous systems to optimize transportation and energy use effectively. For instance, intelligent traffic management systems that optimize traffic flow not only reduce commute times but also diminish idle vehicle emissions. Recent studies indicate that smart traffic signals can cut commute times by 20-30%, leading to a corresponding decrease in greenhouse gas emissions (Donnellan et al. 2019). The Scope for adoption of these technologies can be exemplified by integrating public transport with smart card systems, allowing for more efficient scheduling and route planning. This shift can significantly reduce reliance on personal vehicles, which contribute disproportionately to urban air pollution. The establishment of carbon-neutral zones within cities can be facilitated through smart urban planning, which can prioritize pedestrian-only areas, thus further minimizing carbon emissions (Nikolov, 2024).

Table 1. The impact of climate change

Sector	Projected Impact	Timeframe
Agriculture (Maize)	Decline in yields by up to 55%	By 2050
Agriculture (Cocoa)	Decreased suitability for cocoa production	Ongoing
Fisheries	Reduced fish stocks due to rising sea levels	Ongoing
Overall National Welfare	Increased poverty in urban and northern areas	Ongoing
Temperature Increase	Average rise of 1°C over the past 40 years	Past 40 years

Source: Arhin, 2018

2.3.2 Resource optimization

The implementation of smart resource management solutions reduces waste and enhances the efficiency of essential services. Smart water management systems incorporate IoT sensors to detect leaks and monitor water quality in real time, minimizing wastage. This is particularly vital in Ghana, where water scarcity is a pressing issue. Rao & Samal (2022) estimates indicate that such systems can reduce water loss by up to 30%. In the energy sector, dynamic management of energy consumption through smart meters can lead to significant cost savings for residents while reducing overall energy demand. Integrating renewable energy sources into the grid via smart technologies can facilitate a transition towards a more resilient energy system. For instance, Ghana could benefit from such integration by utilizing its abundant solar resources, allowing homes and businesses to partake in community solar projects (Bibri et al. 2023). By optimizing these resources, smart cities can promote environmental sustainability while addressing basic needs more effectively.

2.3.3 Environmental monitoring and data analytics

Continuous monitoring of air quality, temperature, and meteorological conditions allows for better preparedness and response to environmental challenges. For instance, cities can deploy a network of air quality sensors to track pollution levels and coordinate public health interventions more effectively. Research indicates that real-time environmental data can lead to a 50% improvement in response times to air quality-related health emergencies (Izah, 2025). Leveraging satellite data combined with ground-based sensors can pave the way for smarter environmental management strategies. This approach not only aids in tracking pollution sources but also informs land use planning and disaster management practices. The ability to analyze big data and use predictive modeling helps municipalities anticipate climate events, enabling proactivity rather than reactive measures (Rao & Samal, 2022). These capabilities ensure that urban areas are better equipped to handle disruptions caused by climate change.

2.3.4 Improved urban mobility

Urban mobility is a crucial aspect of sustainability in smart cities. With rapid urbanization in Ghanaian cities, efficient public transport systems must be established to alleviate congestion and reduce the carbon footprint. Smart mobility solutions such as integrated public transport networks allow citizens to access real-time information on transit schedules, effectively reducing wait times and encouraging public transport use (Donnellan et al. 2019). Additionally, bike-sharing and carpooling initiatives, supported by smart technologies, foster the adoption of alternative transportation modes. In cities like Accra, promoting these systems can enhance urban mobility while contributing to lower emissions. Importantly, urban planners must also consider creating pedestrian-friendly spaces that encourage walking and reduce reliance on motorized transport. Cities that prioritize non-motorized transport access report improved air quality and public health outcomes (Rao & Samal, 2022).

2.3.5 Community engagement and awareness

Effective communication strategies utilizing mobile apps, social media, and community workshops can raise awareness about sustainability goals and encourage active participation in local projects. Mobile platforms could provide educational content related to climate change, empowering citizens to make informed decisions regarding their energy use and waste management (Izah, 2025). In areas facing digital divides, targeted outreach programs that focus on inclusive access to technology must be established to ensure that marginalized communities can participate fully. Such engagement acknowledges the voices of

residents in urban planning, leading to initiatives that align with local needs and preferences. Evidence suggests that communities with higher levels of engagement in environmental practices are more likely to adopt sustainable behaviors, thus reinforcing the fundamental role of community involvement in climate action (Rao & Samal, 2022).

2.3.6 Integration of renewable energy

Ghana also boasts high solar potential, and smart grid investment can be utilized in order to integrate decentralized energy consumption. This enables homes and businesses to use solar energy, and this enhances resilience and lowers the reliance on non-renewables (Nikolov, 2024). Emerging technologies like energy storage enable effective management of renewable energy. Surplus solar energy is kept in batteries and sold at peak demand; thus, the system becomes more efficient. There is evidence that smart grids can raise the proportion of renewable energy by 25-30%, which is critical for countries like Ghana's sustainable transitions (Bibri et al. 2023).

2.3.7 Green buildings and sustainable infrastructure

Green buildings with smart technologies can effectively reduce the environmental impact of urbanization. Smart sensors monitor temperatures, ventilation, and water usage, rendering energy efficiency (Rao & Samal, 2022). Green building technologies in Ghana lower developers' and tenants' operating expenses while adhering to environmental regulations. The use of sustainable materials and optimal designs aligns buildings with climate policy. Municipalities must foster policies that incentivize green technologies, making developers incorporate sustainability. Research indicates that green-standard structures can reduce energy by 30-50%, resulting in fewer greenhouse gas emissions (Matemilola, 2022).

2.3.8 Climate resilience and adaptation

Smart governance, supported by data-driven decisions, enables adaptive climate risk planning. GIS technology enables visualization of risk areas and development of flood management systems, which enhance preparedness for extreme weather (Izah, 2025). Ghana's local governments have to focus on building disaster response capacity using technology to enable quick response during climatic emergencies. Climate resilience training will equip municipal employees with skills for implementing solutions at scale. Climate-resilient urban infrastructure has the potential to reduce the effects of climate change while promoting economic growth and social equity.

2.3.9 Holistic planning and policy support

Integrating smart city technologies into urban planning needs strong policy backing and stakeholder alignment. Putting governance of public-private partnerships first can lead to investment in green infrastructure and shared tech initiatives. Policymakers should design regulations to facilitate smart city initiatives in alignment with national sustainability goals (Bibri et al. 2023). Stakeholder engagement promotes collaboration among government, business, and civil society, making sure that smart initiatives are in tandem with community demand. Empirical observation suggests that cities with collaborative planning achieve more sustainability and climate resilience (Nikolov, 2024). Good governance ensures that smart city technology is for the good of urban residents in Ghana who are looking to combat climate change.

3. METHODOLOGY

This study employed a rigorous systematic literature review to analyze peer-reviewed articles, books, and credible reports concerning the intersection of smart city technologies and climate resilience in Ghana's space economy without using primary data. Systematic review is a comprehensive, transparent, and systematic method of identifying, evaluating, and synthesizing all relevant studies on a specific research question, using clearly defined methods and criteria (Higgins et al. 2019). The review prioritized studies published between 2009 and 2025, focusing on empirical data, theoretical insights, and governance considerations related to technological interventions and their socio-political contexts. This comprehensive approach ensured an inclusive understanding of the multifaceted roles smart technologies play, from urban energy management to community engagement in Ghana's climate adaptation pathways.

The review was conducted using a systematic and stringent process in an attempt to traverse extensive and multifaceted literature on the subject, as shown in Fig. 1. Literature searching

was performed against electronic databases including PubMed, Scopus, Web of Science, Science Direct, and Google Scholar. The keywords used were variations on the words "roles," "smart cities technologies," "climate change," and ''Urban Planning and Policy''. The search was conducted only for English-language publications. Irrelevant studies, opinion pieces, and duplications were excluded. Relevant information from the selected studies was extracted, including principal findings, research design, and theoretical frameworks utilized. The data was synthesized thematically to identify emergent themes, patterns, and trends in the literature.

Thematic analysis was conducted to extract recurring patterns and categorize them into nine core domains: emissions reduction, resource efficiency, environmental monitoring, mobility, engagement, energy, infrastructure, adaptation, and policy support. The implications of the literature reviewed were analyzed and interpreted to understand holistically the role of smart city technologies in addressing climate change within Ghana's space economy. The review's limitations were determined, including possible publication bias, weaknesses inherent in the studies chosen, and the extent of the literature search. The weaknesses were taken into account in the interpretation of the results. The paper concluded by recapitulating the principal findings from the literature reviewed, distilling the most prominent findings and implications. The reference list was given in the appropriate citation format to recognize the authors of the literature reviewed.

3.1 Contextual Focus on Ghana

Climate change poses significant challenges to countries around the world, and Ghana is no exception. Over the past four decades, Ghana has witnessed about a 1°C rise in temperature and a troubling increase in sea levels, adversely affecting agricultural productivity and heightening coastal flooding vulnerabilities. In response to these pressing issues, the Ghanaian government has implemented various strategies aimed at building resilience across different economic sectors. Insufficient financing is one of the main obstacles to the implementation of climate change policy objectives.

Smart city technology is essential if Ghana is to fight climate change and achieve economic goals. Smart grids, for instance, have the potential to significantly enhance the country's energy system, which is held back by aging power plants and transmission infrastructure. Intelligent grids have the potential to reshape Ghana's power by incorporating cleaner sources, providing greater agility and responsiveness to disruptions in the climate. This is crucial because increased demand for affordable electricity in the face of climatic variability can be met by it.

Ghana's urban areas, for example, Accra and Tamale, suffer from rapid urbanization and climatic change effects. Smart city technology can strengthen urban resilience through the use of data in planning. This type of technology supports flood hazard risk management, enhances resources, and improves sustainable conditions. Ghana's smart city initiatives have great potential yet are fraught. Stakeholders prioritize short-term fixes over long-term planning, leading to a fragmented resilience approach. Further, a lack of funding, technical capacity, and infrastructure constrains comprehensive implementation. It is essential that these challenges are resolved to maximize the potential of smart technologies for climate change.

The application of smart technologies must extend beyond energy management. Smart city as a holistic idea cutting across transportation, health, and education must be considered in order to manage urban issues in addition to realizing climate resilience. Through partnership, Ghana can create an ecosystem in which smart city technologies can be implemented successfully. Smart city technologies are of utmost significance in combating climate change in the economy of Ghana. The implementation of these innovations helps Ghana overcome climate risks while promoting sustainable development. There is a need for long-term planning, technological investment, and cooperation to create a sustainable society that thrives amidst environmental degradation.

3.2 Analysis and Discussion

After a careful search and assessment, Table 2 lists the academic papers that explicitly addressed how smart city technologies could help Ghana's space economy deal with climate change. These investigations' theoretical, conceptual, and empirical foundations form the basis of the analysis and discussion that follows. With all of this, they provide a contextualized understanding of how Ghana's space economy addresses climate change through smart city technology.
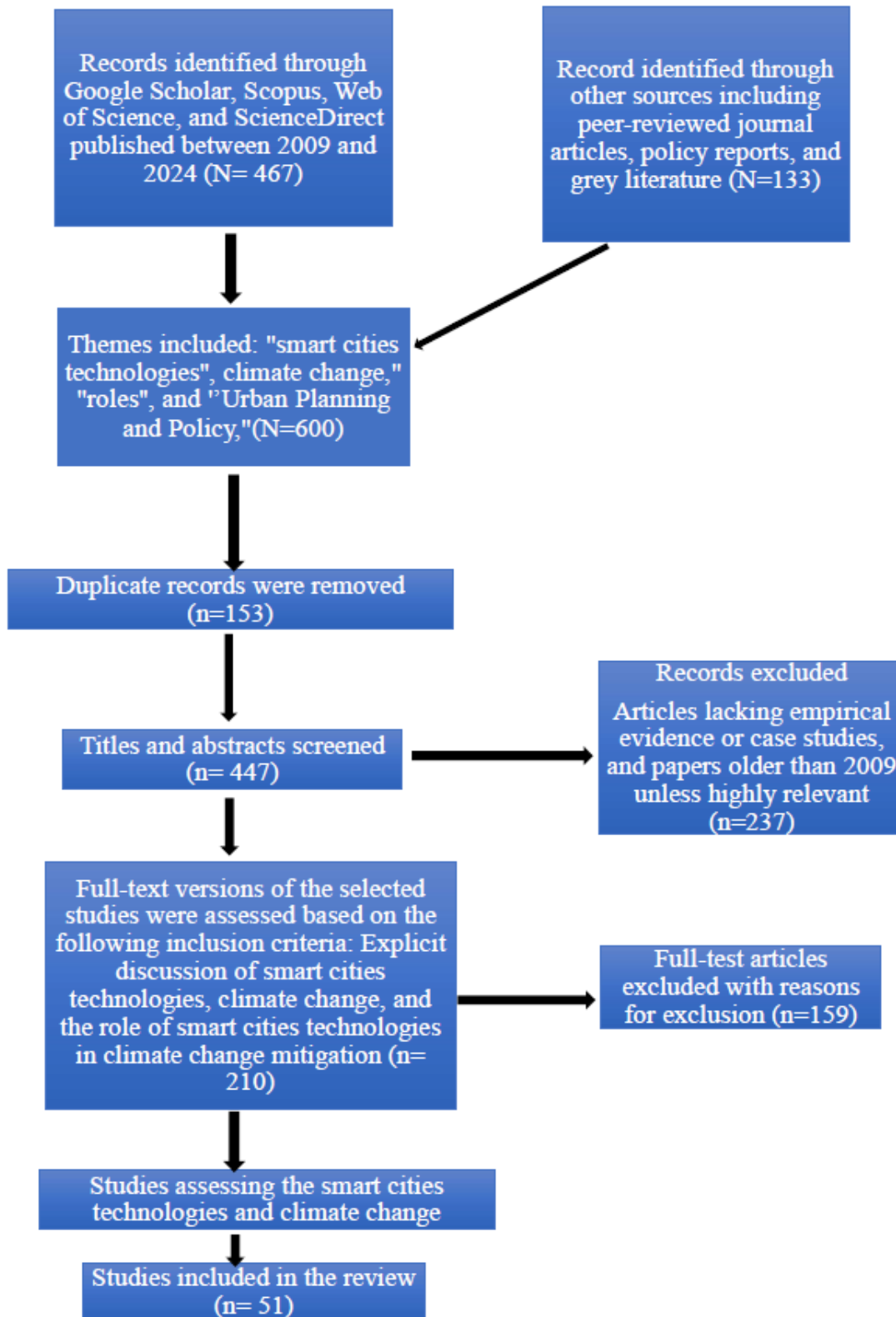
Fig. 1. Systematic Review Process Flow Diagram
Source: Authors' construct

Table 2. Smart Cities Technologies and Climate Change

Author(s)	Year of Publication	Objectives	Methodology	Key Findings	Relevance
Theme 1: Reduction of Carbon Emissions					
Donnellan et al.,	2019	To assess the impact of smart traffic management on reducing emissions	Case study of intelligent traffic management systems	Smart traffic management can reduce commute times by 20-30%, leading to lower emissions	Relevant for Ghana to implement smart traffic systems to reduce vehicle emissions and alleviate congestion.
Nikolov, N.	2024	To explore the role of smart urban planning in reducing carbon emissions	Qualitative analysis of smart urban planning concepts	Establishing carbon-neutral zones through smart planning can significantly reduce carbon emissions	Relevant for Ghana's adoption of carbon-neutral zones in urban planning to reduce emissions and improve air quality.
Theme 2: Resource Optimization					
Rao & Samal	2022	To evaluate the effectiveness of IoT in smart water management systems	Review of IoT-based smart water systems and their applications	IoT sensors can reduce water loss by up to 30% through leak detection and monitoring	Important for Ghana to implement smart water management systems to address water scarcity and optimize resource use.
Bibri et al.	2023	To analyze the integration of renewable energy in smart grids	Data analysis and modeling of smart grid systems	Smart grid adoption can increase renewable energy share by 25-30%, improving energy resilience	Relevant for Ghana, where solar energy integration into smart grids can optimize energy consumption and transition to renewable sources.
Theme 3: Environmental Monitoring and Data Analytics					
Izah	2025	To assess the role of environmental data in improving public health responses	Case study and environmental data analysis	Real-time air quality data can improve response times to pollution-related health	Relevant for Ghana, where air quality monitoring can improve public health strategies

Author(s)	Year of Publication	Objectives	Methodology	Key Findings	Relevance
				crises by up to 50%	and disaster preparedness.
Rao & Samal	2022	To investigate the application of satellite data and sensors in environmental management	Review and analysis of environmental management tools	Predictive modeling and sensor networks can improve urban climate preparedness	This can be applied to Ghana to better manage climate change impacts like floods and pollution through data-driven strategies.
Theme 4: Improved Urban Mobility					
Donnellan et al.	2019	To assess the impact of smart mobility solutions on reducing congestion	Case study of public transport networks and smart mobility systems	Smart mobility solutions, such as real-time public transport apps, can reduce congestion and emissions	Relevant for Ghana to improve urban mobility by integrating smart transport systems and reducing traffic congestion.
Rao & Samal	2022	To explore the benefits of promoting non-motorized transport in cities	Review of bike-sharing, carpooling, and pedestrian-friendly initiatives	Promoting bike-sharing, carpooling, and pedestrian-friendly infrastructure improves air quality and health	Important for Ghana, where promoting non-motorized transport could reduce pollution and traffic congestion.
Theme 5: Community Engagement and Awareness					
Izah	2025	To explore the role of digital platforms in fostering community engagement for sustainability	Analysis of mobile apps and social media campaigns on sustainability	Digital platforms improve community awareness and active participation in environmental initiatives	Relevant for Ghana to raise community awareness and encourage participation in climate action through digital platforms.
Rao & Samal	2022	To evaluate the impact of inclusive access to technology in urban sustainability	Review of community engagement programs and technology accessibility	Inclusive engagement fosters more sustainable behaviors, particularly in marginalized communities	Crucial for Ghana to ensure equitable access to technology for all communities to participate in sustainable urban

Author(s)	Year of Publication	Objectives	Methodology	Key Findings	Relevance
					initiatives.
Theme 6: Integration of Renewable Energy					
Nikolov, N.	2024	To examine the integration of renewable energy into smart cities	Case study and analysis of smart grid systems in urban environments	Integrating renewable energy in smart grids enhances energy resilience and reduces dependency on fossil fuels	Highly relevant for Ghana, where solar energy potential can be harnessed for sustainable and resilient urban energy systems.
Bibri et al.	2023	To analyze the role of smart grids in the integration of renewable energy	Data-driven modeling and smart grid analysis	Smart grid systems can increase renewable energy share by up to 30% in urban areas	Important for Ghana to transition to renewable energy by integrating solar power into the urban energy infrastructure.
Theme 7: Green Buildings and Sustainable Infrastructure					
Rao & Samal et al.	2022	To evaluate the role of smart technologies in energy-efficient buildings	Review of smart building technologies and their applications	Smart sensors in green buildings can achieve energy savings of 30-50%, reducing operational costs and emissions	Relevant for Ghana's building sector to implement smart technologies that reduce energy consumption and environmental impacts in urban developments.
Matemilola	2022	To assess the environmental impact of sustainable building practices	Case study and review of green building designs	Green buildings significantly reduce energy use and greenhouse gas emissions	Relevant for Ghana, promoting green building practices to combat urbanization's environmental impacts and improve sustainability.
Theme 8: Climate Resilience and Adaptation					
Izah	2025	To assess the role of GIS and data-driven decision-	Analysis of GIS tools in urban planning and flood	GIS tools can improve flood management	Important for Ghana to apply GIS in flood

Author(s)	Year of Publication	Objectives	Methodology	Key Findings	Relevance
		making in urban climate resilience	management	planning and urban resilience to extreme weather events	management and climate resilience strategies, particularly in cities like Accra.
Rao & Samal.	2022	To examine how smart cities can improve climate resilience	Review of climate adaptation strategies in urban planning	Data-driven planning improves climate resilience and preparedness for extreme weather	Crucial for Ghana to develop climate resilience strategies and adapt urban infrastructure to climate impacts effectively.
Theme 9: Holistic Planning and Policy Support					
Bibri et al.	2023	To explore the role of integrated planning in smart city governance	Policy review and stakeholder engagement analysis	Coordinated planning frameworks ensure successful smart city initiatives and climate resilience	Relevant for Ghana, where coordinated governance structures are key to implementing smart city projects that align with national sustainability goals.
Nikolov, N.	2024	To analyze the role of policy frameworks in smart city development	Review of governance frameworks and smart city implementation	Effective governance structures foster collaboration and improve smart city outcomes	Important for Ghana to create policies that integrate smart technologies in urban planning and sustainable development.

Source: Authors' Construct

3.3 Smart Cities Technologies and Climate Change

3.3.1 Reduction of carbon emissions

Carbon emission reduction is at the core of climate goals in smart cities. Intelligent traffic management can cut greenhouse gas emissions, and smart signals can reduce commute time by 30% (Donnellan et al. 2019). Nikolov (2024) also believes that intelligent public transportation, like smart card route planning, could reduce the use of private cars in Ghana and minimize urban air pollution. Intelligent infrastructure in both papers will reduce emissions, yet further integration in cities like Accra is very important to achieve measurable impacts. Donnellan et al. (2019) emphasize intelligent transport systems for emissions reduction, whereas Nikolov (2024) includes urban planning interventions like carbon-neutral zones and pedestrianized zones to reduce emissions further. The applicability of technology-based interventions in Ghana depends on their alignment with urban design. A combined strategy that incorporates smart technologies and urban policy will have the greatest effect.

3.3.2 Resource optimization

The use of smarter technology for efficiency has an impact in the supply and management of water, energy, and waste. Rao & Samal (2022) report that smart water management with the Internet of Things (IoT) has the capacity to limit water loss by 30%, which is critical for Ghana because of water shortages. Bibri et al. (2023) recognize that dynamic energy management by using smart meters and renewable energies such as solar energy can decrease energy demand and enhance sustainability.

Rao & Samal (2022) and Bibri et al. (2023) emphasize the interaction of smart water and energy management in cities. Ghana can enhance urban infrastructure by integrating renewable energy, like solar, with water management for better resource efficiency. Water and energy technologies integration would decrease expenses and enhance the resilience of services.

3.3.3 Environmental monitoring and data analytics

To further clarify, while smart technologies promise substantial benefits in environmental monitoring and resource optimization, their effective deployment hinges on overcoming data silos and ensuring interoperability among different systems. From IoT-enabled water management reducing losses by up to 30%, to real-time air quality sensors accelerating response times by 50%, it is evident that the integration of these technologies can significantly strengthen urban resilience. Clear messaging on technical challenges, such as infrastructure gaps and digital literacy, must be foregrounded to frame practical implementation pathways. This will help stakeholders prioritize capacity development and inclusive governance as foundational pillars for smart city success in Ghana.

3.3.4 Improved urban mobility

More intelligent mobility options are required to help fight congestion and carbon emissions in cities like Accra. Donnellan et al. (2019) note that smart public transport systems with real-time information have the potential to decrease waiting times and boost usage, making a change from private vehicles and lowering emissions. Rao & Samal (2022) point out promoting walking and cycling through technology-based solutions for enhancing urban mobility. The two studies agree on the multimodal integration of transport, although Rao & Samal (2022) focus on pedestrianized spaces. To ensure efficient urban mobility improvement, Ghana needs to focus on smart public transportation and non-motorized transportation. Such steps could significantly reduce traffic congestion and enhance air quality, as seen in other cities.

3.3.5 Community engagement and awareness

Effective community engagement is key to smart cities. Izah (2025) claims that mobile apps and social media enhance awareness of climate change and sustainability, which encourages participation. The study indicates that these platforms allow citizens to engage in energy and waste decisions. Rao & Samal (2022) suggest that specific outreach initiatives need to be put in place to facilitate equal access to technologies, especially for marginalized groups at risk of exclusion. Both papers agree on community engagement, although Rao & Samal (2022) emphasize inclusivity. In Ghana, bridging digital divides is essential to allow all residents to be involved in climate action initiatives. Ghana would increase sustainability and give voice to vulnerable populations under the smart city policy.

3.3.6 Integration of renewable energy

The integration of renewable energy is a cornerstone of smart cities, particularly in regions

with abundant natural resources. Nikolov (2024) emphasizes the potential for solar energy in Ghana, proposing the use of smart grid technologies to decentralize energy production. Bibri et al. (2023) also support this idea, suggesting that smart grids can enhance energy efficiency and enable better integration of renewable sources like solar into the urban energy mix. Both authors talk about the role of solar energy in Ghana's energy transition, but Bibri et al. (2023) cover technological dimensions like energy storage for grid stability and peak demand management. Nikolov (2024), on the other hand, talks about smart grid deployment, but adding energy storage, as suggested by Bibri et al., would render the system more resilient. Therefore, combining these approaches could offer Ghana a more sustainable and adaptable energy future.

Integrating renewable energy sources into smart grid systems represents a high-impact opportunity for Ghana to enhance energy resilience and reduce dependence on fossil fuels. Smart grid adoption can increase renewable energy's share in the energy mix by 25-30%, optimizing consumption and expanding access. Ghana's abundant solar resources position it advantageously to implement community solar projects and dynamic energy management enabled by smart meters. These innovations not only reduce carbon footprints but also provide cost savings and improved service reliability, critical for urban and peri-urban populations.

3.3.7 Green buildings and sustainable infrastructure

According to Rao & Samal (2022), smart building technologies like energy management systems and temperature sensors can reduce energy consumption and costs considerably. Matemilola (2022) states that green buildings have the potential to save energy by up to 50%, which is critical in reducing urban environmental impacts. The studies are complementary, with Rao & Samal (2022) covering smart building technology and Matemilola (2022) covering the general environmental and economic gains of green buildings. These findings highlight the need for technology and green construction to contain Ghana's carbon footprint in the face of rapid urbanization.

3.3.8 Climate resilience and adaptation

Enhancing climate resilience through smart city technologies has to be planned. Izah (2025) propose that GIS technology can plot climate risks, assisting urban planning in reducing flooding and severe weather. Rao & Samal (2022) propose combining smart technologies with training city officials in dealing with climate emergencies more effectively. As opposed to Izah (2025), who give precedence to technology for managing climate risk, Rao & Samal (2022) focus on local capacity building. The integration of these solutions in Ghana would improve its climate risk forecast and human capital development. Together, they would strengthen the climate resilience of Ghana and maintain urban development.

3.3.9 Holistic planning and policy support

Successful smart city adoption needs strong governance and policy backing. Bibri et al. (2023) stress public-private partnerships and regulatory frameworks for the adoption of smart technologies. Similarly, Nikolov (2024) highlights integrated planning between levels of governance to make sure projects are aligned with sustainability goals. Both reports emphasize policy coordination and cooperation. Nikolov (2024) also says that good governance in Ghana needs stakeholder participation at the local level for smart city planning to meet the people's needs. Participatory policy can lead to more inclusive solutions for Ghana's climate problems.

4. SUMMARY OF FINDINGS

Smart city technology is one of the measures that counteract climate change and enhance sustainability, especially in urbanizing countries like Ghana. Traffic management and integration of renewable energy are some of the smart city technologies that mitigate carbon emissions and optimize resources. This paper examines the role of smart city technologies in addressing climate change within Ghana's space economy. A primary goal of smart cities is to decrease carbon emissions. Smart traffic control optimizes flow, decreasing travel times and emissions. Research demonstrates a 20-30% reduction in greenhouse gases through improved traffic management (Donnellan et al. 2019). In Ghana, smart public transport systems, like smart cards, would enhance scheduling and diminish the use of private vehicles, which is one of the primary sources of urban air pollution. Creating carbon-free zones, like walking zones, would also minimize emissions (Nikolov, 2024).

Smart cities benefit from optimizing resources. IoT-enabled water management systems can

decrease water wastage and save as much as 30% loss in water-scarce Ghana (Rao & Samal, 2022). Additionally, green energy and smart meters decrease energy demand. Ghana's intelligent grid technology and solar energy resources can enhance decentralized energy production, boosting resilience and lowering non-renewable dependency (Bibri et al. 2023).

Environmental data analytics and monitoring are crucial for the management of climate risks in smart cities. Air quality and environmental parameters are monitored by sensors, enabling better response to pollution and health hazards. Response times to environmental incidents can be enhanced by 50% with real-time information Izah (2025). In Ghana, integrating satellite data and ground-based sensors would enhance environmental management, helping cities track pollution sources and anticipate climate events (Rao & Samal, 2022).

Enhancing urban mobility is key to smart city sustainability. Cities like Accra need efficient public transportation to curb congestion and emissions. Intelligent interventions like real-time public transit information make public transport more efficient. In Ghana, promoting bike-sharing and pedestrian spaces can minimize motorized transport and purify the air (Rao & Samal, 2022). Citizen engagement is the key to smart city achievement. Social media and mobile apps enhance sustainability awareness and climate action participation. In Ghana, targeted focus can draw in marginalized groups under smart city initiatives, enhancing inclusivity towards sustainability Izah (2025).

The incorporation of renewable energy is vital for Ghana's smart city realization. Ghana can leverage its solar potential and smart grid innovation to promote energy resilience and independence from fossil fuels. Smart grids can raise quotas of renewable energy by 30%, in favor of sustainability (Bibri et al. 2023). Smart city technology is a way to counter climate change and ensure sustainability. In Ghana, smart traffic, renewable energy, and resource management can lower emissions and enhance resilience. Good governance, community engagement, and tailor-made urban planning are necessary for effectiveness in implementation. By utilizing the technologies, Ghana can create sustainable cities that can respond to climate issues.

4. CONCLUSION

The smart city technology provides Ghanaian cities with a opportunity to respond to climate change, resource scarcity, and urban sustainability. Through the integration of intelligent systems in transportation, energy, and urban planning, smart cities are capable of reducing climate impacts and enhancing citizens' quality of life. This paper emphasizes the necessity for smart traffic control, resource efficiency, and environmental monitoring. Through the incorporation of renewable energy and community involvement, Ghana can realize a sustainable urban future.

The development of smart technologies in Ghana comes with opportunities as well as challenges. Though the potential advantages, including decreased carbon emissions, energy efficiency, and urban mobility, are apparent, the effective execution of these technologies needs meticulous planning, strong governance, as well as inclusive policy structures. Moreover, bridging digital divides and making technology access equitable are essential towards realizing the complete prospect of smart cities.

While the benefits of smart city technologies in addressing climate challenges in Ghana are increasingly recognized, actionable policy interventions are essential to translate these potentials into tangible outcomes. This paper recommends the following:

- *Establish a National Smart Climate Taskforce:* This specialized body should comprise representatives from the Ministry of Environment, Urban Planning Authorities, local governments, private sector innovators, and civil society. Its mandate would be to coordinate smart city climate initiatives, streamline regulatory frameworks, and monitor implementation progress.
- *Incentivize Private Sector Participation:* Through tax breaks, grants, and regulatory facilitation, encourage private investment in renewable energy integration within smart grids and urban mobility systems. Public-private partnerships can leverage technical expertise and capital while ensuring projects align with sustainable development goals.
- *Capacity Building and Digital Inclusion Programs:* Implement community-targeted educational and training schemes to enhance technical know-how at municipal levels, while bridging digital divides that

currently limit marginalized groups' engagement with smart technologies.

- *Phased Smart City Roadmap:* Develop a strategic roadmap covering near-term actions (e.g., pilot deployments of sensor networks for flood and pollution monitoring), medium-term scaling of interoperable smart infrastructure, and long-term integration with national climate adaptation policies. The roadmap should include clear, measurable targets and mechanisms for iterative evaluation and stakeholder feedback.

Addressing institutional fragmentation and funding constraints through these policy measures will create an enabling environment for Ghana's sustainable urban transformation.

Developing smart cities in Ghana needs a coordinated approach that combines technology, policy, community engagement, and capacity building. By aligning plans with sustainability goals and harnessing local opportunities, Ghana can develop resilient, economically vibrant, and socially inclusive urban areas. Smart cities will have a critical role to play in shaping a low-carbon, sustainable future for Ghana, backing global climate goals, and promoting urban wellness.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

ACKNOWLEDGEMENT

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdulsattar, N. F., Abbas, A. H., Mutar, M. H., Hassan, M. H., Jubair, M. A., & Habelalmateen, M. I. (2022). An investigation study for technologies, challenges, and practices of IoT in smart cities. In: 2022 5th International Conference on Engineering Technology and its Applications (IICETA). IEEE. An Investigation Study for Technologies, Challenges and Practices of IoT in Smart Cities | IEEE Conference Publication | IEEE Xplore.

Addaney, M., Asibey, M. O., Cobbinah, P. B., & Akudugu, J. A. (2021). Climate change in rural Ghana: Perceptions and adaptive responses. *Local Environment: The International Journal of Justice and Sustainability, 26*(12), 1461-1479. https://doi.org/10.1080/13549839.2021.1 978411.

Adewnmi, A., Olu-lawal, K. A., Okoli, C. E., Usman, F. O., & Usiagu, G. S. (2024). Sustainable energy solutions and climate change: A policy review of emerging trends and global responses. *World Journal of Advanced Research and Reviews, 21*(2), 408–420. https://doi.org/10.30574/wjarr.2024.21.2. 0474

Ahad, M. A., Paiva, S., Tripathi, G., & Feroz, N. (2020). Enabling technologies and sustainable smart cities. *Sustainable Cities and Society, 61*, 102301. https://doi.org/10.1016/j.scs.2020.102301

Ankrah, J. (2018). Climate change impacts and coastal livelihoods; an analysis of fishers of coastal Winneba, Ghana. *Ocean & Coastal Management, 161*, 141–146. https://doi.org/10.1016/j.ocecoaman.2018 .04.029

Ankrah, J. (2020). Assessing the impacts of climate change of coastal Winneba-Ghana (Master's thesis, Universidade do Porto, Portugal). ProQuest Dissertations & Theses. https://www.proquest.com/openview/356 a053ca0ac93f7a9098aa0ca368cea/1?cbl =2026366&diss=y&pq-origsite=gscholar

Arhin, A. (2018). Advancing post-2015 Sustainable Development Goals in a changing development landscape: Challenges of NGOs in Ghana. In Civil Society Sustainability (1st ed., pp. 1–14). Routledge. https://www.taylorfrancis.com/chapters/e dit/10.4324/9781315160948-4/advancing-post-2015-sustainable-development-goals-changing-development-landscape-challenges-ngos-ghana-albert-arhin

Armah, F. A., Odoi, J. O., Yengoh, G. T., Obiri, S., Yawson, D. O., & Afrifa, E. K. A. (2011). Food security and climate change in drought-sensitive savanna zones of

Ghana. *Mitigation and Adaptation Strategies for Global Change, 16*, 291–306. https://doi.org/10.1007/s11027-010-9263-9

Arndt, C., Asante, F. A., & Thurlow, J. (2015). Implications of climate change for Ghana's economy. *Sustainability, 7*(6), 7214-7231. https://doi.org/10.3390/su7067214

Asante, F. A., & Amuakwa-Mensah, F. (2014). Climate change and variability in Ghana: Stocktaking. *Climate, 3*(1), 78-101. https://doi.org/10.3390/cli3010078

Awuni, S., Adarkwah, F., Ofori, B. D., Purwestri, R. C., Huertas Bernal, D. C., & Hajek, M. (2023). Managing the challenges of climate change mitigation and adaptation strategies in Ghana. *Heliyon, 9*(5), e15491. https://doi.org/10.1016/j.heliyon.2023.e15491

Bandh, S. A., Shafi, S., Peerzada, M., Rehman, T., Bashir, S., Wani, S. A., & Dar, R. (2021). Multidimensional analysis of global climate change: A review. *Environmental Science and Pollution Research, 28*, 24872–24888. https://doi.org/10.1007/s11356-021-13139-7

Bibri, S. E. (2019). *Big data science and analytics for smart sustainable urbanism: Unprecedented paradigmatic shifts and practical advancements*. Springer. https://doi.org/10.1007/978-3-030-17312-8

Bibri, S. E., Alexandre, A., Sharifi, A., & Krogstie, J. (2023). Environmentally sustainable smart cities and their converging AI, IoT, and big data technologies and solutions: An integrated approach to an extensive literature review. *Energy Informatics, 6*, Article 9. https://doi.org/10.1186/s42162-023-00259-2

Bittencourt, J. C. N., Costa, D. G., Portugal, P., & Vasques, F. (2024). A survey on adaptive smart urban systems. *IEEE Access, 12*, 102826–102850. https://doi.org/10.1109/ACCESS.2024.3433381

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology, 18*(2), 65-82. https://doi.org/10.1080/10630732.2011.601117.

Chaurasia, V. K., Yunus, A., & Singh, M. (2020). An overview of smart city:

Observation, technologies, challenges, and blockchain applications. In *Blockchain technology for smart cities* (pp. 133–154). Springer. https://doi.org/10.1007/978-981-15-2205-5_7

Donnellan, B., Klein, C., Helfert, M., Gusikhin, O., & Pascoal, A. (2019). *Smart cities, green technologies, and intelligent transport systems: Proceedings of the 6th International Conference SMARTGREENS 2017 and the 3rd International Conference VEHITS 2017, Porto, Portugal, April 22-24, 2017*. Communications in Computer and Information Science (CCIS, volume 921). Springer.

Doso Jnr, S., Twumasi-Ankrah, B., & Twum Barimah, P. (2014). Impact of climate change on maize production in Ghana: A review. *Proforest*.

Gupta, A., Pachauri, A., Pachauri, P., Singh, S. V., Chaturvedi, P., & Sharma, S. (2021). A review on conglomeration of technologies for smart cities. In *Proceedings of the 2021 International Conference on Technological Advancements and Innovations (ICTAI)*. IEEE. https://doi.org/10.1109/ICTAI53825.2021.9673458

Hammi, B., Khatoun, R., Zeadally, S., Fayad, A., & Khoukhi, L. (2018). IoT technologies for smart cities. *IET Networks, 7*(1), 1-13. https://doi.org/10.1049/iet-net.2017.0163

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). *Cochrane Handbook for Systematic Reviews of Interventions* (2nd ed.). John Wiley & Sons. https://doi.org/10.1002/9781119536604

Izah, S. C. (2025). Smart technologies in environmental monitoring: Enhancing real-time data for health management. In *Innovative approaches in environmental health management* (pp. 199–224). Springer.

Jalal, A. (2023). Smart cities: Integrating technology for sustainable and efficient urban development. *Liberal Journal of Language and Literature Review, 1*(01), 92–102. https://ljllr.com/index.php/Journal/article/view/12

Jiang, D. (2020). The construction of smart city information system based on the Internet

of Things and cloud computing. *Computer Communications, 150*, 158–166. https://doi.org/10.1016/j.comcom.2019.10.035

Kamana, A. A., Radoine, H., & Nyasulu, C. (2024). Urban challenges and strategies in African cities – A systematic literature review. *City and Environment Interactions, 21*, 100132. https://doi.org/10.1016/j.cacint.2023.100132

Khan, Z., Anjum, A., & Kiani, S. L. (2013). Cloud based big data analytics for smart future cities. *Proceedings of the 2013 IEEE/ACM 6th International Conference on Utility and Cloud Computing*, Dresden, Germany. IEEE. https://doi.org/10.1109/UCC.2013.77

Kiribou, R., Djene, S., Bedadi, B., Ntirenganya, E., Ndemere, J., & Dimobe, K. (2024). Urban climate resilience in Africa: A review of nature-based solutions in African cities' adaptation plans. *Discover Sustainability, 5*, Article 94.

Kutty, A. A., Abdella, G. M., Kucukvar, M., Onat, N. C., & Bulu, M. (2020). A system thinking approach for harmonizing smart and sustainable city initiatives with United Nations sustainable development goals. *Sustainable Development, 28*(5), 1347–1365. https://doi.org/10.1002/sd.2088

Li, S. (2018). Application of blockchain technology in smart city infrastructure. *Proceedings of the 2018 IEEE International Conference on Smart Internet of Things (SmartIoT)*, Xi'an, China. IEEE. https://doi.org/10.1109/SmartIoT.2018.00056

Matemilola, S. and Fadeyi, O. (2022). Smart cities, urban sustainability and climate change: A conceptual review. *African Journal of Housing and Sustainable Development*, 2(1): 83–96. http://dx.doi.org/10.52968/28461475.

Mensah, H., Nalumu, D. J., Simpeh, E. K., & Mensah, A. A. (2022). An overview of climate-sensitive sectors and its implications for future climate change risk and adaptation in sub-Saharan Africa, Ghana. *SN Social Sciences, 2*, 90. https://doi.org/10.1007/s43545-022-00395-8

Mohanty, S. (2016). Everything you wanted to know about smart cities. *IEEE Consumer Electronics Magazine*, 5(3):25–32.

Morlu, J. S. (2024). Smart cities in Ghana: The role of technology in urban development. *JS Morlu's Blog.* *https://jsmorlu.com.gh/blog/technology/role-of-technology-in-ghana/.*

Nikolov, N. (2024). Smart cities as a tool for environmental sustainability: Opportunities and challenges. In: *Proceedings of the International Scientific and Practical Conference.*

Odonkor, S. T., Dei, E. N., & Sallar, A. M. (2020). Knowledge, attitude, and adaptation to climate change in Ghana. *The Scientific World Journal, 2020*(1), Article 3167317. https://doi.org/10.1155/2020/3167317

Omweri, F. S. (2024). A systematic literature review of e-government implementation in developing countries: Examining urban-rural disparities, institutional capacity, and socio-cultural factors in the context of local governance and progress towards SDG 16.6. *International Journal of Research and Innovation in Social Science, 8*(8), 1173–1199. https://dx.doi.org/10.47772/IJRISS.2024.808088

Osman, A. M. S. (2019). A novel big data analytics framework for smart cities. *Future Generation Computer Systems, 91*, 620–633. https://doi.org/10.1016/j.future.2018.06.046

Paskaleva, K. and Curwell, S. (2009). SMART cities and protecting the climate: Urban sustainability and governance. In: *Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools*: 227–234. Shaker Verlag. https://dl.gi.de/items/0379403d-bc49-49bc-aef3-a17a69dffc08.

Rao, V. M., & Samal, A. (2022). Smart and sustainable buildings and infrastructure. *YMER Digital, 21*: 64. https://ymerdigital.com/uploads/YMER2106C1.pdf.

Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science, 2*, 160. https://doi.org/10.1007/s42979-021-00592-x

Suhaeb, F. W., Tamrin, S., Jumadi, J., & Irwan, I. (2024). Community adaptation strategies to climate change: Towards sustainable social development.

Migration Letters, 21(S2), 943–953. https://eprints.unm.ac.id/35656/

Sui, D. (2014). The new science of cities. *International Journal of Geographical Information Science, 28*(12). https://doi.org/10.1080/13658816.2014.9 37717.

Tao, W. (2013). Interdisciplinary urban GIS for smart cities: Advancements and opportunities. *Geo-spatial Information Science, 16*(1), 25–34. https://doi.org/10.1080/10095020.2013.7 74108

Umamaheswari, S., Priya, K. H., & Kumar, S. A. (2021). Technologies used in smart city applications – An overview. In *Proceedings of the 2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA)*:101–106. IEEE.

UN-Habitat (2021). *Smart cities and climate change adaptation in Africa*. Nairobi: UN-Habitat.

United Nations (2022). *World urbanization prospects: The 2022 revision*. New York: United Nations Department of Economic and Social Affairs. World Urbanization Prospects.

Whaiduzzaman, M., Barros, A., Chanda, M., Barman, S., Sultana, T., Rahman, M.S., Roy, S. and Fidge, C. (2022). A review of emerging technologies for IoT-based smart cities. *Sensors*, 22(23): 9271. https://doi.org/10.3390/s22239271

World Bank (2020). *The future of cities in Africa: Urbanization trends and climate risks*. Washington, DC: World Bank Group.

Yeh, H. (2017). The effects of successful ICT-based smart city services: From citizens' perspectives. *Government Information Quarterly, 34*(3), 556–565. https://doi.org/10.1016/j.giq.2017.05.001

Yigitcanlar, T., Kamruzzaman, M., Foth, M., Sabatini-Marques, J., Da Costa, E. and Ioppolo, G. (2019). Can smart cities reduce urban environmental problems? *Environment International*, 128: 49–57.

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/138068