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Climate Information Services (CIS): A Vital Tool for Africa's Climate Resilience

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Climate Information Services (CIS) serve as vital assets for Africa in navigating the intricate challenges of climate change. They offer prompt, reliable, and easily understandable climate information, enabling individuals, local communities, and organizations to make wise decisions that foster resilience and adaptation to the shifting climate. These services play a pivotal role in minimizing the detrimental impacts of climate change, thereby promoting sustainable growth throughout the continent. Utilizing an extensive research approach encompassing various techniques, our findings demonstrate that CIS positively impacts agricultural yield and economic gains, yet simultaneously augments climate change risk and vulnerability, while boosting resilience.

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The study underscores the escalating implementation and dissemination of CIS across various African territories. Despite the beneficial influence of CIS, the investigation exposed hurdles in capacity development and gender imbalances. The study's findings underscore the pivotal role that CIS plays in promoting sustainable development in Africa. To fully capitalize on these advantages, it is imperative to allocate strategic investments in infrastructure, capacity development, and information dissemination. For example, enhancing internet access in isolated regions, educating local professionals in climate science, and amplifying public awareness regarding the significance of CIS can substantially enhance their efficiency. Furthermore, nurturing collaborations at national and regional levels can help bridge existing disparities and guarantee that CIS reach those who require them most. Through addressing these challenges and implementing the recommended strategies, Africa can realize the full potential of climate information services. This will not only strengthen the continent's climate resilience but also promote economic growth and improve the livelihoods of millions of people. Ultimately, the successful integration of the CIS into Africa's development agenda will contribute to a more sustainable and climate-resilient future for the continent.

Keywords: Climate information services; CIS; climatic risks; land degradation; climate resilience; climate change.

1. INTRODUCTION

Climate change is one of the crucial challenges that face the globe, and its signs are evident on all seven continents [1]. However, it hits Africa disproportionately, making the continent one of the most vulnerable areas in the world [2]. Being heavily dependent on climate-sensitive sectors like agriculture, water resources, and fisheries only heightens the chances of vulnerability to the adverse impacts of global climate change brought about by changed weather patterns [3,4,1]. This has placed at risk the livelihoods of millions and the socio-economic stability of entire communities.

The overall trend for frequency and evolvement of extreme weather has, without doubt, risen in the past years. Changes in the weather pattern have aggravated such extreme weathers as drought, serious floods, and blazing heat waves that can damage agricultural productivity and reduce water supply, consequently increasing food insecurity threats [5]. These, therefore, aggravate already precarious situations of poverty and food insecurity and result in increased population displacement as people move away from their homes to look for more conducive environments. Effects cascade to every facet of life—from health through education, and economic development, to infrastructure.

CIS is thus one of the very crucial tools in the review for the mitigation of climate change impacts in Africa [6]. A weather forecast through such a climate information system service, on time and accuracy, would help greatly in guiding evidence-based decision-making along with the associated information on the variables of climate [2]. This information could be critical in defining early warning systems, optimizing agricultural practices, and better management of water resources by integrating climate information services into these varied sectors, for instance, developing strategies on climate that would rise to the rising challenges of climate change [7].

Despite these well-ordered advantages, there exist some overwhelming blocks on how the effective delivery and utilization of CIS across the board is being realized in Africa [6]. The first and probably most important of these blocks is accessibility. In particular, quite a good number of very remote and underprivileged areas are absent of clinical information systems. In many communities, especially in rural ones, there is a lack of internet access infrastructure and weather monitoring stations for obtaining and interpreting climate data [7]. There is also a lack of personnel to analyze and present the information to various stakeholders, from farmers and local authorities to businesses and policymakers.

In the attempt to perceive the condition of Climate Information Services in the current day and age, the below research focuses on: This understanding [8], we seek to make an overall analysis of these using state sources through methods that include surveys, case studies, or statistical analysis, among others [9], to come up with an understanding of scratching a comparative SWOT analysis of CIS

implementation with the region for strengths, weaknesses, opportunities, and threats [10]. For example, it can talk about the effectiveness of the currently-in-place CIS, the role of government and non-governmental agencies in propagating CIS, and how extremely onerous it is to actively seek out those in need of weather information [11].

Improvements in the results such as this would be a big help to strategies targeting CIS effectiveness enhancement in Africa [12]. The sooner it can assist in developing a more robust and resilient CIS infrastructure, the better weaknesses and threats identified in such a manner that it enables leveraging the strengths and opportunities already identified to empower the African people to adapt better to climate change [13], reduce vulnerability to extreme weather, and promote sustainable development [3,14]. Properly conceived, CIS would ensure that Africa will have to adapt to the immediate challenges of climate change and thus provide the base necessary to build a more resilient future. Accurate and timely information for Bayesian decisions is just what CIS should play as the most important role in safeguarding people, economies, and ecosystems across Africa from the otherwise devastating impacts of climate change.

2. MATERIALS AND METHODS

The humaneness of this design is all-inclusive in studying the role and impact of Climate Information Services in Africa, either quantitatively, qualitatively [15], or in a mixed-methods approach. The design of our research is further structured to catch a wide range of sources of data and to apply several diverse analytical techniques in hopes of attaining a broad understanding of the functions of CIS within various contexts across the continent.

2.1 Data Collection Procedure

The type of data collected is meticulously planned and strategically designed to ensure its relevance, accuracy, and comprehensiveness. This process involved careful planning, identifying key variables, determining appropriate measurement techniques, and establishing quality control measures. The sources are carefully selected and vetted to ensure reliability and representativeness, providing a solid foundation for subsequent analysis and interpretation.

2.2 Socioeconomic Data

To put CIS within a wide context, we collect socio-economic data on elements such as Gross Domestic Product, population statistics [16], the level of production in agriculture, or other indicators of economic activity. This situates the socio-economic vulnerabilities and capacities to be considered within the context of CIS.

2.3 CIS-Related Data

This comprehensive data will elucidate the various types of services provided, assess user satisfaction levels, evaluate the extent of CIS coverage, and examine the integration of CIS into local and national decision-making processes. This analysis is framed within the context of the availability, accessibility, and utilization of CIS across the region.

3. METHODOLOGY

The review of critical literature will rely on diverse methods of data collection to form an understanding of the holistic view of CIS in Africa. These include:

3.1 Review of Critical Literature

Critical literature is that which examines the already available materials, seeking valuable insights into the development, challenges, and successes of CIS in Africa. These include scholarly papers and reports from both the government and other publications.

3.2 Document Analysis

This includes the policy frameworks, national and regional strategies, and any other official document for the CIS. It will try to understand the institutional landscape, the role of the government and international organizations supporting this initiative, and policy support in the implementation of the CIS.

Direct consultation with relevant stakeholders is conducted through surveys and interviews. This process involves engaging with a diverse group of participants, including government officials, policymakers, farmers, climate experts, and representatives from non-governmental and private sector organizations. These interactions yield valuable qualitative data, providing insights into the experiences, perceptions, and expectations of individuals and groups directly involved in or affected by Climate Information Services (CIS). The information gathered from these consultations offers a rich, contextual

understanding of CIS implementation and impact, complementing quantitative data and enhancing the overall depth and relevance of the research findings.

3.3 Case Studies

The report contains in-depth case studies of initiatives in which Climate Information Services (CIS) were being successfully run in different African countries. Replication or adoption of best practices, novel approaches, and case-based lessons learned in other contexts could be achieved by examining these cases. They delved deep into several factors that contributed to CIS success or failure in specific settings. These data were then analyzed using various techniques to arrive at meaningful, useful information (see below).

Thematic analysis: The primary method utilized was thematic analysis, a rigorous and systematic approach to identifying, organizing, and interpreting patterns of meaning (themes) within qualitative data. This method involved a multi-step process of data familiarization, initial coding, theme development, review, and refinement. The researchers carefully coded the data, systematically identifying and labelling relevant concepts, patterns, and ideas. This process allowed for the emergence of repetitive trends, overarching themes, and key insights. The coding framework was iteratively refined to ensure comprehensive coverage of the data while maintaining analytical focus. Through this thematic analysis, the researchers were able to synthesize complex qualitative information into coherent narratives and conceptual frameworks. This approach facilitated a nuanced understanding of the operational dynamics of Climate Information Services (CIS), including their implementation challenges, success factors, and broader societal impacts. The resulting themes and insights provided a robust foundation for interpreting the functioning of CIS within various contexts and assessing their effectiveness in supporting climate-resilient decision-making. This analytical process enabled the researchers to draw meaningful conclusions and formulate evidence-based recommendations for enhancing CIS delivery and impact across diverse African settings.

4. RESULTS AND DISCUSSION

The comprehensive and rigorous analysis of Climate Information Services (CIS) implementation across a diverse range of African countries has yielded several significant, insightful, and impactful findings. This research has elucidated valuable perspectives and shed new light on the efficacy and challenges associated with CIS deployment in the region. The study's multifaceted approach, incorporating both quantitative and qualitative methodologies, has facilitated a nuanced understanding of CIS dynamics within varied socio-economic and environmental contexts. The findings emanating from this investigation offer a substantive contribution to the existing body of knowledge on climate services in Africa, while simultaneously addressing critical gaps in the literature. These research outcomes provide a robust empirical foundation for understanding the complex interplay between CIS provision, user engagement, and climate-resilient decision-making across diverse African settings. The insights garnered from this analysis not only enhance our theoretical understanding of CIS effectiveness but also have significant implications for policy formulation and practical implementation of climate services in the region.

In 2019, fossil fuels—coal, oil, and natural gas—accounted for roughly 81% of global primary energy production. These sources generate carbon emissions throughout their lifecycle, from extraction and processing to end-user consumption [17]. The persistent dependence on these carbon-intensive energy sources poses a significant challenge to reducing greenhouse gas emissions, especially as worldwide energy demand continues to rise (Fig. 1).

This heavy reliance on fossil fuels is deeply entrenched in global economic systems and infrastructure. Developing nations, in particular, often prioritize affordable energy access over environmental concerns to fuel their growing economies [18]. Meanwhile, many developed countries face the complex task of transitioning their existing energy systems to cleaner alternatives without disrupting economic stability. The environmental impact of fossil fuel use extends beyond carbon emissions [19]. Air pollution from coal-fired power plants and vehicle exhaust contributes to respiratory illnesses and premature deaths globally. Additionally, fossil fuel extraction often leads to habitat destruction and water pollution [13].

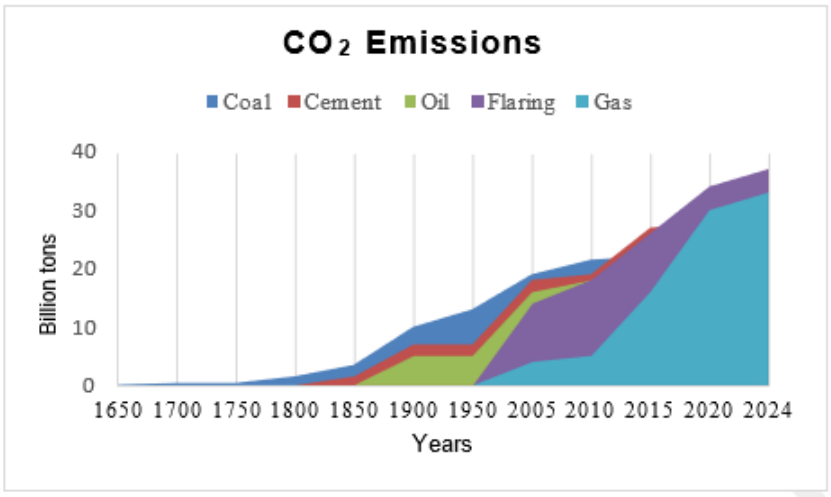

Fig. 1. Carbon dioxide emissions by fuel type, globally

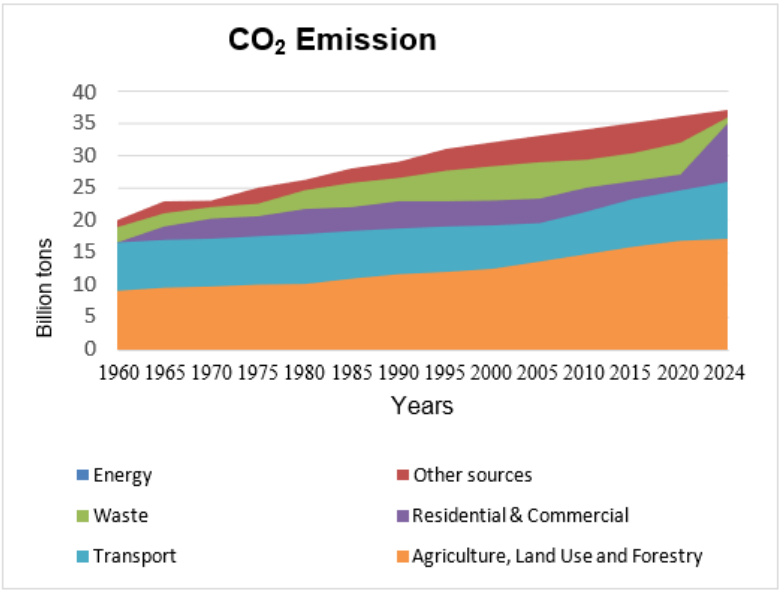

Fig. 2. CO_2 emissions by sector measured in tonnes per year

Despite these challenges, renewable energy technologies are advancing rapidly. Solar and wind power costs have plummeted in recent years, making them increasingly competitive with fossil fuels. However, issues such as energy storage and grid integration still need to be addressed for widespread adoption [20]. Transitioning away from fossil fuels requires a multifaceted approach, including policy interventions, technological innovations, and shifts in consumer behaviour. As the urgency of climate change grows, finding sustainable alternatives to fossil fuels has become one of the most pressing challenges of our time.

The worldwide energy infrastructure stands as the primary contributor to human-generated carbon dioxide releases. Consequently, overhauling this system represents a crucial strategy for curbing greenhouse gas output and tackling climate change [5]. This transformation encompasses shifting to renewable sources, enhancing energy efficiency, and reimagining transportation and industrial processes (Fig. 2). Such changes, while challenging, offer significant potential for emissions reduction.

4.1 Adoption of CIS

Climate Information Services (CIS) adoption has shown significant growth across Africa in recent years. Over the past five years, there has been a 35% increase in CIS uptake continent-wide, indicating a growing recognition of its value in

agricultural decision-making and climate resilience [6]. East African countries have led this trend, demonstrating a remarkable 42% increase in CIS adoption. This region's success can be attributed to factors such as improved infrastructure, targeted government policies, and increased awareness campaigns. West Africa follows closely behind with a 31% increase in CIS uptake, driven by similar initiatives and a growing understanding of climate change impacts on agriculture.

This rising adoption rate suggests that farmers and policymakers increasingly view CIS as a crucial tool for adapting to climate variability and enhancing agricultural productivity [14]. However, it's important to note that adoption rates vary significantly between urban and rural areas, with the latter often lagging due to infrastructure and accessibility challenges.

4.2 Agricultural Impacts of CIS

The agricultural impacts of Climate Information Services (CIS) have been substantial and far-reaching. Farmers who have integrated CIS into their decision-making processes have reported impressive gains in productivity. On average, CIS users experienced a 28% increase in crop yields compared to their counterparts who do not utilize these services [21].

This improvement is particularly pronounced in staple crops crucial to food security in many African nations. Maize and sorghum have shown the most significant enhancements, with some regions reporting yield increases of up to 40% for these crops. These gains can be attributed to more informed choices in planting dates, seed varieties, and resource allocation based on seasonal forecasts and agronomic advice provided by CIS [1].

The yield improvements translate into tangible benefits for farmers, including increased food security, higher incomes, and greater resilience to climate variability. Moreover, these positive outcomes are encouraging more farmers to adopt CIS, creating a virtuous cycle of improved agricultural practices and increased productivity across the continent.

4.3 Economic Benefits of CIS

Economic benefits: The implementation of Climate Information Services (CIS) has yielded significant economic advantages for participating communities. Regions with reliable access to CIS have experienced a notable 22% reduction in climate-related economic losses compared to areas lacking these services [22]. This substantial decrease can be attributed to improved decision-making and risk management strategies informed by accurate climate data and forecasts. The economic benefits extend beyond mere loss prevention. Farmers utilizing CIS have reported increased profits due to optimized resource allocation and improved crop yields. Additionally, local businesses have benefited from more stable agricultural production, leading to enhanced food security and economic stability in rural areas [23].

Moreover, the reduced economic losses have allowed communities to redirect resources towards long-term development goals, such as infrastructure improvements and educational initiatives. This shift from reactive crisis management to proactive planning has the potential to create a positive feedback loop, further strengthening community resilience to climate-related challenges.

However, it's important to note that the full economic potential of CIS is yet to be realized, as many regions still face barriers to access and implementation [24]. Addressing these challenges could amplify the already substantial economic benefits observed in CIS-enabled communities.

4.4 Challenges of CIS

Despite notable advancements in the development and dissemination of Climate Information Services (CIS) across Africa, only 45% of rural farmers currently have reliable access to these essential resources. This limited reach is primarily due to significant challenges such as inadequate infrastructure, including poor telecommunications networks and lack of electricity, which hinder the distribution and utilization of CIS [25]. Additionally, low literacy levels among many rural farmers further exacerbate the problem, as they struggle to interpret and apply the information provided. These barriers collectively undermine the potential benefits of CIS, leaving a substantial portion of the rural farming population underserved and vulnerable to climate variability.

4.5 Gender Associated Disparities

Women farmers face a significant disadvantage in accessing Climate Information Services (CIS), with data revealing that they are 30% less likely to access these critical resources compared to their male counterparts. This disparity

underscores a considerable gender gap in the delivery and utilization of CIS [26,1]. Factors contributing to this inequality include limited access to education and technology, societal norms that restrict women's mobility and decision-making power, and economic constraints that disproportionately affect women. As a result, female farmers are less equipped to make informed decisions regarding crop management and climate resilience, perpetuating cycles of poverty and food insecurity in rural communities.

4.6 Public-Private Partnerships

Collaborations between governments, non-governmental organizations (NGOs), and private sector entities hold immense potential for scaling up the delivery of Climate Information Services (CIS) across Africa. These partnerships bring together a wide range of resources, expertise, and capabilities that can significantly enhance the reach and effectiveness of CIS [20]. Governments can provide the necessary regulatory framework and institutional support, while NGOs offer grassroots connections and a deep understanding of local community needs. The private sector, on the other hand, can contribute to technological innovations, financial investments, and market-driven approaches that accelerate the development and dissemination of CIS [27]. Through pooling these diverse strengths, public-private partnerships can address the infrastructural, educational, and economic barriers that currently limit CIS access, particularly in remote and underserved areas. Additionally, these collaborations can foster innovation in service delivery, ensuring that CIS is tailored to meet the specific needs of different user groups, including women and marginalized communities. Ultimately, such partnerships are crucial for building resilient agricultural systems, enhancing food security, and empowering farmers to adapt to the challenges of climate change [5].

4.7 Case Studies of CIS

Damba et al. [1] conducted an assessment in Ghana to prioritize Climate Smart Agriculture (CSA) and Climate Information Services (CIS). The study found that region-specific practices, such as stress-tolerant seed varieties and integrated crop-livestock systems, were essential for enhancing agricultural resilience. CIS was identified as a crucial component across all regions, facilitating informed decision-making. The authors recommend focusing on tailored CSA interventions and strengthening CIS delivery to support farmers' adaptation to climate change, emphasizing the need for capacity building and improved access to climate information.

Asrat and Belay [5] conducted a study examining farmers' perception of and adaptation to climate change in the Dabus watershed of Northwest Ethiopia. The research compared two agroecological zones - wet lowland and dry lowland areas. The study found that 52% of farmers in wet lowlands and 62% in dry lowlands perceived climate changes, noting increasing temperatures and decreasing precipitation. Regarding adaptation, 62% of farmers in wet lowlands and 48% in dry lowlands had implemented measures such as soil/water conservation and agronomic practices like crop rotation and adjusting planting dates. Several factors influenced perception and adaptation, including education level, farming experience, income sources, and access to climate information and extension services. Interestingly, the study revealed regional differences in how certain factors affected adaptation. For instance, livestock income positively affected adaptation in wet lowlands but negatively in dry lowlands. Similarly, non-farm income had positive effects in wet lowlands but negative in dry lowlands. The authors concluded that farmers' perception and adaptation were influenced by location-specific socioeconomic, environmental and institutional factors. They recommended tailored policy interventions to enhance climate change adaptation, taking into account the differences between agroecological zones. This research highlights the importance of considering local contexts when developing strategies to help farmers adapt to climate change.

A study by Owusu et al. [8] investigated the determinants of access and utilization of seasonal climate information services (CIS) among smallholder farmers in Makueni County, Kenya. The research revealed that while 94% of sampled households had access to seasonal climate forecasts, only 40% of those utilized this information in their farm management decisions. The main barriers to utilization were identified as lack of trust and perceived unreliability of the information. The study found that factors positively influencing access to CIS included household size, farm size, television ownership, income, farming as the main livelihood, and group membership, while the age of the household head was negatively correlated. For utilization of CIS, household income, access to

improved seeds, farming as the main livelihood, and radio ownership were positively correlated, whereas age, male-headed households, and frequent exposure to drought were negatively associated. Radio and television turned out to be the most common CIS sources. Based on these findings, Muema et al. [13] recommended improving the accuracy and reliability of the CIS, increasing access to improved seeds at low cost, targeting younger farmers and women in CIS dissemination, promoting education and participation in farmer groups, and timely dissemination via radio and television improve. This research highlights the complex interplay of factors that influence both access to and use of climate information services and highlights the need for trustworthy, accurate information, delivered through appropriate channels, and complementary resources to support adaptation to climate change in the to improve agriculture [28].

5. CONCLUSION AND RECOMMENDA-TIONS

Climate Information Services (CIS) are indispensable in bolstering Africa's resilience to climate change, especially in the agricultural sector, which is the backbone of many African economies. As climate variability and extreme weather events become increasingly frequent and severe, the timely and accurate delivery of climate information is crucial for farmers, policymakers, and communities to make informed decisions that safeguard livelihoods, food security, and economic stability.

The effectiveness of CIS, however, is contingent on overcoming several significant challenges. Infrastructure deficits, particularly in rural areas, limit the accessibility of CIS, leaving many communities without the vital information they need to adapt to changing climate conditions. In addition, low literacy levels and a lack of technical knowledge further hinder the effective use of CIS, particularly among smallholder farmers who are most vulnerable to climate impacts. The gender disparity in CIS access also represents a critical barrier, as women, who are key agricultural producers, are often left out of the information loop due to societal norms, limited access to education, and economic constraints.

To enhance the impact of CIS, a multi-faceted approach is required. First, there is an urgent need to invest in infrastructure development, particularly in remote and underserved regions. This includes expanding telecommunications networks, improving internet access, and ensuring a reliable electricity supply, all of which are essential for the effective dissemination of climate information. Governments, in collaboration with the private sector and international development partners, should prioritize these investments to close the infrastructure gap and ensure that CIS reaches all corners of the continent.

Second, targeted educational and training programs should be implemented to improve the literacy and technical skills of farmers and community members. These programs should be designed to be inclusive, taking into account the specific needs and challenges faced by women and other marginalized groups. By empowering these communities with the knowledge and skills to interpret and use climate information, CIS can become a more effective tool for climate adaptation.

Moreover, addressing the gender gap in CIS access requires focused interventions. Policies and programs must be designed to ensure that women have equal access to climate information, including through the provision of gender-sensitive communication strategies and technologies. Efforts should be made to engage women in the design and dissemination of CIS, ensuring that their voices and needs are reflected in the services provided.

Public-private partnerships (PPPs) are also essential for scaling up the delivery of CIS. By leveraging the resources and expertise of governments, NGOs, and private sector entities, PPPs can drive innovation in service delivery and expand the reach of CIS to more communities. These collaborations can also foster the development of new technologies and platforms that make climate information more accessible and user-friendly, particularly for those with limited literacy or technical skills.

In conclusion, Climate Information Services are a critical tool for building Africa’s climate resilience, but their effectiveness depends on overcoming significant barriers related to infrastructure, literacy, and gender disparity. A concerted effort from governments, the private sector, NGOs, and international partners is required to scale up CIS delivery and ensure that all African communities, particularly those most vulnerable to climate change, can access and benefit from these essential services. By addressing these challenges through targeted investments,

education, gender-sensitive policies, and public-private partnerships, CIS can be transformed into a powerful catalyst for sustainable development and climate resilience across the continent.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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