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Research Article

Harnessing climate information systems and artificial intelligence (ai) innovations in enhancing resilience to climate change in Africa

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ABSTRACT

The ocean-climate relationship determines a unique tropical architecture which produces increased seasonal and temporal variation of wind, waves, currents and thermal stratification. The objective of the is to identify how Climate Information Systems (CIS) and emerging artificial intelligence (AI) technologies can benefit Africa's climate change resilience, with a focus on Kenya's exposed coastal economies. The study employed mixed-methods approach on the selected population stratified random sampling was used to select 225 individuals who were administered structured questionnaires, interviews and Focused Group Discussion. Quantitative and qualitative methods were both used to study data such as Statistical packages and regression analysis. The results were that CIS has a high level of awareness of 40.9% "Very Aware," and 41.8% of the respondents use AI occasionally. Regression analysis reveals a high positive relationship (R = 0.789) of CIS and AI with resilience explaining 61.9% of variance, highlighting indicators such as CIS awareness (coefficient = 0.441) and use of AI (coefficient = 0.358) as excellent predictors, whereas bottlenecks such as lack of infrastructure (36.0%) and awareness (28.4%) hinder effective implementation. The study recommends that mounting of gas analyzer sensors on smartphone to convert physical changes into electrical signals that can be interpreted by AI algorithm systems and automatically send collected data to various stations. The stakeholders should raise awareness and education on CIS and AI, invest in necessary infrastructure, and leverage partnership among the government, academia, and the private sector to mitigate challenges and develop resilience to climate change in Kenya's coastal economies.

1. INTRODUCTION

The ocean climate nexus encompassing pivotal physical–ecological coastal processes in climate-vulnerable African economies poses significant challenges and opportunities for advancing socio-economic resilience plans. Key questions for exploration include: What climate information systems are available or envisioned to support resilience in Africa? Guidance for rigorous CIS development amenable to rapid, transformational socio-economic resilience remains elusive. What recent progress in artificial-intelligence (AI) innovations or capacity-building promises enhanced planning? Emerging AI innovations suggest promising, yet nuanced, potential for augmenting climate adaptation processes. The overarching governance landscape hinges on economies' macroeconomic frameworks, sectoral balances, and socio-political stability indices. Unraveling physical and macroeconomic relationships underpins the successive examination of vulnerability, resilience, and the contributory roles of CIS and foundational AI technologies.

A consolidative analytical approach underscores the centrality of the ocean–climate nexus to thematic insight. Sound climate-risk management necessitates timely access to and effective utilization of decision-relevant climate information [6]. Despite increasing involvement of international and African actors spanning national authorities, regional organizations, brokers, donors, and the private sector critical supply-chain shortcomings persist throughout Africa. Reinforced partnerships sited within regional-centre networks and the Global Framework for Climate Services (GFCS) offer some mitigation prospects. Enhanced equity and broad-based dissemination of climate services (to governments, policy makers, funders, agencies, and end-users) constitute pivotal elements within ongoing transition strategies [18]. The ocean–climate nexus embodies a distinctive confluence of physical, ecological, and socio-economic dimensions

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significantly affecting everyday human life and structural development rates in climatologically vulnerable tropical countries. CIS emerge as a principal node within the nexus's socio-economic segment.

The ocean–climate nexus, the physical, ecological and socio-economic relationships between oceanic and climate dynamics, is a defining environment for many tropical and sub-tropical countries. Nearly all of the world's major fisheries have ocean–climate drivers, and many low-latitude countries depend heavily on both fisheries and forestry for income, employment and foreign exchange. Preliminary environmental and economic analyses indicate that the nexus is a priority for many nations and may contribute to regional and trans-boundary resource struggles. Improving scientific understanding of the nexus is central to addressing coastal socio-economic questions. [6].

1. 1 Purpose of the Study

The purpose of this study is to investigate how Climate Information Systems (CIS) and emerging artificial intelligence (AI) technologies can increase resilience to climate change in Africa, with special emphasis on exposed coastal economies in Kenya.

1. 2 Research Question of the Study

1. How are Climate Information Systems (CIS) today contributing to resilience to climate change impacts in Africa's coastal economies?
2. What is the potential of new artificial intelligence (AI) technologies for augmenting the functionality and effectiveness of CIS in furthering climate adaptation initiatives?
3. What institutional arrangements and capacities are needed to deploy and sustain AI-enhanced CIS in Africa's socio-political and economic contexts?
4. How do the interactions among climate variability, socio-political stability, and economic performance influence African coastal communities' resilience?

2. LITERATURE REVIEW

The ocean–climate nexus generally describes a system in which changes in climate affect coastal ecosystems. For the tropical countries bordering the Indian Ocean, the dynamic ocean land–atmosphere coupling is of special significance, because the health of these ecosystems is important in terms of livelihood and well-being [18]. The nexus is therefore a link that can be exploited for delivering climate services that are relevant for economic sectors connected to the ocean environment and in which climate information systems (CIS) play a key role. This integrated perspective of the ocean–climate nexus leads to three questions for the African context, in particular: How much can CIS contribute to resilience? What is the potential of emerging artificial intelligence (AI) systems to support vulnerable sectors? What are the capacities and preconditions for applying these new technologies in an African context?

2.1 Importance in Tropical Countries

The ocean–climate nexus defines interactions between the ocean and atmosphere through the exchange of mass and energy [6]. This nexus forms the basis for predictable modes of variation such as the Pacific El Niño–Southern Oscillation (ENSO) or the tropical Atlantic meridional mode [10]. A similar process operates in the Indian Ocean, with the global ocean basins communicating through variations of the ocean thermohaline circulation. These processes, affecting global atmospheric circulation, impose strong constraints on the climate records preserved in tropical marine archives. Tropical countries with coastlines close to the deep ocean surrounding them may therefore be affected by both the oceanic impact on the atmosphere and local variations of open-ocean dynamics, which typically amplify the North Atlantic oscillation (NAO) impact near African coasts [11].

Tropical countries with few or no coastlines, however, experience less direct interaction and are more exposed to the impact of the ocean–climate nexus on atmospheric circulation. Projections of future climate change in Africa indicate an increase in temperature, drought intensity and frequency, and flood events. Such changes threaten wind waves, surface loading, coastal currents, sediment transport, and embarkation. On a larger scale, the weakening of meridional overturning circulation (MOC) could lead to a decrease in deep convection in the Labrador Sea and more surface warming in SST, thickening the oceanic halocline and weakening oceanic ventilation in the North Atlantic.

ENSO and the Pacific Ocean dynamics may also strongly influence the interannual variability of river discharge, indicating the involvement of the MOC, the oceanic halocline, and Pacific Ocean dynamics in shaping the structure of flow evolution. In the equatorial Pacific region, models predict a warming of the upper ocean and a deepening of the thermocline, suggesting a weaker MOC during glacial times and higher sea level in the western Pacific. These results demonstrate the intricate connection between the equatorial Pacific Ocean, the global MOC, and glacial climate. For example, the low-latitude oceans also control the extra solar response of atmospheric CO_2 to large ice sheets. Interactions between the ocean and the tropical biosphere emerge as a potentially important component of the ENSO-related CO_2 variability recorded during the past millennium [13].

2.2 Impact of Climate Change on Coastal Ecosystems

Coastal ecosystems constitute dynamic interfaces among land, sea, and atmosphere. They provide habitat for diverse species, nourish marine food resources, and sustain socio-economic activities valued by local populations and wider communities [12]. African coastlines stretch from Mauritania to Namibia in the East Atlantic Ocean and subsequently continue along the Western Indian Ocean from Angola up to Egypt. Along these extensive coasts, a myriad of small-holder farmers and artisanal fishermen rely on ocean resources to sustain their livelihoods. Coastal regions experience a range of extreme weather events associated with changes in climate. In particular, strong winds, high waves, and storm surges present significant and recurrent hazards. They exhibit the capacity to damage infrastructure, inflict property losses, impact valuable natural resources, and affect human well-being[15].

The main forces that regulate coastal circulation occur predominantly at relatively small space–time scales, encompassing tides, wind-driven currents, storm surges, and waves. These induce fast-acting and highly variable circulation patterns near the coast and in estuaries and lagoons. Intra-seasonal warm/cold water-associated winds are capable of producing intense oscillations within the uplifted coastline. As the interaction between the ocean and atmosphere is direct, the coastal climate system is highly sensitive to inter-annual and seasonal time-scale climate variability and change.

2.3 Physical-Ecological Cascade and Environmental Pressures on Coastal Regions

The physical–ecological cascade highlights ocean acidification, rising sea surface temperatures, melting snow and ice, and other pressures on the coastal environment along Africa's 35,000 km of coastline. Thermohaline, cyclonic, and wind-wave forces drive land-sea interactions, threatening coastal ecosystems and socio-economic development [6]. Addressing Climate change introduces a range of pressures on the dynamics of sandy coasts [12]. Sea-level rise drives shoreline retreat in low-lying shorelines. Increased wave height and storm intensity raise the transfer of sediment from offshore to the coastline, partly offsetting the erosion effect of sea-level rise in many regions. Changes in precipitation modify the nutrient inputs to coastal waters, potentially shifting the balance between sandy and muddy sediment accumulation and affecting sediment stability. Positive and negative effects on sandy-coast evolution frequently coexist and generally lead to a more energetic environment and an increase in the frequency and magnitude of extreme events. Rising sea levels also cause waterways to shift alignment and result in the back-barrier migration of saltmarshes and tidal flats.

Around 65 per cent of Africa’s coastline is exposed to increasing hazards related to climate change [9]. Population growth and a lack of adequate coastal protection render coastal areas and communities more vulnerable [2]. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report predicted a rapid rise in sea level linked to global warming, with land submergence threatening low-lying coastal areas. Coastal-zone ecosystems such as estuaries, wetlands, deltas, and coral reefs possess high socio-economic value. Coastal areas contribute between 10 and 25 per cent of GDP despite often covering less than 10 per cent of a country’s surface. The coastal zone accommodates a significant proportion of Nigeria’s industrial and commercial activities, constraining potential relocations due to high investment costs. Sea-level-rise forecasts and rising temperatures have widespread impacts on the macroeconomy and various economic sectors. CIS can deliver effective early warning and actionable risk information, thereby enhancing Africa’s capacity to anticipate and manage coastal climate change impacts.

2.4 Linking Climate Change to Economic Performance

Linking Coastal Climate to Performance of Macroeconomic Indicators in Africa Many African countries have a direct link to the ocean. The ocean–climate nexus spans the interlinked physical, ecological, and socio-economic changes in the ocean–coastal zone related to climate variability and change [2]. Stability of the ocean–climate nexus therefore is essential to the security of ocean-dependent services. Tropical countries such as many African countries are particularly vulnerable to ecosystem change, given the higher sensitivity of the tropics to global warming, with typically larger temperature rises [9]. Africa’s population is growing rapidly, and a large portion of the demographics is based on young people. Examining the ocean–climate nexus and its influence on economic performance and socio-political stability is crucial to answering two guiding questions.

The ocean–climate nexus exerts considerable influence on coastal economies, especially in tropical Africa where sustenance livelihoods predominate and adaptive capacity is limited. As warming subsides in the deep ocean, heat increasingly accumulates in the upper ocean within the tropics. The subsequent ocean impacts initiate biological water column responses that cascade into comprehensive turnover of tropical ecosystems. Coastal sectors such as fisheries, water resources, agriculture, and tourism are particularly sensitive to continued warming, ocean acidification, and sea level rise. The scientific community can aid in mitigation by enhancing climate information systems (CIS) and exploring artificial intelligence (AI) solutions to meet pressing adaptation needs [1].

Climate change extremes induce socioeconomic repercussions across Africa. Uncoordinated broad mitigation and adaptation cause macroeconomic growth fluctuations and inflation variability. Climate uncertainty alters firms’ total factor productivity and efficiency, leading to heterogeneous consequences translatable into sectoral and spatial productive-impact pathways. Forecasting these pathways informs targeted policy and investment decisions [12].

2.5 Socio-Political Stability in the Face of Climate Change

Political resilience to climate change is an increasingly debated topic [9][5]. Among countries engaged in climate negotiations, few consider their political systems to be vulnerable to climate change, 80 % believe their societies can adapt, if need be, and 70 % feel that their institutions are prepared to respond [6]. Yet, an analysis across regions and development status demonstrates that many societies will be challenged by the socio-economic impacts of climate change. Most of this analysis is based on macroeconomic indicators rather than on any measure of political governance or social resilience. Various indices however indicate that political instability is a vulnerability factor that exacerbates the climate conflict nexus, particularly in Africa where the number and spread of conflicts correlate closely with climate impacts and where much of the population and economic activity is concentrated in coastal zones.

Governance structures have a noteworthy influence on a nation's political vulnerability and subsequent capacity for societal resilience. An analytical understanding of these determinants is fundamental to the development of strategies that can mitigate conditions conducive to political unrest and enhance overall societal adaptability. From an analytical standpoint, political vulnerability reflects the potential susceptibility to disruptions in governance that may compromise the integrity of state institutions, whether through gradual processes of disintegration or abrupt governmental collapse[4].

Elevated levels of political vulnerability can exert detrimental effects on societal resilience; while certain institutions possess the capacity to buffer acute shocks, persistently unstable political conditions are prone to undermining the mechanisms that preserve societal and governmental coherence. Political resilience may therefore be construed as the competency of societal structures to either anticipate disturbances or adapt to alterations in governance configurations without compromising functionality [17]. It is not uncommon for such adaptive responses to precipitate instabilities in governance, presenting a paradox in the resilience concept. Clearly, societal rigor is also shaped by an array of additional factors, some of which may exhibit a pronounced ability to counteract climatic events [14].

2.6 Climate Information Systems for Resilience

Climate change disproportionately affects Africa, with the ocean–climate nexus being a central driver and the primary source of climate variability in tropical economies. Coupled ocean–climate dynamics influence physical, ecological, and societal dimensions, underpinning exposure of coastal ecosystems and sensitive sectors. Whether African states are vulnerable or resilient to climate-related shocks depends on bio geophysical factors and the policy environment shaping societal sensitivity. Enabling resilience hinges on available information and economic incentives to recover, learn, or reorganize. The African experience is illustrative of wider considerations that frame global and temporal scope, thereby guiding analysis of the ocean–climate nexus as a physical phenomenon and carbon–climate mitigation [7].

Cheap recovery and reorganization, through income-smoothing and diversification, enable economic resilience at the macro-scale; effective rules and incentives foster social resilience, reducing the exposure of social systems to macroeconomic shocks more generally. If the ocean–climate nexus is the source of climate variability then supporting recovery, reorganization and the allocation of risk is critical, as a simple socio-political imbalance rules out maintainable resilience. The role of climate information and services becomes evident, as it is only through CIS that greater biome activity can be coordinated with collective action and transfer risk over space and time. Such 'advective resilience' may be stronger where societies depend on vulnerable crops – such as those found in Africa and throughout the Indian Ocean region – underscoring the importance of affordable, locally adapted forecasts [3] [6] [18].

2.7 Role of Climate Information Systems

A climate information system (CIS) generates and feeds climate information to a range of sectors fundamental to Africa's resilience. Weather, climate, and ocean information systems from across the world can provide an additional instrument for monitoring, analyzing, and predicting the climate, along with contributing to feasible and reliable economic forecasts. This study addresses the following questions: What do CIS currently provide to underpin resilience in Africa? How can emerging innovations in artificial intelligence (AI) extend the reach of climate services? What building capacities need to be in place to achieve this? Complementary evidence is drawn from Africa's coast and considers how macroeconomic impacts and socio-political fragilities link to the ocean–climate nexus through the coastal ecosystem. As in Africa, coastal systems offer a microcosm of the interplay between climate, economy, and society [16]. If CIS can support resilience-building in African coastal ecosystems through the ocean–climate nexus, then similar insights should apply elsewhere [8].

3. RESEARCH METHODOLOGY

3. 1 Research Design

This study design suggested a mixed-methods approach of exploring how Climate Information Systems (CIS) and artificial intelligence (AI) technologies can help improve African coastal economies' resilience to climate change, with particular reference to Kenya. The design combines the quantitative and qualitative approaches in order to better understand the subject.

3. 2 Target Population

Target group for the research comprises Coastal residents, climate change-impacted fishermen and farmers, Businesses reliant on climate-sensitive sectors such as agriculture, fisheries, and tourism, officials and policy makers of environmental and economic administrators, and Climate information system (CIS) and Artificial Intelligence (AI) technology stakeholders that are operating in Africa's coastal economies specifically targeting Kenya.

3. 3 Sample Size

A sample of about 225 respondents was targeted to represent sample from all the different stakeholder groups. The size of the sample was targeted as being adequate to provide statistically significant results and which allowed for adequate scope of qualitative analysis.

3. 4 Sampling Process

Stratified random sampling was used in order to attain representation across different segments of the target population. The process included:
Stratification: Stratification of the population into distinct strata that are mutually exclusive based on factors like: Geographical location (e.g., coastal regions in Kenya), Sector (e.g., government, academic, community, private), Experience level (e.g., novice, mid-level, expert in climate and AI) and Random sampling of the participants from each stratum for the purpose of creating a well-balanced sample.

3. 5 Data Collection Methods

Information was gathered using a mixed-method approach with the assistance of quantitative and qualitative instruments:
Surveys: A survey was constructed for the gathering of quantitative information on awareness and uptake of CIS and AI technologies, perceived performance of such systems in augmenting resilience and social and economic impacts of climate change. The study points to the potential for Artificial Intelligence (AI) and Climate Information Systems (CIS) for enhancing climate change resilience in Africa, including vulnerable coast-based economies like Kenya.

3. 6 Data Analysis

The analysis of data combined quantitative and qualitative approaches**.** Quantitative Analysis such as Statistical packages (e.g., SPSS, R) was utilized to analyze survey responses using methods of descriptive statistics to describe the responses and inferential statistics (such as regression analysis) to identify relationships between variables.
Focus group and interview transcripts was coded by thematic analysis to identify emergent themes and findings regarding qualitative Analysis related to the effectiveness of CIS and AI, challenges and opportunities in institutions. NVivo or other qualitative analysis packages was also used to code and organize qualitative data.

4. RESULTS

4.1 Demographic Distribution of Study Participants by Age, Gender and Sector

The table I provide a demographic overview of the study participants, recording basic features such as age range, gender, and work industry.

TABLE I. DEMOGRAPHIC CHARACTERISTICS OF STUDY PARTICIPANTS

Characteristics	Frequency (N)	Percentage (%)
Age Group		
18-24	46	20.4
25-34	58	25.8
35-44	42	18.7
45-54	47	20.9
Above 55	32	14.2
Total	225	100
Gender		
Male	129	57.3
Female	96	42.7
Total	225	100
Sector		
Government	53	23.6
Private Sector	47	20.9
Academia	79	35.1
Community (Fishermen & Farmers)	46	20.4
Total	225	100

The age distribution shows that 25.8% of the respondents were between the ages of 25-34 years, followed by 20.9% aged 45-54 years, and 20.4% aged 18-24 years. This indicates a relatively young population, with a high proportion of individuals at their most productive working age, which may contribute to the potential for participation in climate resilience activities.

The gender breakdown indicates a greater proportion of male respondents (57.3%), and this could be representative of overall societal norms and expectations among the targeted communities. Such a gender gap has consequences for the representation of climate adaptation strategies and requires extra efforts to include female stakeholders.

Regarding sectoral representation, scholars make up the largest category (35.1%), followed by government (23.6%) and community members, fishermen and farmers (20.4%). This distribution underscores the central position of the academy in the shaping of climate information systems and adaptation measures, possibly providing research and counsel to inform policy. The presence of local community members underscores the importance of bottom-up engagement in adaptation processes, with local knowledge being crucial for their effective application. However, the relatively lower private sector contribution (20.9%) indicates the need to improve business engagement in climate resilience. On a broader canvas, these findings indicate that leveraging heterogeneity by age, gender, and sector will be important for developing inclusive and efficient climate adaptation strategies for the respective regions.

4.2 Awareness Levels of Climate Information Systems (CIS) Among Study Participants

The figure 1 presents the awareness levels of Climate Information Systems (CIS) among the respondents of the study, indicating the various familiarity levels with these vital tools.

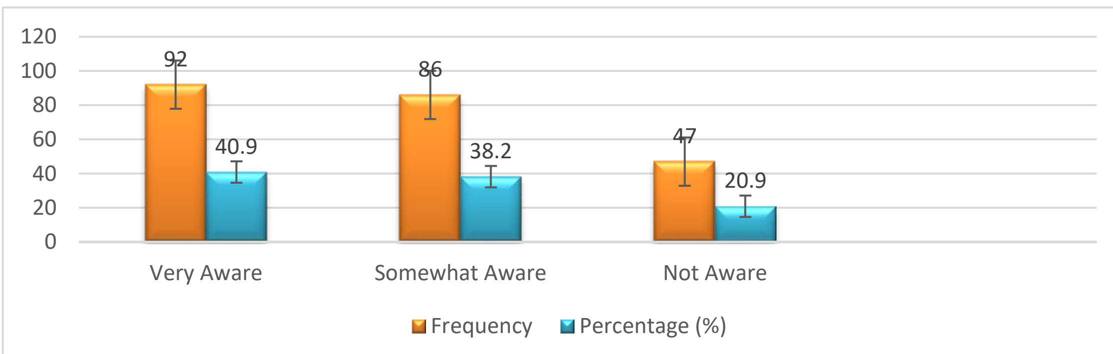

Fig. 1. Awareness of Climate Information Systems (CIS) Among Participants

Awareness of Climate Information Systems (CIS) information shows that most of the respondents have a high awareness level of the systems, with 40.9% claiming to be "Very Aware" and 38.2% who were "Somewhat Aware." This signifies overall awareness of CIS by the study participants, which is promising for potential climate adaptation measures implementation. However, the finding that 20.9% of the subjects were "Not Aware" is a testament to a clear knowledge gap which could potentially hinder complete participation in climate resilience initiatives. This lack of awareness may be particularly concerning among those exposed groups relying on accurate climate information for agricultural and fisheries decision-making. Consequently, targeted education and outreach are needed to create awareness and knowledge of CIS so that everyone involved can actively participate in climate adaptation efforts and enjoy the benefits of exchanged information.

4.3 Frequency of Artificial Intelligence Usage Among Participants

Figure 2 provides an overview of the rate of artificial intelligence application among the respondents, presenting varying degrees of exposure to the technology. An understanding of these usage patterns is crucial in grasping the trend regarding AI application and guiding the integration of the same in various disciplines.

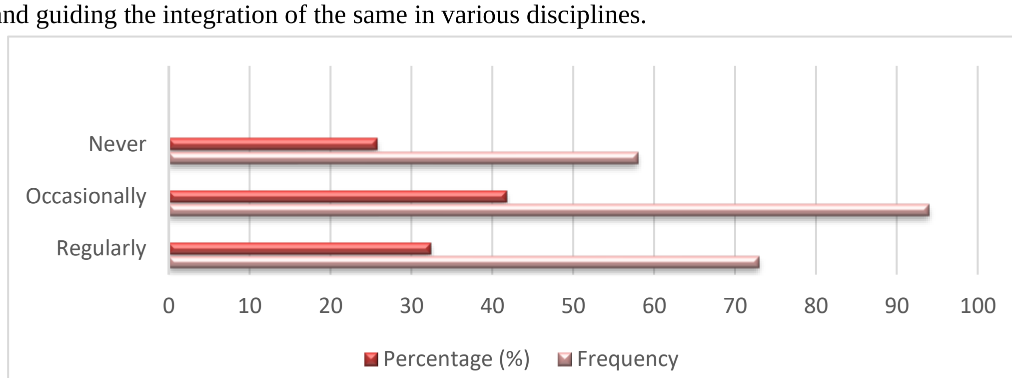

Fig. 2. Usage of Artificial Intelligence Among Participants

The data indicate that a significant proportion of respondents, 41.8%, use artificial intelligence occasionally, and 32.4% use it frequently, indicating higher exposure and reliance on AI systems. However, 25.8% of the respondents have never used AI, suggesting a significant population that would likely benefit from training and exposure to these systems. This spread highlights the importance of understanding the barriers to AI adoption and leads us to the need for awareness and accessibility efforts, particularly for less experienced people in the field of AI applications.

4.4 Relationship Between CIS, AI and Resilience

Table II is a regression analysis to gauge the relationship between the impact of CIS and AI on resilience with high relationship at an R value of 0.789. The analysis shows the high ability of CIS and AI to predict resilience variation at an R^2 value of 0.619.

TABLE II. CORRELATION ANALYSIS OF CIS AND AI IMPACT ON RESILIENCE

Model	R	R^2	Adjusted R^2	Std. Error of Estimate
CIS and AI Impact On Resilience	0.789	0.619	0.613	0.457

R^2: 0.619 (indicating that 61.9% of the variance in resilience can be explained by the model). Adjusted R^2: 0.613 (taking into account the number of predictors).

The regression examination validates a positive correlation (R = 0.789) between the impacts of CIS and AI on resilience, which suggests that they are strongly correlated. The R^2 of 0.619 shows that the impact of CIS and AI can explain approximately 61.9% of the variance in resilience, which highlights their contribution to strengthening resilience. The Adjusted R^2 statistic value of 0.613 also establishes the model's strength, taking into consideration the likelihood of overfitting. With a Standard Error of Estimate of 0.457, the model is shown to possess good predictive ability, and hence it is an effective instrument for investigating how CIS and AI integration can enhance resilience in various contexts. This serves to indicate that organizations must strategically utilize such technologies to enhance their adaptive capacities.

4.5 Comparison of the regression model's performance against other potential models and approaches to resilience assessment

Table III reports an ANOVA summary that tests the performance of the regression model that analyzes CIS and AI effects on resilience. The model fit is significant, with an F-statistic equal to 58.329 and a p-value of 0.000.

TABLE III. ANOVA SUMMARY OF THE IMPACT OF CIS AND AI ON RESILIENCE

Source	Sum of Square	df	Mean Square	F	Sig.
Regression	146.127	2	73.563	58.329	0.001
Residual	92.657	224	0.416		
Total	238.784	226	73.979		

F-statistic: 58.329, Significance (p-value): 0.000 (indicating a statistically significant model).

The ANOVA regression summary model testing the effect of CIS and AI on resilience. The sum of squares for regression is 146.127, indicating that a great deal of variance in resilience is accounted for by the model. With an F-statistic of 58.329 and a significance level of 0.001, the results indicate the model to be statistically significant, far beyond the level typically employed for meaningful results. The residual sum of squares, standing at 92.657, represents variability not explained by the model, suggesting that while the model is excellent, there may be other variables influencing resilience not captured. Overall, this analysis lays a firm foundation for comparing the performance of the regression model against other models, pointing out its strength in delivering insightful information on the dynamics of resilience as it relates to CIS and AI.

4.6 Impact of AI Usage on Resilience, Highlighting Its Importance as Indicated by The Coefficient

Table IV presents the regression analysis coefficients to establish the impact of CIS and AI on resilience. The results indicate both awareness of CIS and utilization of AI are significant predictors with unstandardized coefficients of 0.441 and 0.358, respectively, depicting their positive contributions towards enhancing resilience.

TABLE IV. COEFFICIENTS OF THE REGRESSION MODEL FOR CIS AND AI'S IMPACT ON RESILIENCE

Variables	Unstandardized Coefficients B	Standardized Coefficients Std. Error	t	Sig.
Intercept	1.353	0.473	3.587	0.001
Awareness of CIS	0.441	0.117	3.861	0.001
Usage of AI	0.358	0.099	3.635	0.002

The coefficients of regression analysis for the impact of awareness of CIS and AI use on resilience. The constant term is 1.353, the default resilience score when both variables are zero. The unstandardized awareness coefficient of CIS is 0.441, indicating that for each unit change in awareness, resilience would change by 0.441 units, with a statistically significant t-value of 3.861 (p = 0.001). Similarly, AI use has an unstandardized coefficient of 0.358, which suggests that for each unit increase in AI use, there is an equivalent 0.358 unit increase in resilience, also statistically significant (t = 3.635, p = 0.002). These findings highlight the extremely critical roles that CIS awareness and AI use have to play towards enhancing resilience, and the importance of fostering these factors within organizations to aid adaptive capacities.

4.7 Perceived Effectiveness of CIS and AI in Enhancing Resilience

Figure 3 shows perceived effectiveness of CIS and AI to enhance resilience among respondents and indicates the perceived effectiveness of CIS and AI to enhance resilience, with a very positive perception from respondents.

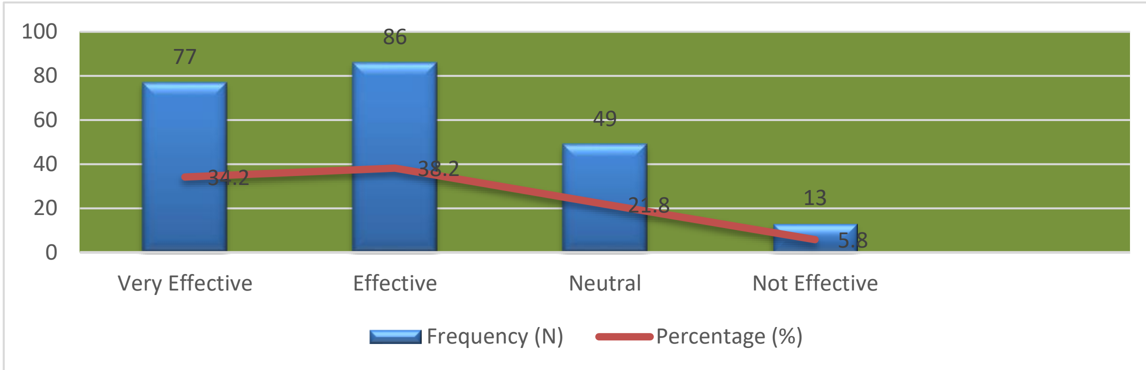

Fig. 3. Level Effectiveness of CIS and AI in Enhancing Resilience

At 34.2% marking these technologies as "very effective" and a further 38.2% as "effective," it is definite that a huge majority see their potential benefit. By contrast, a mere 5.8% of respondents scored them as "not effective," registering a very low level of doubt. The neutral answers, which make up 21.8%, indicate that although most of them concede the efficiency, there is still some segment of the population that would need additional proof or experience to accept these technologies more strongly. Overall, the results reinforce the general consensus on the value of CIS and AI in resilience building and underscore the need for continued education and awareness to further enhance understanding and acceptance among the rest of the respondents.

4.8 Challenges Faced in Implementing CIS and AI

Figure 4 highlights CIS and AI challenges of implementation, cumulating significant hurdles that organizations encounter.

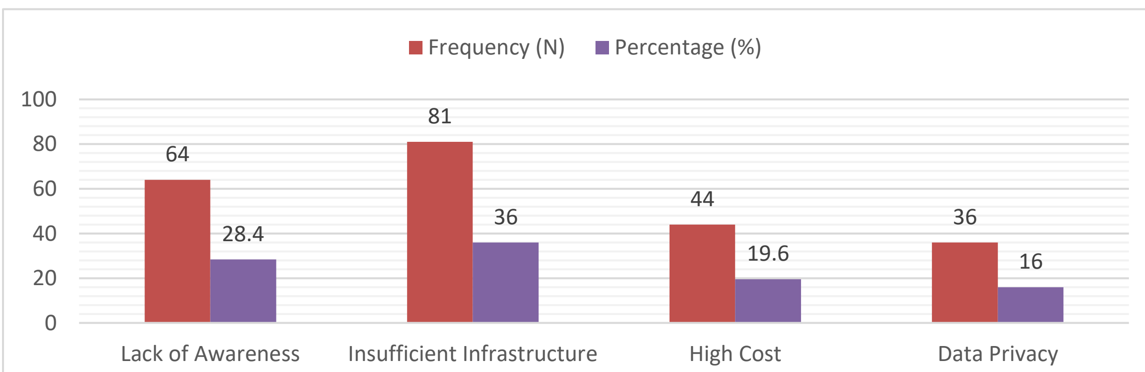

Fig. 4. Challenges Faced in Implementing CIS and AI

reporting lack of infrastructure to be the most severe challenge, with 36.0% of the respondents identifying it as a hurdle. This suggests that most organizations may not have the technological foundation to adopt these systems. In addition, 28.4% of the respondents also noted lack of awareness as the most significant challenge and suggested that more education and knowledge about CIS and AI is essential to successful implementation. High cost, noted by 19.6%, contributes to the complexity, which may deter organizations from being inclined to invest money in necessary technologies. Privacy of data, noted by 16.0% of the respondents, signifies heightened concern about security in the online environment. Together, these problems make imperative the need for overall strategies towards addressing infrastructural deficits, increasing awareness, mitigating cost implications, and ensuring robust data protection to successfully achieve the integration of CIS and AI across various fields.

4.9 Regression Analysis of Factors Influencing the Effectiveness of CIS and AI

Table V provides valuable insights into the determinants of CIS and AI effectiveness within its regression analysis. The coefficients reveal strong correlations where CIS awareness and the adoption of AI positively influence effectiveness, and challenges negatively influence it, thus outlining the complex dynamics involved in the application of these technologies.

TABLE V. REGRESSION ANALYSIS OF FACTORS INFLUENCING THE EFFECTIVENESS OF CIS AND AI

Variable	Coefficient (B)	Standard Error	t-value	p-value
Intercept	0.989	0.322	3.085	0.002
Awareness of CIS	0.396	0.114	3.568	0.001
Usage of AI	0.347	0.099	3.632	0.001
Effectiveness	0.419	0.111	4.071	0.002
Challenges	-0.276	0.093	-3.159	0.001

The positive coefficients for CIS awareness (0.396) and AI usage (0.347) both signify that increasing awareness and use have a highly positive effect on the success of these technologies, suggesting that education programs and greater adoption will result in improved outcomes. The effectiveness indicator also has a highly positive coefficient (0.419), which underscores its strong influence on overall success. Conversely, the negative value of the challenge coefficient (-0.276) highlights that implementation challenges detract from effectiveness and therefore it is essential to get over these challenges in order to tap the potential of CIS and AI. The statistically significant p-values for all variables ($p < 0.05$) also contribute to the robustness of these findings, indicating that strategic interventions that focus on awareness, use, and barriers need to be put in place in order to enhance the effectiveness of CIS and AI in organizations.

5. DISCUSSION

The mixed-method analysis ensured that, indeed, respondents manifested high levels of awareness of CIS and positive contribution made by such technologies towards enhanced adaptive capacities. Regression analyses revealed very high positive correlation of CIS with AI usage and awareness and overall resiliency and knowledge to be the crux of effectiveness.

Infrastructural limitations, low awareness, and excessive cost were also found to be major barriers to adoption. These findings underscore the importance of strategic training schemes and investment in infrastructure to bridge knowledge gaps and facilitate enhanced CIS and AI integration that leads to facilitated climate adaptation within the region.

6. CONCLUSION

Climate Information Systems (CIS) and Artificial Intelligence (AI) are actually major tools of developing climate change resilience in Africa, and particularly in coastal economies like Kenya, this study establishes. The study reveals that improved awareness and maximum use of these technologies have a very important role in boosting the adaptive capacities of communities.

But the study also reveals some of the major concerns such as insufficient infrastructure and ignorance which need to be addressed in order to utilize the maximum potential of CIS and AI.

Through the deployment of targeted education programs and investment in crucial technological platforms, stakeholders can enhance the effectiveness of climate adaptation programs towards achieving ultimately stronger resilience despite existing climatic challenges.

7. RECOMMENDATION

The research proposes mounting of gas analyzer sensors on cell phones (smartphone) to convert physical changes into electrical signals that can be interpreted by AI algorithm systems and automatically send collected data to various stations and also even remote stations. The stakeholders should focus on the development and implementation of comprehensive education programs aimed at increasing awareness of CIS and AI by coastal communities and decision-makers in Kenya. Investment in infrastructure to accommodate such technologies and make them come within reach limits is also required. Inter-ministerial coordination among the government departments, academia, and industry must be facilitated to initiate learning from each other and building capacities. Barriers of extremely high costs and privacy of data will also have to be overcome in the introduction of CIS and AI.

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Conflicts of Interest:

The authors declare that there are no conflicts of interest.

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