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Climate Change Effect in Nigeria Mitigation, Adaptation, Strategies and Way Forward in the World of Internet of Things

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Abstract:- This paper delves into the comprehensive impact of climate change in Nigeria, emphasising the critical role of Internet of Things (IoT) technology in formulating mitigation and adaptation strategies. It highlights the significant threats climate change poses to Nigeria's ecological balance, economy, and societal structure, including altered temperature patterns, more frequent extreme weather events, and ramifications for agriculture, water supply, and health. It underscores the urgency for effective responses to protect the nation's welfare and economic integrity. The study showcases the potential of IoT technology as a pivotal tool in crafting innovative responses to climate change challenges. It demonstrates how IoT can bolster Nigeria's resilience through enhanced agricultural methods, better management of water resources, and more efficient energy utilisation. IoT devices' real-time data gathering and analytical prowess facilitate precise environmental monitoring, timely disaster warnings, and resource optimisation. The discussion extends to mitigation tactics like shifting towards renewable energy, improving energy efficiency, and sustainable land use, alongside adaptation strategies that include building climate-resilient structures, advocating for water conservation, and applying climate-smart agricultural practices to safeguard food security. Advocating for a cooperative strategy that integrates efforts from the government, private sector, academia, and communities, the paper stresses the importance of incorporating IoT solutions into national climate action and development strategies for a unified and robust approach to climate-related challenges. It concludes with a roadmap for the future, proposing policy reforms, investments in IoT infrastructure, skill development, and heightened public awareness as essential moves towards a sustainable, climate-resilient Nigeria. By strategically deploying IoT technologies, Nigeria can mitigate the detrimental impacts of climate change and tap into new avenues for economic and environmental prosperity.

I. INTRODUCTION

While the Internet of Things (IoT) continues to revolutionise the world with tens of billions of interconnected devices, it offers great potential for learning more about the environment. It helps to address the issue of climate change, which is becoming critical both in the developing and developed world. Nigeria, the focus of this paper, is one of the developing countries experiencing the effects of climate change at a faster and more extreme rate. According to a climate risk index, Nigeria has been placed in the 95th percentile to ascertain its future vulnerability and readiness to adapt to global trends (Wajim2020). In 2012, Nigeria faced a deforestation rate of 3.5% per annum, arguing with clean-up measures such as re-afforestation (Deekor). Much of this deforestation has been caused by erratic, unseasonal weather, which has affected the agriculture sector, producing output failures (Alkali et al., 2022). Nigeria currently depends on a linear economy, and the general way of life finds a significant proportion of the population at or below the poverty line. In essence, poor and vulnerable people are very likely to be affected by climate change (Nwandu, 2020). With government policies and the general living of the population, this cycle is prolonged to change and will, therefore, continue and exacerbate the effects of climate change (Okafor et al., 2023). This is where the IoT can come into the equation to alter and reconstruct the future outcome.

A. Background

There is an urgent need for mitigative and adaptive actions that will help cushion the impacts of climate change and sustain development in a rapidly changing climate. However, an understanding of climate change and its impacts is needed to develop such strategies and actions, which is, in most cases, lacking. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) provides the most detailed and comprehensive information on climate change and the impacts available (Daba & You, 2020). Much information is also available in the global databases and models that IPCC experts have developed (Ishtiaque et al., 2022). However,

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this information is mostly in technical forms and inaccessible to people working on development at the national level in Nigeria (Howarth & Viner, 2022). This project aims to address this by summarising AR4 information specific to Nigeria and making available a package of climate change information, scenarios, and impact data applicable for future national-level climate change vulnerability assessments and adaptation strategies (van der Geest & Warner, 2020). This will be facilitated through collaboration with experts from Nigeria's relevant sectors - Agriculture, Water Resources, Health, and Environment.

Nigeria's high vulnerability and low adaptive capacity have already increased its people's and ecosystems' exposure to extreme events, and its capacity to cope with the adverse impacts of climate variability and change is fragile (Awolala et al., 2022). Obafemi et al. (2008) stated that there is a strong likelihood that climate variability and change could undo or severely compromise some of the development and poverty alleviation gains that Nigeria has struggled to make in recent decades (Dukiya & Benjamine, 2021). This could make Nigeria more dependent on external assistance and concessional funding for development programs (Raimi et al., 2021). Climate change is a natural and severe threat to Nigeria's economic prosperity and social and political stability, seriously challenging human health, basic food security, water supply, biodiversity, and productive natural resources (Raimi et al., 2021). Extreme weather events cause significant damage to infrastructure and threaten human life (Agom-Ucha & Nwodeh, 2020). Climate-related disasters have increased, including heatwaves, droughts, desertification, harmattan, gully erosion, epidemics, and flooding (Ifeanacho & Okudu, 2020).

B. Purpose

This research delves into the impact of climate change on Nigeria, underscoring the need for rapid dissemination of findings and solutions. It discusses how climate change and global warming affect Nigeria's environment and livelihoods, exacerbated by challenges like high poverty, conflicts, and limited adaptive capacity. The study examines mitigation and adaptation strategies by local authorities and researchers and explores how the Internet of Things (IoT) could enhance these efforts. Additionally, it reviews Nigeria's participation in global environmental initiatives and multilateral agreements, focusing on current impacts, response strategies, and future directions for addressing climate change in Nigeria, with an emphasis on sustainable development.

C. Scope

This paper reviews the impact of climate change in Nigeria and proposes the use of IoT technologies as adaptive responses. It details the current climate trends and the effects of climate change on the country, advocating for IoT-enabled technology to provide near real-time, data-driven insights. These insights are crucial for decision-makers, enabling them to prepare for and mitigate future climate impacts. The paper is highly relevant as it utilizes global climate projections and locally generated scenarios to inform decisions ranging from seasonal weather forecasting to long-term infrastructure planning. This research serves as a valuable resource for policymakers and government organizations, offering an integrative approach to understanding climate change factors and implementing specific remedial actions in response to anticipated future effects in Nigeria.

II. CLIMATE CHANGE IN NIGERIA

Nigeria is richly endowed with various natural resources but has often been overexploited and undermanaged. The pursuit of economic gain has often led to the neglect of a healthy environment. Logging and deforestation in Nigeria have occurred alarmingly (Babatunde et al., 2020). Economic motives have led to uncontrolled timber exploitation and land clearance for agriculture. This has profound environmental implications regarding soil erosion and biodiversity loss (Heinemann et al., 2022). Nigeria's consumer class has grown exponentially (Adoghe et al., 2023). This has strained the country's power and energy resources, with consumers resorting to private electricity generators predominantly run on petrol or diesel. These private generators supply over 50% of Nigeria's power (Babajide & Brito, 2021). This has significant implications concerning greenhouse gas emissions and indoor air pollution (Owebor et al., 2021). The causes of climate change in Nigeria can be understood in terms of the effect of population growth, consumerism, and the overexploitation of its natural resources. Nigeria is one of the most populous countries in the world. The population has grown from 36.7 million in 1950 to 140 million in 2006. Population growth results in urbanisation, infrastructure development, and increased industrial activities, which inadvertently lead to higher greenhouse gas emissions.

A. Causes

Nigeria is experiencing significant climate changes, including higher temperatures, extreme weather events, altered rainfall patterns, and rising sea levels, a pattern also seen across West Africa (Olagunju et al., 2021). Research identifies human activities, particularly since the mid-20th century, as the primary cause of these changes (Raimi et al., 2021). The increase in greenhouse gases like carbon dioxide, methane, and nitrous oxide, largely from fossil fuel use and reliance on fuelwood in developing countries, is trapping more heat in the Earth's atmosphere (Dioha & Kumar, 2020). Other contributing factors include land use changes (Okedere et al., 2021) and policy missteps linked to Nigeria's oil boom, which have led to increased emissions through expanded energy and electric infrastructure. With its high population growth, Nigeria is poised to be a major future contributor to global climate change, underscoring the urgent need for mitigation and adaptation strategies to address the potential severe impacts of these climatic shifts.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24APR1096

B. Impacts

Agriculture is Nigeria's primary livelihood source, contributing to about 70% of the GDP and employing about 90% of the people (Tochukwu et al., 2021). Climate change will lead to an increase in temperature and changes in rainfall with potentially adverse effects, particularly on agriculture (Omodero, 2021). With the current approach to farming, climate change will lead to a decrease in arable land due to soil degradation and erosion. Inland water resources and increased pressure on the already limited groundwater resources will also be affected. Fisheries will be adversely affected, and livestock production will be reduced (Bello, 2020). High temperatures and changing rainfall will also change the distribution of different ecological zones and increase health-related problems (Opeyemi et al., 2021). Adaptation strategies and a change in farming methods will be necessary to counter these effects, and it will be necessary to utilise weather and climate predictions and generate climate-resilient agricultural practices. An increase in extreme climate events will be particularly damaging regarding physical damage and the effect on the economy. This will include increased flooding and drought, the frequency of which will lead to an increase in desertification in the North and adverse effects in the rest of the country. The damage caused by the increase in climate extremes will have a compounding negative effect and will make it more difficult for Nigeria to develop; it is, therefore, crucial for the country to take steps to mitigate the effects of climate change.

C. Current State

After several decades of oil booms, the Nigerian economy is still highly dependent on oil and the associated government revenue. It is now generally expected that global climate policy and action will lead to a substantial and permanent reduction in global oil demand over the coming decades (Ighosewe et al., 2021). If Nigeria does not diversify its economy away from oil, the consequences for the Nigerian government and its people will be dire (Ogunjimi, 2020). At the same time, the government is faced with a massive and growing population, and the sheer scale of current and future developmental needs means that climate change and its associated impacts are not at the forefront of the government's or the people's concerns (Idris & Oruonye, 2020). There is a lack of awareness and appreciation of climate change's relevance to Nigeria: its causes, the likely impacts, and the necessary policies for mitigation and adaptation are all poorly understood (Oduyemi & Owoeye, 2020). Therefore, it is clear that a major strategic redirection is needed - climate change must become a serious consideration of Nigeria's policy and development planning. At the same time, all climate change impacts have to be seen in the context of Nigeria's current challenges and difficulties. This includes highly complex political, social, and security issues, widespread poverty and inequality, and a long and difficult recovery from a history of poor governance and mismanagement of public resources. All of these issues have created deeply embedded institutional, economic, and social structures that can both help and hinder effective adaptation to climate change, and any attempt to address climate change must seek to either utilise or reform these structures to achieve results.

III. MITIGATION STRATEGIES

Afforestation and reforestation are key strategies to enhance carbon sinks by absorbing CO2, and under the Kyoto Protocol's Clean Development Mechanism (CDM), these projects can generate Certified Emissions Reduction credits for trade in the carbon market, creating an additional revenue source (Olujobi et al., 2023; Okonkwo et al., 2021). Carbon pricing, including carbon taxes and cap and trade systems, monetizes the cost of carbon emissions, funding renewable energy projects (Olujobi & Olusola-Olujobi, 2020; Garba et al., 2022; Olujobi et al., 2022). In Nigeria, renewable energy is critical for reducing emissions and improving energy security. Despite widespread access, energy often comes from unreliable diesel generators. Biomass dominates the energy supply, offering significant potential for growth in renewables with the aim of achieving universal modern energy access by 2030 (World Bank, 2002). The World Bank's project in Katsina, which involved energy-efficient lighting and appliances, successfully reduced CO2 emissions significantly, demonstrating the benefits of energy efficiency.

A. Renewable Energy

The National Energy Policy (2003) aims to increase the share of RE in the national energy mix primarily to reduce dependence on fossil fuels for energy security and to diversify the economy (Owebor et al., 2021). Much of the additional electricity-generating capacity required to meet Nigeria's burgeoning energy demand comes from RE technologies (Adewuyi, 2020). Nigerian RE resources continue to play a prominent role in meeting sustainable development goals outlined in the NEEDS (2004) and Vision 2020 documents focusing on poverty alleviation and regional development (Tambari et al., 2020). It is widely acknowledged that the climatic and developmental benefits of RE technologies can only be realised if there is a shift in the patterns of traditional energy sources to RE on account of the modular nature of RE investments and technologies (Ibrahim et al., 2021). In the context of climate change mitigation, it has been suggested that the best approach would be to promote decentralised RE applications and investments in rural areas, given that they are usually more reliant on traditional energy sources and are often negatively impacted by climate change (Agbo et al., 2021). Renewable energy (RE) technologies benefit Nigeria's effort to mitigate climate change impacts. The key benefits of many RE technologies include their abundant availability and widespread applicability, which offer significant climate change mitigation potential. RE also offers energy supply diversity, which could guard Nigeria against future energy security risks. Given the country's high solar radiation, wind speeds, and abundant biomass resources, Nigeria has the potential to become a significant generator and exporter of RE technologies without compromising primary energy supply and security.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24APR1096

B. Energy Efficiency

An energy-efficient Nigeria will shift from energy-inefficient hand-set diesel-powered electricity generators to decentralised renewable energy power sources. This will require a great deal of investment; however, it will be cheaper in the long run due to the free energy source. It is predicted that if the cost of renewable energy sources can be reduced to that of the cost of generator power, there will be a massive shift towards renewable energies (He et al., 2021). With the Internet of Things technology, saving money on modern energy bills is possible without changing current comfort levels (Huo et al., 2022). According to the International Energy Agency, an energy efficiency increase of 4.3% per year could enable the world to maintain current energy usage levels while outputting 60% less carbon by 2033 (Jäger-Waldau et al., 2020). For such technology to be implemented in Nigeria, it might require foreign aid, where some people think that the government might be "spending our money to buy their money." However, an approach involving funding schemes could show that initial spending can lead to profit (Ren et al., 2022).

C. Carbon Pricing

Carbon pricing is a cost applied to carbon pollution to encourage polluters to reduce greenhouse gas emissions. Typically, it is a charge or a tax on each ton of carbon dioxide emitted. It can also be a cap and trade system (Oguh et al., 2021). The aim is to provide an economic signal to those responsible for emitting the carbon that they should reduce their emissions. When carbon is priced, the polluter is incentivised to reduce their emissions to avoid the higher costs associated with the carbon price. The money raised from the carbon price can be used by governments to invest in a cleaner and more sustainable energy supply, enhancing energy efficiency and supporting the communities and workers most affected by the transition to a clean energy future (Imarhiagbe et al., 2020). Pakistan and South Africa are among many other countries with similar ideas for carbon pricing but have had difficulty applying them in practical scenarios due to ongoing political issues and economic strain (Fenta et al., 2020). In Nigeria, it could be largely beneficial and a successful method for mitigating climate change. The World Bank stated 2015 that Nigeria had the highest levels of natural biodiversity and ecosystem services of any African country and was ranked 3rd in living natural capital. Nigeria can expect significant revenue by valuing and conserving forests, wetlands, endangered species, and critical habitats. These actions can now be linked with carbon payments, compensating for foregone development opportunities (Ahononga et al., 2020). Carbon pricing, being a market-based approach, was the preferred method of mitigation by the previous Minister for the Federal Ministry of Environment, Laurentia Mallam, who at the Durban climate change conference said, "We would like to see a global market in carbon trading to be part of the solution, but Nigeria would like to see regulations to prevent market failure and an agenda for reform based on evidence". This was in response to Article 6 of the Kyoto Protocol, which aimed to create international emissions trading, a clean development mechanism, and joint implementation projects. Unfortunately, Nigeria did agree to ratify the Kyoto Protocol but did not follow the agreement with any law or policy changes for implementation.

D. Afforestation and Reforestation

Afforestation, the practice of planting trees in an area that has never been planted before, involves the establishment of forests on land converted to other land use (Flury). Reforestation restocks existing forests and woodlands that have been depleted using native or exotic tree seeds (Adiaha et al., 2020). The policies of afforestation and reforestation have been mentioned under the Kyoto Protocol, which was agreed upon in 1997 between a host of developed and developing countries (Burke et al., 2021). Since then, these policies have been in process at national and international levels. Developing countries signatories to the Kyoto Protocol are engaged in reducing atmospheric CO2, thus avoiding economic penalties that developed countries may impose through carbon tax or carbon trade (Osman et al., 2023). Also, they are finding solutions to the problems of land under use for shifting cultivation and other forms of agriculture. At the national level, they are trying to meet the requirements of sufficient wood demand and conservation of natural resources (Hasegawa et al., 2023).

IV. ADAPTATION STRATEGIES

Climate-Resilient Agriculture: Nigeria's economy heavily depends on agriculture for employment, income generation, food security, and poverty reduction. It is also a very vulnerable sector to changing climates, with over 90% of agricultural activities being rain-fed (Azare et al., 2020). In light of this, promoting sustainable land management practices is considered a robust and effective means of adapting agriculture to climate change. This can increase the resilience of farming systems, enhance food security, and offset additional costs for food importation (Onyeneke et al., 2021). As a proof of concept for risk reduction and adaptation, the NESP is developing and implementing a climate risk management approach to build resilience in the agriculture sector in the north-central zone of Nigeria (Ikhuoso et al., 2020). The ultimate goal is to develop a package that can be upscaled throughout the nation and the region. Nigeria is trying its best to adapt to the adverse effects of climate change instead of mitigating the problem. One aspect of adaptation is employing traditional mechanisms to cope with impacts and initiating new innovative strategies (Anabaraonye et al., 2021). According to the Nigerian Environmental Study/Action Team (NEST), climate change threatens to reduce agricultural yields by up to 30% in the savannah and up to 50% in the already stressed Sahel. Therefore, promoting a shift from subsistence farming to commercial farming and more efficient use of resources on the farm will be critical. This will require the capacity building of farmers, market access for inputs and produce, and the development of an enabling policy environment in the agricultural sector.

A. Climate-Resilient Agriculture

To create a more sustainable and diverse agriculture system, there needs to be more investment in research and extension to create climate-resilient agriculture (Srivastav et

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al., 2021). This will involve developing new techniques and modifying current ones to equip agriculture to tolerate and adapt to climate change. Building more climate-resilient agriculture will help ensure food security and reduce the vulnerability of the millions of poor people who depend on agriculture for their livelihoods. Generally, the most significant risk is faced by agriculture in low-income, food-deficit countries where resources to adapt are limited (Fahad et al., 2021). These countries are increasingly turning to the emerging concept of climate-resilient agriculture. Climate-resilient agriculture is a way to approach developing the agriculture industry by combining adaptive strategies and resource conservation to produce a more tolerable environment for the effects of climate change (Azadi et al., 2021). It aims to achieve a suitable level of food security and nutrition, increase the resilience of livelihoods and production of services, and respond to climate change in a way that does not threaten the environment or natural resources. This approach can be broken down into several key elements. The first is targeted research that is needs-based and impact-led (Leippert et al., 2020). It will provide new evidence-based solutions to tackle the effects of climate change on agriculture. This will involve creating a solid knowledge base on the future effects of climate change on specific agriculture products and regions and developing new technologies and knowledge to enable a practical and policy environment for change.

B. Water Management

Though Nigeria has a relative abundance of water resources, the uneven temporal and spatial distribution and high population growth rates cause increasing water stress (Shiru et al., 2020). Surface water is Nigeria's main domestic water supply, but there are highly significant differences in availability between agroecological zones (Onanuga et al., 2022). These are all reasons why water is a critical issue in Nigeria's development and affects many important sectors for poverty alleviation. Climate change will further stress Nigeria's water resources, and proactive measures must be taken to sustain them (Ngene et al., 2021). Adaptation strategies are about changing proposed use and infrastructure to reduce vulnerability to the changing climate. Following the discussion concerns the potential impacts of climate change in Nigeria and the proposed adaptation strategies for its water resources (Okon et al., 2021). Water is likely to be an essential variable in the impact of climate change, both on a regional and global scale. The Intergovernmental Panel on Climate Change (IPCC) has indicated that climate change will increase the risk of decreased water resources in arid and semiarid regions. The changes will induce a change in runoff and water availability. Increased water scarcity is projected to impact human health and well-being significantly, given the importance of water resources on socioeconomic development and the coping capacity of many sectors.

C. Infrastructure Resilience

Nigeria will need between $600 and $700 billion in infrastructure investment in the next decade to meet its development aspirations (Yeboua et al.). With much of this new infrastructure investment yet to be made, multiple opportunities exist to ensure it is built to be resilient to the changing climate. The first challenge in making infrastructure resilient to climate change is understanding how the climate may change and what the impacts of those changes might be (Babalola & Iwegbu, 2021). Specific attention needs to be given to engineering designs to ensure that they can accommodate the changes and are not based on the assumption of a stable climate (Kalu et al., 2021). In most cases, a change in building standards or slight infrastructure re-design will not significantly increase the cost, but retrofitting infrastructure later would be significantly more expensive. New buildings without information on climate change are in danger of becoming unfit for purpose during their design life or will require expensive refits (Yeboua et al., 2022). A key example would be an increase in temperature leading to significant energy savings from not having to retrofit buildings or install air conditioning at a later date. In addition to investing in stable infrastructure, there are often simple 'no-regrets' measures that can be taken to lessen the impact of climate change on infrastructure. For example, forests are being planted to stabilise dunes in Northern Nigeria so that the villages behind the dunes will not be flooded when the predicted increase in intense rainfall occurs. Finally, the location of infrastructure should be chosen to minimize the exposure to climate-related impacts. For example, it would be advisable not to invest in infrastructure close to current river channels, as a change in rainfall patterns may lead to increased flooding and erosion.

V. INTERNET OF THINGS (IOT) AND CLIMATE CHANGE

The Internet of Things (IoT) involves connecting various devices to the internet, enabling them to collect and transmit data without human intervention (Al-Sarawi et al., 2020; Communications Commission, 2020). As sensor and communication costs decrease, IoT emerges as a promising platform for global business integration and smart device exploitation (SG Andrae, 2020). By 2020, it's estimated that over 40 billion devices will be connected, generating approximately 22.9 trillion gigabytes of data (Lombardi et al., 2021). This vast amount of data and its analysis could contribute over $600 billion in global industry value, driving significant growth in IoT applications, software development, and business investments. IoT's capacity for real-time monitoring of locations, things, and people enhances its value, particularly in scenarios where timely and accurate data is crucial. This technology is set to revolutionize consumer, enterprise, infrastructure, and embedded solutions by creating a more connected and intelligent system.

A. Overview of IoT

The Internet of Things (IoT) can be described as connecting everyday things to the Internet and allowing them to send and receive data. 'Things' in this sense can refer to a wide variety of objects, including buildings, vehicles, and other items embedded with electronics, software, and sensors (Salam & Salam, 2020). These things connected to the Internet allow them to collect and exchange

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data with minimum human intervention. The IoT concept originated in the 1960s with the development of the Internet and the idea of "connected devices." However, the technology to enable IoT has only recently become possible, with the combination of wireless technologies, micro-electromechanical systems, and the Internet (Nižetić et al., 2020). The adoption of IPv6 has also provided the resources for an almost limitless number of IP addresses, making it possible to connect an incredibly high number of devices to the Internet (Hossein Motlagh et al., 2020). This wave of technology has created a significant concept which has the potential to be incredibly beneficial for climate change in both mitigation and adaptation (Sinha & Dhanalakshmi, 2022). The types of devices in an IoT system can vary greatly. It could be a simple device such as a thermometer, measuring the local temperature and sending this data to another location. On the other hand, a device could be embedded with an actuator software and send information, such as a tidal radar system. Sometimes, a "thing" in the IoT could be a very complex system, such as a vehicle with built-in sensors and an IP address. Overall, the IoT enables devices to be "smarter" as they can carry out their regular function and operate in the internet environment to produce information. This technological wave has the potential to provide climate research with abundant information and significantly improve monitoring and understanding of the current and future climate.

B. IoT Applications in Climate Change Mitigation

In the context of climate change mitigation, IoT technology can be applied in many intelligent systems to improve energy efficiency, slow it down, or reverse climate change. Examples of applications include IoT devices to monitor energy use (in residential homes, commercial buildings, and industrial plants), IoT devices that can be utilised to study and monitor changes in the climate and its effects on the earth, IoT devices to automate and optimise systems (smart grid, smart irrigation), and many others (Shahbaz et al., 2020). Energy efficiency directly addresses climate change mitigation by reducing global energy intensity. Global warming can be reduced by reducing the amount of energy used. Studies have suggested that it is possible to reduce the growth of carbon emissions to zero and possibly even reduce the level of carbon emissions with an absolute reduction in the amount of energy used over the next 50 years (Yuan et al., 2022). This can be achieved by deploying more efficient energy technologies or changing the behaviour of energy end-users. More efficient energy technologies are developing ways to produce the same quality and quantity of energy products with fewer energy resources (Meys et al., 2021). The development, diffusion, and use of cleaner energy technologies can lead to a reduction in the emission of greenhouse gases (Bataille, 2020). The behaviour of energy end-users is a broad area that various technologies can influence. Monitoring and providing feedback on energy consumption have been shown to lead to a 5-15% reduction in the energy usage of a building or a home. This can be achieved with IoT devices to monitor energy use, automatically report generation of energy use, and compare with historical data and trends to identify areas or times of high energy use.

C. IoT Applications in Climate Change Adaptation

With IoT, we can control different systems, which are brighter than old ones, and the more these systems are interconnected, the more intelligent they can become. IoT allows us to get climate change under a certain amount of control by primarily focusing on its adaptation. Monitoring is the first and the most crucial step in understanding a problem. Climate is a very complex system with many non-linear processes, and a slight change in one part of the system can result in a significant difference in the overall system (Narayana et al., 2024). So, it is tough to determine the root cause of a problem. IoT devices can continuously monitor environmental variables such as temperature, humidity, and precipitation. Information can be logged and analysed to understand the problem better and make future predictions (Almalki et al., 2021). Another critical aspect of climate change adaptation is ensuring people's safety during natural disasters such as heat waves, forest fires, and floods. In the case of a sudden disaster, traditional monitoring systems are often damaged and rendered useless. IoT devices can provide real-time monitoring, which is much more reliable than the current system. An example is wireless networks and low-cost communication to make automatic weather alarm systems in areas with a high risk of natural disasters (Yu et al., 2021). Such devices can also monitor the safety of infrastructures such as bridges and provide early warnings for potential failures.

VI. INTEGRATION OF IOT IN CLIMATE CHANGE STRATEGIES

Climate change has become a significant concern for many organisations and individuals alike. It is currently one of the world's most debated and researched issues (Salam & Salam, 2020). If funding to resolve this issue continues and more strategies are developed, its impact and effects may be reduced or even reversed. Climate change strategies focus on mitigating the effects of climate change, adapting to the current effects, and developing new technologies and pathways to move to a more sustainable and low-carbon economy (Ahmad & Zhang, 2021). One of the keys to success in developing climate change strategies is information. Access to reliable and timely information, not only on the current state of the climate but on the effectiveness of various strategies used to change this state, is essential (Hossein Motlagh et al., 2020). Data is an important resource currently underused in climate change research and policy. IoT presents an opportunity to change this. Through the automated monitoring of the environment and human activity, vast amounts of data can be collected on the factors contributing to climate change and the effectiveness of strategies to reduce or reverse these factors (Sarker et al., 2020). This data is a resource that can be exploited by using decision support systems to guide policy and behaviour change towards more sustainable outcomes.

A. Monitoring and Data Collection

The public entities identified in this research need to monitor climate variables specific to regional and local impacts, which greatly influence our ability to identify and mitigate the effects of climate change (Akinleye &

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Kolawole, 2020). They require a system or tool that provides access to sufficient information on climate variables at various temporal and spatial scales. This information can identify trends and anomalous behaviour in these variables, which can then be addressed with policy and planning decisions (Ishaku et al., 2020). The specific requirements of public sector users and the sheer volume of data from various sources demand an intelligent system for data assimilation, data interrogation, and trend analysis (Chijoke-Mgbame et al., 2020). This same information can also be used as indicators for climate change vulnerability and to track vulnerability changes over time. In either case, monitoring said variables can be taken as within an adaptive management framework, with the ability to revise management and policy decisions as new information is obtained (Okon et al., 2021). As mentioned in the introduction to this research, the sheer complexity and large quantity of data in climate and climate change research far surpasses the abilities of traditional methods and tools of data collection and analysis. This is where the integration of Internet of Things (IoT) technologies holds the potential to provide a solution.

B. Decision Support Systems

Decision Support Systems (DSS) are computer-based applications that collect and analyse data and other information to support managerial decision-making. IoT-enabled DSS can provide timely and practical information and permit user and system interaction (Li et al., 2021). Decision support systems are diverse and target many different kinds of decisions. Senior management might use an executive dashboard to track the company's key performance indicators (Guo et al., 2020). Marketing managers might use forecast sales and market potential for a new product. Middle managers might use a geographic information system to analyse the best location for a new retail outlet (Qinxia et al., 2021). A DSS can be built as a software system with a user interface, model base, and database. This will be necessary for complex decisions like parliament deciding where to invest extra spending on healthcare (Koot et al., 2021). Other DSSs can be very simple, such as a mobile phone alerting a person with diabetes when his blood sugar goes too low. This can be done automatically by an IoT-enabled sensor collecting data from the diabetic's continuous blood glucose monitor.

C. Smart Grids and Energy Management

The IoT Impact: Smart grids collect data from the energy consumer and transfer it to the utility for real-time monitoring. This is made possible through IoT technologies, which facilitate the automatic exchange of information between energy-consuming devices and the utility (Moreno et al., 2021). Smart grids have numerous benefits for energy consumers, as the automation of the electricity infrastructure reduces energy consumption costs, increases reliability and transparency of supply, and, in the long run, will enable a sustainable energy future (Rabie et al., 2021). Using IoT devices and sensors, smart grids can detect and withstand an event that may cause supply disruption. An example of this would be an event that affects an increase in energy demand, causing an overload to the electricity supply and blowing a transformer (Mufana & Ibrahim, 2022). Smart grids will automatically detect the change in demand and take action to rectify the situation. This may involve controlled islanding of an area by directing the load to different grid areas or voltage or reactive power control (Ahmad & Zhang, 2021). As years pass by, the effects of climate change continue to increase risk to future generations. There is a need to shift to cleaner and greener energy resources and reduce the energy used. The future of controlling our energy consumption lies in smart grids. A smart grid is a modern electricity network that runs on top of the current electricity infrastructure, enabling two-way communication and computer processing technology to generate, transmit, distribute, and consume electricity.

VII. CHALLENGES AND OPPORTUNITIES

The implementation of IoT for climate adaptation faces significant technological challenges, including the development of new sensors and sensor networks, improving the accuracy of climate monitoring and prediction, and enhancing decision support systems. Effective climate adaptation requires access to diverse data forms, often lacking precision or relevance, such as soil moisture levels influencing agricultural practices. Advanced IoT can autonomously monitor multiple parameters in real time, facilitating informed decision-making. However, this requires extensive data and sophisticated systems to evaluate possible actions. Challenges extend to managing invasive species like water hyacinths by altering environmental conditions to hinder their survival, showcasing the need for robust, data-driven adaptive management strategies. Developing these technologies is crucial for enhancing climate adaptation efforts, necessitating significant advancements in data accessibility and analytical capabilities.

A. Technological Challenges

Climate change and variability is a global problem, but the effects are not uniform. Nigeria is one of the countries most affected by climate change (Im et al., 2021). Future climate scenarios suggest that the mean annual temperature will increase throughout Nigeria, accompanied by more hot days and fewer cool days. The magnitude of the temperature increase is expected to be larger inland compared to the coastal areas (Murphy et al., 2021). The Intergovernmental Panel on Climate Change (IPCC), in its third assessment report (TAR), predicts a temperature increase of between 1°C and 3°C in the 2010s and 2020s, with lower increases in the coastal regions (Brouillet & Sultan, 2023). This temperature increase will and is already having significant effects on the health and well-being of Nigerians. Temperature increases will likely increase the range and transmission rates of infectious diseases such as malaria, a significant public health problem in Nigeria (Alemayehu et al., 2022). It is also likely to increase heat stress and mortality from extreme events.

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B. Policy and Regulatory Challenges

The Energy Commission proposes that Nigeria cut a minimum of 5% greenhouse gas emissions between 2008 and 2020. This is minuscule compared to Nigeria's original international 2006 agreement to reduce emissions by 35% over the same period (Adeoye & Spataru, 2020). There has been very little progress in implementing this change. The Nigerian government currently has an estimated 1172 energy policies distributed across the various ministries. This has caused coordination problems, contradiction, and conflict in the policies (Okubanjo et al., 2020). For example, the Nigerian National Petroleum Corporation (NNPC) has a gas flaring and venting commercialization programme. This program contradicts the Ministry of Environment's stance on eliminating gas flaring in Nigeria (Xiang & Oluduro, 2023). The sheer amount of energy policies makes tracking and evaluating their progress hard; some may become outdated and irrelevant (Khatri et al., 2021). This jumbled policy structure is not favourable for deploying new technologies as there is no clear path or incentive. With no policy changes, the status quo will remain as there is no incentive for energy companies to reach the 35% gas emission reduction target. High-polluting methods will remain cheaper. This would hinder the deployment of clean energy technologies as they are often more expensive than their fossil fuel-burning counterparts. An example is the current method of crude oil processing called "open pit burning". This is oil burning in the open air to assist in refining. It releases large amounts of hydrocarbons, carbon monoxide, and other airborne pollutants that are hazardous to human health and the environment. Measures and policies are needed to phase out and eventually eliminate these harmful methods.

C. Socioeconomic Opportunities

Urbanization can be an opportunity for Nigeria if it is done with proper planning and consideration towards climate change (Adebanji et al., 2022). Developing new urban centres will allow for better infrastructure implementation utilizing modern technology. The smart grid is an electrical grid that utilizes information technology to gather and act on information to improve efficiency. This can benefit urban centres, and the development of the smart grid can coincide with the buildup of new urban areas in Nigeria (Abdulsalam et al., 2023). The smart grid is highly flexible and can be implemented in stages during urban development to ensure cost efficiency (Zubairu, 2020). Step-by-step implementation can benefit Nigeria in that costs can be spread out, and funding can come from different sources, from personal sector investment combined with foreign aid and investment (Antwi-Afari et al., 2021).

Nigeria has high socioeconomic opportunities due to its large population and rapidly growing economy. Most of Nigeria's population resides in rural regions and is highly dependent on agriculture. Climate change is predicted to lead to increased drought and desertification in the northern regions, offset by increased rain and flooding in the southern regions. Increased CO2 levels will likely have a fertilization effect and increase agricultural productivity in Nigeria. In response to climate change, Nigeria will need to urbanize sustainably. This will involve moving people out of regions affected by climate change and into new or existing urban centres.

VIII. CONCLUSION

Nigeria, located on the southern edge of the Sahara in the Sahel belt, faces significant vulnerabilities due to its climate, which ranges from arid in the north to equatorial in the south. Small shifts in precipitation can lead to major impacts, including increased droughts that threaten traditional livelihoods and prompt migrations, potentially causing conflicts over land. Moreover, the expectation of more frequent and intense extreme weather events like floods and droughts poses immediate challenges. Africa's overall susceptibility to climate change is exacerbated by factors such as widespread poverty, underdeveloped institutions, and environmental degradation. These conditions are likely to drive poverty and impact health, agriculture, food security, and economic development across the continent by 2030.

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