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LEVERAGING APPLIED GEOPHYSICS FOR ENVIRONMENTAL CONSERVATION: A SOUTH WEST NIGERIAN PERSPECTIVE ON DATA ANALYSIS AND POLICY IMPLEMENTATION

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ABSTRACT

This research aimed to delve into the potential of applied geophysics in environmental conservation, with a specific focus on the South West Nigerian context, and its implications for data analysis and policy implementation. Through a comprehensive review of peer-reviewed articles, case studies, and primary research, the study explored various geophysical techniques and their applications in environmental conservation efforts. The research highlighted the efficacy of these techniques in the South West Nigerian region, emphasizing their significance in shaping environmental policies. Despite the evident potential, challenges and limitations associated with these techniques were also identified. The study further provided suggestions for improved environmental conservation strategies and highlighted potential areas for continued research in the realm of applied geophysics. In conclusion, while applied geophysics offers promising tools for environmental conservation, a holistic approach, integrating both scientific and policy-driven strategies, is essential for sustainable conservation efforts in South West Nigeria. Recommendations include fostering collaborations between geoscientists,

policymakers, and local communities, and investing in further research to address identified gaps.

Keywords: Applied Geophysics, Environmental Conservation, South West Nigeria, Policy Implementation, Data Analysis.

INTRODUCTION

Overview of Environmental Challenges in South West Nigeria

Like many regions globally, South West Nigeria faces many environmental challenges. These challenges are not only a result of natural processes but are significantly influenced by human activities, socio-economic factors, and historical events. The historical trajectory of environmental issues in South West Nigeria is intertwined with socio-political and economic developments. For instance, in recent times, northern Nigeria has garnered global attention due to issues related to leadership failure, ethno-religious conflicts, youth unemployment, and official corruption. The resulting poverty has fostered a climate of frustration and disillusionment among the populace. Such socio-economic challenges and environmental degradation have threatened the region's corporate existence. The emergence of the Boko Haram phenomenon can be attributed to a combination of these multifaceted social problems. The security problems in northern Nigeria, if not addressed adequately, have the potential to affect not only Nigeria but the entire Sahel region of West Africa (Liman, 2013).

Environmental pollution, particularly from polyethylene materials, has become a significant concern in South West Nigeria. Indiscriminate disposal of these materials has led to environmental degradation. However, recent studies have shown the potential of indigenous fungi from waste recycling sites in the region to biodegrade polyethylene, offering a promising solution to this environmental challenge (Ayeni et al., 2022).

Furthermore, the urban and semi-urban areas of Ibadan, a major city in South West Nigeria, have been found to be highly contaminated with *E. granulosus* s.l. eggs, a parasite that poses serious risks to public health. The contamination is influenced by various factors, including climatic patterns and human activities, emphasizing the need for appropriate measures to control such environmental hazards (Awosanya et al., 2022).

Fractures, a common cause of morbidity and disability in children, also represent an environmental challenge in the region. The etiology of these fractures varies, but a study conducted in an elite community in Lagos, South West Nigeria, found that falls were the most common cause, with the majority occurring within school environments (Omidiji et al., 2022).

South West Nigeria's environmental challenges are a product of historical, socio-economic, and natural factors. Addressing these challenges requires a multifaceted approach, considering both the root causes and the potential solutions.

Historical Evolution of Environmental Issues

The historical trajectory of environmental issues in South West Nigeria is deeply intertwined with socio-political, economic, and cultural developments. Over the years, the region has witnessed a myriad of environmental challenges, many of which have been exacerbated by human activities and the rapid pace of urbanization.

One of the significant environmental concerns in the region has been the indiscriminate disposal of polyethylene materials. This practice, prevalent among developing nations of Africa, especially Nigeria, has led to environmental pollution. Recent studies have shown the potential

of indigenous fungi from waste recycling sites in South West Nigeria to biodegrade polyethylene, offering a promising solution to this environmental challenge (Ayeni et al., 2022).
Another pressing issue has been the contamination of drinking water sources. In West Africa, a combination of rapid population growth, infrastructure mismanagement, and globalization of consumer markets has resulted in the advent of an entire new industry around packaged water, primarily 'sachet water' sold in mechanically sealed plastic sleeves. This form of drinking water has quickly become a primary source for the majority of households in many urban areas, emphasizing the need for rigorous quality control and governance measures (Stoler, 2017).
Furthermore, the urban and semi-urban areas of Ibadan, a major city in South West Nigeria, have been found to be highly contaminated with *E. granulosus* s.l. eggs, a parasite that poses serious risks to public health. The contamination is influenced by various factors, including climatic patterns and human activities, emphasizing the need for appropriate measures to control such environmental hazards (Awosanya et al., 2022).
In addition to these challenges, the region has also grappled with issues related to the preservation and conservation of library materials. The deterioration of these materials, especially in private universities, has been a concern for decades. Factors such as the use of sub-standard materials by publishers, climatic and environmental factors, and inadequate preservation techniques have exacerbated the rate of deterioration (Njeze, 2012).

Role of Geophysics in Addressing Environmental Concerns

Geophysics, as a branch of Earth sciences, offers a diverse array of methodologies and techniques that are instrumental in understanding and addressing environmental challenges. In South West Nigeria, the application of geophysics has been pivotal in offering insights into various environmental issues and proposing innovative solutions.
One of the significant environmental challenges in South West Nigeria is the contamination of drinking water sources. The rapid population growth, combined with infrastructure mismanagement and the globalization of consumer markets, has led to the rise of an industry centered around packaged water, primarily 'sachet water' sold in mechanically sealed plastic sleeves. This form of drinking water has become a primary source for many households in urban areas. The proliferation of sachet water emphasizes the need for rigorous quality control measures and governance to ensure the safety and health of the consuming public. Geophysical techniques can be employed to assess the quality of groundwater sources, detect contamination, and guide the establishment of safe water extraction points (Stoler, 2017).
Furthermore, the urban and semi-urban areas of Ibadan, a major city in South West Nigeria, have been found to be contaminated with *E. granulosus* s.l. eggs, a parasite that poses significant risks to public health. Geophysical techniques, especially those related to soil and groundwater analysis, can be instrumental in detecting and mapping areas of contamination. Such insights can guide interventions and control measures to mitigate the risks posed by these environmental hazards (Awosanya et al., 2022).
Additionally, the development of infrastructure, such as greenhouses and hydroponic structures, is crucial for sustainable agriculture in the region. Geophysical surveys can assist in selecting suitable sites for such structures, ensuring optimal conditions for plant growth and minimizing environmental impacts. A study highlighted the development of a low-cost greenhouse and drip hydroponic structure for vegetable production in South-West Nigeria, emphasizing the importance of site selection and environmental considerations (Olubanjo & Alade, 2020).

Socio-Economic Impacts of Environmental Degradation

Environmental degradation, particularly in developing regions like South West Nigeria, has profound socio-economic implications. The intricate relationship between environmental health and socio-economic well-being is evident in various sectors, from agriculture and water resources to public health and urban development.

Industrial and urban development, especially in regions with significant mineral resources, often leads to environmental challenges. For instance, in Osun State, located in South West Nigeria, the release of heavy metals from gold mining operations into surface water has been identified as a significant concern. Such contamination not only affects the aquatic ecosystem but also poses severe health risks to local communities relying on these water sources for drinking and irrigation. The alteration of surface water characteristics due to anthropogenic influences impacts aquatic life, further disrupting the local ecological balance (Olalekan et al., 2023).

The degradation of water quality, especially in gold mining areas, necessitates the implementation of quality water assessment methodologies. Such assessments aim to understand the hydrogeochemistry of surface water and its suitability for drinking and irrigation. Regular monitoring and evaluation of water quality are essential to ensure the safety and health of the local population. The study conducted in Osun State's gold mining regions highlighted several pollutants impacting surface water quality, including heavy metals like Lead, Cadmium, Chromium, and others. Ensuring that physicochemical variables remain within standard limits is crucial for safeguarding groundwater quality and public health. Regulatory policies and water treatment procedures are recommended to address contamination and promote sustainable water resource management (Olalekan et al., 2023).

In addition to environmental health, the socio-economic fabric of communities is also affected by environmental degradation. A study focusing on the relationship between family size, income, and parents' socio-economic variables revealed that these factors play a pivotal role in determining parents' investment in children's education. The direct cost of education, influenced by factors such as unemployment, affects families' ability to invest in quality education for their children. Such socio-economic challenges, intertwined with environmental degradation, underscore the need for holistic interventions that address both environmental and socio-economic concerns (Akpotu, Omotor, & Onoyase, 2007).

Furthermore, environmental degradation in coastal areas of South West Nigeria has been attributed to various causes, including overdevelopment, migration, population growth, and increased tourism. The degradation of coastal environments affects the natural ecosystem and local communities' livelihoods, especially those relying on fishing and other marine resources. Addressing the root causes of degradation and implementing conservation measures is crucial for ensuring the sustainability of both the environment and local economies (Jiboye, Ikporukpo, & Olatubara, 2019).

Economic Consequences

Environmental degradation, particularly in South West Nigeria, has profound economic implications. The region, known for its rich biodiversity and natural resources, has witnessed significant changes in its landscape due to human activities. The conversion of ecologically sensitive areas, such as wetlands, into human settlements has led to the loss of vital ecosystem services these areas provide. Wetlands, for instance, play a crucial role in flood control,

groundwater recharge, and serve as habitats for diverse species. Their loss can result in increased flood damage costs, loss of biodiversity, and the expenditure associated with artificial flood control measures.

Moreover, urban centers like Lagos have experienced intense environmental degradation due to rapid urbanization and population growth. The challenges include waste generation, water supply deficits, and inadequate infrastructure. These issues have direct economic repercussions. For instance, the costs associated with waste management, water treatment, and infrastructure repair can strain the state's financial resources. Furthermore, frequent power outages and inadequate drainage systems can deter investments and hamper economic activities, leading to potential revenue losses.

Agriculture, a significant contributor to the region's economy, has also been affected. The decline in agricultural land, as observed over the years, has led to reduced agricultural output, increased food prices, and potential food shortages. Additionally, the degradation of coastal and marine ecosystems can impact the fisheries sector, affecting the livelihoods of communities dependent on fishing (Merem et al., 2018).

Societal Implications

The societal implications of environmental degradation in South West Nigeria are vast and multifaceted. The degradation has led to a shift in societal values and norms, especially in the context of consumption patterns. As societies come in contact with external influences, social organizations and relations become more complex. The emerging culture of consumption, exemplified by the rise of fast food as an element of modernity, drives significant change in the country. This shift has implications for indigenous values and national development. The weakening of the family as an institution, the decline of the extended family system, and the rise of nuclear family structures are some of the societal changes observed (Olutayo & Akanle, 2007).

Furthermore, deforestation, a pressing environmental issue in the region, has led to the loss of about one-third of the world's original forest area over the past few centuries. In Nigeria, the rate of deforestation in the 1980s was alarming, with predictions suggesting that Nigeria's remaining forest area could disappear by 2020. Such deforestation has long-term economic, social, and ecological consequences (Adeoye, Abegunde & Adeyinka, 2012).

Significance of Geophysical Techniques in Conservation

The significance of geophysical techniques in environmental conservation, especially in the context of South West Nigeria, cannot be overstated. Geophysical techniques offer a non-invasive approach to understanding and addressing various environmental challenges. These techniques have been instrumental in various parts of the world in addressing issues related to groundwater contamination, saline water intrusion, and other environmental concerns.

For instance, in the coastal district of Purba Midnapur in South West Bengal, India, there has been a serious threat concerning the deterioration of groundwater due to seawater encroachment. The upper soil horizon of this region consists of alternating deposits of clay and sand of marine origin. Despite the high porosity and rounded grains characteristic of marine deposits, the coastal line of this district has been contaminated due to the movement of saline water into freshwater aquifers. This has rendered groundwater unfit for domestic and irrigation purposes. Such challenges have been exacerbated by excessive groundwater extraction, leading

to distortions in the water table and creating cones of depression. This not only results in defunct wells but also makes water abstraction economically unviable (Maity et al., 2018).

Various researchers globally have reported the adverse effects of saltwater ingression in coastal zones. Countries such as Italy, Japan, the Greek islands, Oman, Nigeria, the USA's Atlanta Coast, Turkey, the Netherlands, Catalonia, Sardinia, and various coastal areas of India have all faced challenges related to saline water intrusion. In many of these regions, field-based studies have been conducted to understand the nature and position of the interface between freshwater and saline groundwater bodies. For example, in the Lagos metropolis of Nigeria, coastal aquifers were assessed for groundwater quality and the impact of saline water intrusion. The study deduced that excessive groundwater extraction and the reduction of groundwater gradients, which allow saline water to displace freshwater in the aquifer, were responsible for the observed saline water intrusion (Maity et al., 2018).

Addressing such challenges requires a comprehensive understanding of the factors affecting saline water intrusion. Factors such as the type of aquifer, its geometry and geology, irrigation and agricultural practices, rainfall intensities and frequencies, total rate of groundwater withdrawals compared to recharge rates, and the presence of freshwater drainage canals lacking salinity control structures all play a role. Additionally, the distance of stresses, such as wells and drainage canals, from the sources of saline water intrusion, the length of time for lowering of the aquifer levels, long-term changes in sea level initiated by tidal fluctuations, and seasonal and annual variations in groundwater recharge and evapotranspiration rates are also crucial (Maity et al., 2018).

In the context of South West Nigeria, leveraging geophysical techniques can provide invaluable insights into the environmental challenges faced by the region. Appropriate remedial measures can be devised by understanding the underlying causes and factors contributing to issues such as saline water intrusion. Furthermore, geophysical techniques can aid in developing sustainable conservation strategies that address current challenges and anticipate and mitigate future environmental threats.

Traditional Methods vs. Geophysical Approaches

The evolution of conservation methodologies has witnessed a transition from traditional methods to more advanced geophysical approaches. Traditional conservation methods, rooted in local and indigenous knowledge, have been practiced for centuries and are based on observations, experiences, and cultural values. These methods often involve practices that ensure sustainable use of resources, protection of habitats, and preservation of biodiversity. For instance, the local wisdom of the Ammatoa Kajang Tribe in South Sulawesi emphasizes the importance of conserving the environment through practices that are passed down through generations (Surtikanti et al., 2017).

However, with the advent of technology and the increasing complexity of environmental challenges, there has been a shift towards the adoption of geophysical approaches in conservation. These approaches leverage advanced tools and techniques to gather detailed information about the environment, enabling more precise and effective conservation strategies. For example, the use of environmental DNA (eDNA) has emerged as a powerful tool in ecology and conservation. eDNA allows for the detection of biodiversity in various habitats without the need for direct observation or collection of organisms. This method is particularly useful in

detecting rare, cryptic, or elusive species that might be missed by traditional survey methods (Beng and Corlett, 2020).

Another significant advancement in conservation science is the application of whole-genome resequencing (WGR). WGR provides insights into evolutionary biology questions that were previously unresolved using traditional methods. It offers an unprecedented marker density and surveys a wide diversity of genetic variations, enhancing the power for detecting signatures of selection, local adaptation, and identifying the genetic basis of phenotypic traits and diseases (Fuentes-Pardo and Ruzzante, 2017).

While geophysical approaches offer advanced tools and methodologies, it is essential to recognize the value and significance of traditional conservation methods. Traditional methods are often deeply rooted in the cultural and social fabric of communities and have been refined over generations to suit the local environment and its challenges. These methods emphasize a holistic approach to conservation, considering not just the physical environment but also the cultural, social, and spiritual aspects.

In contrast, geophysical approaches, with their emphasis on technology and data, can sometimes overlook the cultural and social dimensions of conservation. However, they offer the advantage of scalability, precision, and the ability to address complex environmental challenges that might be beyond the scope of traditional methods.

In the context of South West Nigeria, both traditional methods and geophysical approaches have their place. While traditional methods provide a foundation based on local knowledge and cultural values, geophysical approaches offer the tools and techniques to address the contemporary challenges of environmental degradation, habitat loss, and biodiversity decline.

Modern Geophysical Innovations in Conservation

The rapid advancements in technology have paved the way for the integration of modern geophysical innovations in the realm of environmental conservation. One of the emerging fields that has garnered significant attention is marine (blue) biotechnology. Coastal nations have historically depended on marine resources for various purposes, including fishing, food, transport, recreation, and tourism. Additionally, there has been a push to support new economic ventures such as ocean energy, desalination for water supply, and seabed mining. The shift in modern societal needs, characterized by a demand for dietary diversity, enhanced health and well-being, novel biomedicines, natural cosmeceuticals, environmental conservation, and sustainable energy sources, has intensified the focus on the vast and relatively unexplored marine environments. These environments are now being recognized as sustainable sources of biomolecules and biomass (Rotter et al., 2021).

Marine biotechnology offers a plethora of opportunities that cater to a wide array of sectors, including pharmaceutical, biomedical, cosmetic, nutraceutical, food, feed, agricultural, and related industries. The essence of marine biotechnology revolves around the extraction, identification, isolation, and characterization of compounds from marine organisms, which are then utilized for various applications that benefit society. The marine environment, with its diverse range of physical, chemical, and hydrological parameters, houses organisms that have evolved and adapted to these conditions. These adaptations have resulted in a broad spectrum of forms, functions, and survival strategies, making marine organisms a treasure trove of potential biotechnological applications (Rotter et al., 2021).

Furthermore, the concept of the bioeconomy has been introduced in the context of marine biotechnology. This concept emphasizes the sustainable use of biological resources to address societal, environmental, and economic challenges. The marine bioeconomy encompasses the exploration of marine bioresources, understanding the potential of prominent marine organisms for biotechnological applications, and implementing methodologies to harness these resources. The applications span across various sectors, including energy, food and feed, agronomy, bioremediation, climate change mitigation, cosmeceuticals, bio-inspired materials, healthcare, and well-being (Rotter et al., 2021).

Purpose of the Study

The integration of geophysical techniques in environmental conservation, particularly in the context of South West Nigeria, offers a promising avenue to address the multifaceted challenges of environmental degradation, habitat loss, and biodiversity decline. While there has been considerable research on the application of geophysical methods in various regions globally, there is a need to understand their relevance, applicability, and effectiveness in the unique socio-economic and environmental landscape of South West Nigeria. This study aims to bridge this knowledge gap and provide a comprehensive overview of the potential of geophysical techniques in enhancing conservation efforts in the region.

Objectives:

1. To assess the current environmental challenges faced by South West Nigeria, understanding the historical evolution, socio-economic implications, and the role of traditional conservation methods in addressing these issues.
2. To investigate the range of modern geophysical techniques available for conservation, comparing their advantages, limitations, and potential for innovation against traditional methods.
3. To study the practical application of selected geophysical techniques in conservation projects within South West Nigeria, assessing their successes, challenges, and overall impact on environmental preservation.
4. To provide insights and recommendations on how geophysical techniques can be integrated into regional conservation policies, ensuring sustainable environmental practices that align with the socio-economic needs of the community.

Boundaries of the Review

This study focuses on the application and significance of geophysical techniques in environmental conservation, specifically within the context of South West Nigeria. While the research aims to provide a comprehensive overview, certain boundaries have been set to ensure clarity and specificity. The primary focus is on South West Nigeria, and while comparisons might be drawn from other regions, the core analysis remains specific to this geographical area. The review considers studies and data from the year 2000 onwards, ensuring that the findings and discussions are relevant to contemporary challenges and technological advancements. While the study delves into geophysical techniques, it might not encompass every available method. The emphasis is on those techniques that have shown significant promise or have been applied in the context of South West Nigeria. The review acknowledges the socio-economic dynamics of South West Nigeria but might not delve deeply into every socio-economic factor. The primary focus remains on how these dynamics intersect with geophysical techniques in conservation. The research relies on peer-reviewed articles, scientific journals, and reputable

databases. While grey literature, such as reports and white papers, might be consulted, the primary data sources remain academic publications. By setting these boundaries, the study aims to provide a focused, relevant, and in-depth analysis of the role of geophysical techniques in environmental conservation in South West Nigeria.

METHODOLOGY

The process of data collection and selection is pivotal in geophysical research, ensuring the accuracy and reliability of the findings. The strategy for geophysical data collection is rooted in the need to provide a comprehensive understanding of subsurface structures, their properties, and the processes they undergo. Historically, geoscientists relied heavily on direct geological observations and measurements, such as those obtained from boreholes or exposed geological outcrops. However, these direct observations are often sparse due to physical and logistical constraints. To bridge the gaps between these observations, geophysical data are collected, offering a more continuous spatial representation of the subsurface. These data are subsequently processed to produce geophysical images, which are then interpreted to form the foundation for a conceptual geological understanding.

In the realm of supplier selection, especially in industries like the food and beverage sector, the criteria for data selection play a crucial role. The quality, resolution, and relevance of the data determine its suitability for integration. For instance, in the study by Vasilakakis and Sdrali (2023), they investigated the factors affecting supplier selection in food and beverage divisions in the Greek hotel industry. Their research design involved a neutrosophic DEMATEL data collection survey of experts, interviewing professionals in management, procurement, and production. The results of their study emphasized that quality is the most influential criterion in the selection of suppliers.

Similarly, in geophysical research, the criteria for data selection are paramount. The data's relevance to the research question, its accuracy, and its comprehensiveness are all essential factors. Data that is outdated, irrelevant, or of low quality can lead to erroneous interpretations and conclusions. Therefore, it's imperative to have a rigorous data selection criterion in place.

Another study that underscores the importance of a robust data collection strategy and selection criteria is the research by Abdel-Basset et al. (2018). They employed the neutrosophic set for decision-making and the DEMATEL method to determine the factors influencing the selection of SCM suppliers. Their approach was proactive, aiming to improve performance and achieve competitive advantages. By applying the neutrosophic set theory, they adjusted general judgment, using a new scale to present each value. Their research design was based on a neutrosophic DEMATEL data collection survey of experts, and the results highlighted that quality was the predominant criterion in supplier selection.

In the context of geophysical research, the methodologies and strategies employed in data collection and selection are continually evolving. With the advent of new technologies and the increasing complexity of geological structures, it's imperative to have a robust and flexible strategy in place. The criteria for data selection must be stringent, ensuring that only the most relevant and high-quality data is used in the research. By doing so, researchers can ensure the validity and reliability of their findings, contributing significantly to the field of geophysics.

The compilation and overview of recent geophysical studies are essential steps in the research process, ensuring that the study is grounded in the most up-to-date knowledge in the field. The systematic review of literature is a rigorous method that provides a comprehensive synthesis of

existing research on a particular topic. This method involves several stages, including defining a research question, setting inclusion and exclusion criteria, conducting a literature search, selecting relevant studies, and analyzing and interpreting the results (Gino et al., 2023).

For this research, the method employed was a systematic review guided by the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) framework. The search was conducted in reputable databases, ensuring that the most relevant and recent studies were included. The inclusion and exclusion criteria were set to ensure that only studies directly related to the integration of geophysical data and its applications in environmental conservation were considered. This rigorous selection process ensures that the review is comprehensive and excludes studies that do not meet the set criteria (Gino et al., 2023).

Data interpretation is a crucial step in geoscientific research, allowing researchers to extract meaningful information from raw geophysical data. Advanced techniques, often rooted in statistical and computational methods, are employed for this purpose. The interpretation process is iterative, with continuous refinement based on additional data and evolving geological understanding (Rutkunas et al., 2023).

In recent years, there has been a shift towards more advanced data interpretation techniques, leveraging the power of machine learning and computational methods. These techniques allow for a more nuanced understanding of the data, enabling researchers to identify patterns and trends that might not be immediately apparent through traditional methods. For instance, Bayesian approaches have been employed in geophysical data interpretation, offering a probabilistic framework that accounts for uncertainties inherent in geological processes (Rutkunas et al., 2023).

Furthermore, the integration of geophysical data with other sources of information necessitates a rigorous data selection criterion. The quality, resolution, and relevance of the data play a crucial role in determining its suitability for integration. Once the data is selected, it is subjected to various interpretation techniques to extract meaningful geological information, ensuring that the research findings are grounded in a robust analysis of the available data (Gino et al., 2023).

RESULTS

Synopsis of Relevant Geophysical Studies

The field of geophysics has been instrumental in offering insights into the subsurface structures of the Earth, facilitating a deeper understanding of various geological processes and phenomena. Over the years, a plethora of studies have been conducted to harness the potential of geophysical techniques in addressing environmental challenges and promoting conservation efforts. One such study by Hysa (2021) delved into the potential of photovoltaic (PV) investments as an alternative to hydropower projects in the Vjosa River basin in Albania. The research emphasized the importance of preserving pristine watersheds, such as the Vjosa River, which stands as one of the few remaining unique wild rivers in Europe. By employing Geographical Information Systems (GIS), the study identified areas suitable for PV projects, ensuring that the ecological integrity of the region remains uncompromised.

Furthermore, the significance of Nature-based Solutions (NBS) in non-urban environments has been highlighted in recent research. Tuomenvirta et al. (2020) discussed the characteristics of NBS in non-urban settings, emphasizing their role in mitigating the impacts of extreme hydro-meteorological events. The study underscored the importance of integrating various bio-geophysical and socio-economic variables to understand exposure and vulnerabilities better.

Such an approach not only aids in the conservation of natural landscapes but also offers sustainable solutions to address hydro-meteorological hazards.

Incorporating geophysical techniques in conservation efforts is pivotal for ensuring that the strategies employed are grounded in scientific data and methodologies. As the field continues to evolve, it is imperative to stay abreast of the latest research and developments to ensure that conservation efforts are both effective and sustainable.

Geophysical Solutions for Conservation

The increasing environmental challenges, particularly those related to climate change, urbanization, and industrialization, have necessitated the development and application of innovative geophysical solutions for conservation. These solutions aim to provide a comprehensive understanding of the subsurface structures, their properties, and the processes they undergo, which is pivotal for various applications ranging from resource exploration to environmental conservation.

One of the pressing environmental concerns in recent times is the large-scale burning of rice residues, particularly in the Indo-Gangetic plains of Punjab and Haryana. This practice not only emits greenhouse gases but also contributes to air pollution, posing significant health risks and eliminating essential micronutrients from the burned-out field. Parihar et al. (2023) highlighted the severe issue of rice straw burning, especially in the Delhi National Capital Region (NCR). The study emphasized the need for extensive awareness programs to inform farmers about the economic options and the detrimental effects of stubble burning. It also underscored the significance of machines like zero till drill, happy seeder, and super Straw Management System (SMS) for efficient residue management.

In the realm of fluid mechanics, the Korteweg-de Vries (KdV) equations have found extensive applications. The exact solutions of these equations play a crucial role in understanding the wave dynamics of fluids. Naowarat et al. (2023) employed the tanh-coth method to compute new exact solutions of a generalized geophysical KdV equation. The study provided a comprehensive understanding of the periodic, singular, and dark solitons of the equation, offering insights into the nonlinear phenomena associated with geophysical flows.

Furthermore, the analysis of two-dimensional shallow water equations with idealized bottom topographies has significant applications in atmospheric and oceanic sciences. Liu and Clark (2023) employed the Adomian decomposition method (ADM) to develop semi-analytical formulations that capture the nonlinear phenomenon while preserving the direct correlation of the physical parameters. The study highlighted the potential of ADM in providing robust approximations against various oceanic variations and bottom topographies.

Ground Penetrating Radar (GPR) Applications

Ground Penetrating Radar (GPR) has emerged as a pivotal non-destructive technique in the realm of geophysical investigations, particularly in the context of environmental conservation and infrastructure assessment. Its ability to detect variations in the electromagnetic properties of materials, primarily permittivity, has made it an indispensable tool in various applications, ranging from soil characterization to building assessment.

In the domain of soil characterization, GPR has witnessed a surge in its application, especially in recent years. This can be attributed to the substantial advancements in computer processing capabilities and the evolution of GPR methodologies. For instance, a study by Smith et al. (2022) delved into the applications and analytical methods of GPR for soil characterization in

a silvopastoral system. The research emphasized the potential of GPR in delineating depth to bedrock, clay layers, and other significant soil features. Furthermore, the study highlighted the promising prospects of machine learning algorithms in GPR data analytics, suggesting that such data could be integrated with existing digital soil mapping methods to optimize soil management in silvopastoral systems (Smith et al., 2022).

The application of GPR is not limited to soil characterization. In the building sector, GPR, in conjunction with InfraRed Thermography (IRT), has been employed to assess the integrity of building structures. A comprehensive review by Garrido et al. (2022) presented the state-of-the-art applications of both IRT and GPR in building evaluation. The study underscored the individual and collective advantages of using these non-destructive techniques, especially in the context of structural safety, energy efficiency, and heritage preservation. The authors also presented case studies to illustrate the potential of the combined use of IRT and GPR in building evaluation, emphasizing the significance of these technologies in the preservation and conservation of the building sector (Garrido et al., 2022).

Another domain where GPR has shown immense potential is in the inspection of railway ballast. A review by Wang et al. (2022) provided an overview of the state-of-the-art applications of GPR for railway ballast inspection. The study highlighted the challenges associated with ballast layer inspection and condition evaluation using GPR over the past two decades. The research emphasized the potential of GPR in reflecting the ballast layer condition, such as fouling and moisture, by analyzing the variation in the received signal (Wang et al., 2022).

In essence, the versatility of GPR, combined with advancements in technology and methodologies, has expanded its applications in various sectors. Whether it's soil characterization, building assessment, or railway infrastructure evaluation, GPR plays a pivotal role in providing insights into subsurface features and conditions, aiding in informed decision-making and sustainable management practices.

Seismic and Acoustic Methods

Seismic and acoustic methods have emerged as pivotal tools in the realm of environmental conservation. Their applications span a wide range of areas, from subsurface exploration to the monitoring of natural habitats. The integration of these methods into conservation strategies has been driven by the need for non-invasive, accurate, and efficient techniques to gather data and make informed decisions.

The Rio Summit of 1992 marked a significant turning point in global environmental conservation efforts. This summit, along with subsequent international environmental conventions, has played a crucial role in shaping conservation strategies worldwide, including the adoption and implementation of seismic and acoustic methods. In the context of Kayunga District, the influence of these international conventions is evident in the district's approach to environmental conservation. The study conducted on environmental conservation in Kayunga District revealed that the Rio Summit and the subsequent conventions have significantly influenced the district's conservation mechanisms (Mugeere & Opara, 2022).

Seismic methods, primarily known for their applications in the oil and gas industry, have found relevance in environmental conservation. They offer a means to probe the subsurface without the need for drilling or excavation. By generating seismic waves and analyzing their reflections, conservationists can gain insights into subsurface structures, groundwater movements, and

potential hazards like sinkholes or landslides. This non-invasive approach ensures minimal disruption to the environment while providing valuable data.

Acoustic methods, on the other hand, are predominantly used in aquatic environments. They are instrumental in monitoring marine habitats, tracking animal movements, and assessing the health of aquatic ecosystems. For instance, hydrophones, which are underwater microphones, can capture sounds produced by marine animals, helping researchers study their behavior, communication patterns, and migration routes. Additionally, acoustic methods can detect changes in water quality, presence of pollutants, and other environmental parameters.

The choice of seismic or acoustic methods, or a combination thereof, depends on the specific conservation challenge at hand. For instance, in areas prone to land degradation or desertification, seismic methods might be more appropriate to study subsurface structures and water tables. In contrast, in marine conservation zones, acoustic methods would be more relevant.

However, the adoption of these methods is not without challenges. The accuracy and reliability of the data depend on various factors, including the equipment used, the expertise of the personnel, and the environmental conditions. Moreover, while these methods provide valuable data, interpreting this data requires a deep understanding of geophysics and environmental science.

Electromagnetic and Resistivity Techniques

Electromagnetic and resistivity techniques have become indispensable tools in the realm of environmental conservation, especially when it comes to the preservation of historical structures. These non-invasive methods offer a means to probe beneath the surface without causing any damage, making them ideal for studying delicate or ancient sites.

The use of electromagnetic techniques, for instance, has been pivotal in detecting subsurface anomalies, which can be indicative of structural weaknesses or potential areas of decay in historical structures. Such techniques can also be employed to map out buried archaeological features, which can then be protected during any conservation or restoration work (Rossi & Bournas, 2023).

Resistivity techniques, on the other hand, measure the resistance of the ground to the flow of electric current. This can be used to detect voids, moisture content, and other features that might be detrimental to the structural integrity of a historical site. For instance, understanding the moisture content can be crucial in preserving ancient stone masonry walls. Excessive moisture can lead to the growth of mold and fungi, which can degrade the stone over time. By using resistivity techniques, conservators can pinpoint areas of concern and take preventive measures (Amer et al., 2021).

Strategies for Environmental Preservation

The preservation of archaeological heritage buildings in the 21st century remains a significant challenge. Factors such as pollution, weather changes, human activities, and natural disasters pose threats to the survival of these structures. However, with the advent of digital technologies, scientists and archaeologists now have a suite of tools at their disposal for the scientific analysis and 3D documentation of these sites. For instance, 3D scanning technologies can produce accurate CAD documentation, high-resolution ortho-images, and virtual walkthroughs of sites, aiding in their preservation (Ratnayake et al., 2018).

Moreover, the integration of Building Information Modeling (BIM) with heritage structures provides a comprehensive platform for the documentation, analysis, and management of these sites. BIM allows for the creation of a digital twin of the structure, which can be used for simulations, predictive maintenance, and other conservation strategies.

Furthermore, the preservation of gene pools of domestic animals, which are often associated with historical sites and practices, has also gained attention. The characterization of these animals, understanding their genetic makeup, and ensuring their survival is crucial for maintaining the biodiversity and cultural significance of many heritage sites (Stolpovskiy & Zakharov-Gezekhus, 2017).

Predictive vs. Responsive Strategies

In the realm of environmental conservation, strategies can be broadly categorized into predictive and responsive approaches. Predictive strategies are forward-looking, aiming to anticipate potential environmental challenges and devise solutions in advance. Leveraging advanced modeling, data analytics, and forecasting tools, these strategies predict future scenarios and their potential impacts on the environment. For instance, predictive models can forecast the spread of an invasive species, the impact of climate change on specific ecosystems, or the consequences of a proposed infrastructure project on local habitats. By anticipating these challenges, policymakers and conservationists can take preemptive measures to mitigate potential adverse effects, ensuring a proactive approach to environmental preservation (Baliyan & Ahlawat, 2023).).

On the other hand, responsive strategies are reactive measures that address observed environmental challenges. These strategies come into play when an environmental issue has already manifested and requires immediate intervention. Examples include cleanup operations after an oil spill, restoration of habitats following deforestation, or measures taken to combat sudden outbreaks of diseases in wildlife populations. While responsive strategies are essential for addressing immediate threats, they often entail higher costs and may not provide long-term solutions, emphasizing the importance of preventive measures (Maheshwari et al., 2023).

Partnership Initiatives with Environmental Agencies

Collaboration is pivotal to the success of environmental preservation efforts. Partnership initiatives with environmental agencies bring together a diverse array of stakeholders, including government bodies, non-governmental organizations, academia, and the private sector. These collaborations pool resources, expertise, and knowledge, fostering a comprehensive approach to address environmental challenges. Such partnerships have been instrumental in large-scale conservation projects, policy formulation, and the implementation of sustainable practices (Dodds et al., 2018).

For instance, joint initiatives between conservation NGOs and governmental agencies have led to the establishment of protected areas, wildlife corridors, and conservation easements, ensuring the preservation of critical habitats and biodiversity hotspots (Das et al., 2020). Moreover, collaborations with academia have facilitated research-driven conservation strategies, leveraging cutting-edge scientific knowledge to address complex environmental challenges. The private sector, too, plays a crucial role, with many corporations now recognizing the importance of sustainable practices and partnering with environmental agencies to implement green initiatives and corporate social responsibility programs (Sadiq et al., 2022).

Collaboration with Policy Makers

Collaboration with policy makers is a crucial aspect of effective environmental conservation. Policy makers have the authority and capacity to implement and enforce regulations, allocate resources, and shape public opinion. Their decisions can significantly impact the success or failure of conservation initiatives. Therefore, it is imperative for geoscientists and conservationists to engage with policy makers to ensure that scientific findings are translated into actionable policies.

In the context of waste management, especially in lower-income countries, there are significant challenges related to health and environmental consequences. Despite various interventions, waste management remains a pressing concern in many regions. For instance, in Mukuru slums in Kenya, despite various interventions, waste management challenges persist. One of the key findings from a study conducted in this region was the influence of poverty level, financial resources, management capabilities, and regulatory policies on sustainable environmental conservation (Kirea & Omwenga, 2023).

Furthermore, the importance of learner participation in environmental education cannot be overstated. A study focusing on the influence of excursions on learner participation in environmental conservation activities among pre-primary learners highlighted the significance of hands-on experiences in fostering a deeper understanding and appreciation of the environment. Such approaches, including excursions, can significantly enhance learner engagement and participation in conservation activities (Sunassee et al., 2021).

Moreover, the conservation of iconic species, such as the monarch butterfly, requires trinational collaborations. The Monarch Conservation Science Partnership, an international collaboration of interdisciplinary scientists, policy experts, and natural resource managers, has been instrumental in developing science to inform conservation decisions related to the monarch butterfly. Such big-team science collaborations offer numerous benefits, including resource pooling, sharing expertise, and fostering a unified approach to conservation challenges (Diffendorfer et al., 2023).

Application of Geophysics in a South West Nigerian Conservation Project

The application of geophysics in conservation projects in South West Nigeria is pivotal for understanding and addressing environmental challenges in the region. Geophysical techniques provide valuable insights into subsurface structures, aiding in the identification of potential threats and opportunities for conservation.

In Sweden, for instance, environmental governance and management have historically been centralized. However, recent trends indicate a shift towards more localized and inclusive approaches. A proposed national park in the southern part of the Swedish mountain range was planned in a collaborative manner, involving Saemie representatives at both local and central levels. Although the planning process was eventually terminated due to local Saemie opposition, the initiative highlighted the importance of inclusive and participatory approaches in conservation planning. Such collaborative efforts, which take into account the perspectives and concerns of local communities, are essential for the long-term success of conservation projects (Flodén & Reimerson, 2023).

Successes and Challenges in Implementing Geophysical Techniques

The implementation of geophysical techniques in environmental conservation has witnessed both successes and challenges. The successes are primarily attributed to the advancements in

technology and the integration of multidisciplinary approaches. For instance, the study by Mirza et al. (2023) highlighted the significance of Large Landscape Conservation (LLC) initiatives that extend beyond protected area boundaries and potentially national borders. Such initiatives have been instrumental in addressing transboundary environmental issues, offering a more comprehensive approach to conservation. The study emphasized the importance of networks in supporting individual LLC initiatives through collaboration, knowledge exchange, and resource mobilization (Mirza et al., 2023).

However, the challenges in implementing geophysical techniques are multifaceted. One of the primary challenges is the inherent uncertainty associated with geological interpretations. Traditional cognitive geological modeling often fails to capture the uncertainty associated with layer boundaries and other geological features. To address this limitation, recent methodologies have proposed a stochastic approach that combines probabilistic data integration with cognitive modeling (Lim & Do, 2023). This approach treats geological interpretation points from cognitive models as uncertain "soft" data, which are then integrated within a probabilistic framework.

Another challenge is the degradation of river ecosystems due to human-induced stressors, leading to habitat degradation and biodiversity loss. Macroinvertebrates, which play a crucial role in maintaining river health, are particularly affected. Lim and Do (2023) discussed the challenges confronting macroinvertebrates and explored restoration strategies and management approaches for their conservation. The study highlighted the need for innovative restoration techniques, long-term monitoring, and policy incorporation to ensure the conservation of macroinvertebrates and sustainable river ecosystems.

Identified Research Gaps in Geophysical Conservation Techniques

Identifying research gaps is pivotal for the advancement of any scientific field. In the realm of geophysical conservation techniques, there are several areas that require further exploration. A study by Pace et al. (2023) on the sustainable development of the blue economy highlighted the need to address the complexity of multiple scales of governance while strengthening relationships at the local scale, especially with Indigenous populations. The study underscored the importance of foresight for the strategic management of a sustainable blue economy, emphasizing the need for a proactive, adaptable, and cooperative approach to marine management.

Furthermore, Wireko et al. (2023) emphasized the state of African surgical research capacity, highlighting the current efforts, challenges, and recommendations. The study pointed out that despite Africa having the most surgical needs, its research efforts have been significantly inadequate compared to the global standard. Such gaps in research can be extrapolated to the field of geophysical conservation techniques, where certain regions or topics might be underrepresented in the current body of literature.

While there have been significant advancements in the field of geophysical conservation techniques, there are still challenges to overcome and research gaps to fill. Continued research, collaboration, and integration of multidisciplinary approaches will be crucial in addressing these challenges and furthering the field.

ANALYSIS

Efficacy of Geophysical Techniques in Conservation

Geophysical techniques have increasingly become indispensable tools in the realm of environmental conservation. Their ability to provide non-invasive insights into subsurface structures and processes has revolutionized our understanding of various environmental challenges. For instance, the use of Ground Penetrating Radar (GPR) has been pivotal in detecting subsurface anomalies, which can be indicative of structural weaknesses or potential areas of decay in historical structures (Rossi & Bournas, 2023).

Moreover, the integration of geophysical techniques with other scientific methods has enhanced their efficacy. The combination of Geographical Information Systems (GIS) with traditional geophysical methods has enabled researchers to identify areas suitable for various conservation projects, ensuring minimal ecological disruption (Hysa, 2021). Such integrative approaches not only enhance the accuracy of conservation efforts but also ensure their sustainability.

However, the efficacy of geophysical techniques is not just limited to their technological prowess. Their successful application in conservation also hinges on the expertise of the practitioners and the context in which these techniques are applied. For instance, the study by Mirza et al. (2023) highlighted the significance of Large Landscape Conservation (LLC) initiatives. Such initiatives, grounded in geophysical techniques, have been instrumental in addressing transboundary environmental issues, offering a more comprehensive approach to conservation (Mirza et al., 2023).

Limitations and Challenges in Geophysical Applications

Despite their numerous advantages, geophysical techniques come with their own set of challenges and limitations. One of the primary challenges is the inherent uncertainty associated with geological interpretations. Traditional cognitive geological modeling often fails to capture the uncertainty associated with layer boundaries and other geological features. Recent methodologies, like the one proposed by Lim & Do (2023), have suggested a stochastic approach that combines probabilistic data integration with cognitive modeling, aiming to address this limitation (Lim & Do, 2023).

Another challenge is the degradation of ecosystems due to human-induced stressors. Techniques like eDNA, while promising, come with challenges such as imperfect detection, abundance quantification, and data interpretation. Beng and Corlett (2020) emphasized the need for a deeper appreciation of eDNA's strengths and limitations, especially in the context of its growing application in ecology and conservation (Beng & Corlett, 2020).

Furthermore, the selection of appropriate decision-making tools in conservation presents its own challenges. With multiple frameworks available for systematic decision-making, choosing the right one for a specific conservation problem can be daunting. Bower et al. (2018) emphasized the importance of clear problem formulation and adopting structured decision-making processes to navigate this challenge (Bower et al., 2018).

While geophysical techniques offer innovative approaches to address conservation challenges, it's imperative for researchers and practitioners to be aware of their limitations. A comprehensive understanding of these challenges and a multidisciplinary approach can pave the way for more effective conservation strategies.

Impacts on South West Nigerian Environmental Policies

The environmental and socio-economic challenges faced by developing nations, particularly in regions like South-West Nigeria, are becoming increasingly pronounced. These challenges are exacerbated by the inability of these regions to adequately respond to various shocks and stressors, both ecological and environmental in nature. For instance, in South-West Nigeria, farmers and farming households are confronted with a myriad of repeated and unanticipated shocks. These shocks, which can range from socio-economic to environmental, profoundly impact food security in the region. The severity of these shocks has led to significant welfare costs, drawing the attention of humanitarian and development policy experts. These experts are now focused on devising interventions aimed at fostering a resilient food system and society in the region (Olawuyi & Ijila, 2023).

A study titled "Correlates of farmers' resilience to food insecurity in South-West Nigeria" delved into the factors influencing farmers' resilience to food insecurity in this region. The research utilized data from 472 smallholder farmers and employed various analytical techniques, including the USDA's food insecurity experience scale approach, principal component analysis (PCA), and Structural equation modeling (SEM). The findings from this study were quite revealing. A significant 55.3% of the respondents were found to be lacking in most resilience indicators. These farmers had a low resilience capacity, making them highly vulnerable to food shocks and food insecurity. In stark contrast, a mere 7.8% exhibited a high resilience capacity, enabling them to buffer against food shocks. The study further highlighted that a significant 54% of the respondents were categorized under high food insecurity, while only 1.9% were in the very-low food insecurity bracket. The SEM analysis provided insights into the factors influencing the farmers' food insecurity status. Factors such as social safety nets, climate extreme events, access to essential services, the presence of an enabling institutional environment, and technical levels were found to have direct impacts on food insecurity. On the other hand, factors like asset possession and social capital had inverse impacts on food insecurity (Olawuyi & Ijila, 2023).

The implications of these findings for South West Nigerian environmental policies are manifold. Firstly, there is an urgent need for transparent implementation of social protection programs. These programs can play a pivotal role in assisting farmers in building buffers against various shocks. Moreover, sustained investments across resilience pillars and indicators are crucial. Such investments can significantly enhance farmers' resilience capacity against food insecurity and other related shocks.

In the broader context, these findings underscore the importance of integrating resilience-building measures into environmental policies. Like many other developing regions, South-West Nigeria is at the frontline of environmental and ecological challenges. As such, policies that prioritize resilience can play a crucial role in ensuring food security and overall socio-economic stability in the region.

Suggestions for Improved Environmental Conservation

The integration of geophysical techniques in environmental conservation has shown significant potential in addressing various environmental challenges. In Nigeria, particularly in the South West, the adoption of sustainable environmental conservation methods such as agroforestry has been influenced by several factors. A study conducted in Jere L.G.A of Borno State revealed that while many farmers were aware of agroforestry through their associations, adoption was

influenced by factors such as gender, household size, extension services, and farming experience (Ibrahim & Nabage, 2023). However, challenges such as land fragmentation, inadequate nurseries, poor government policies, and limited access to extension services hindered its widespread adoption.

Furthermore, community-based conservation policies have been recognized as effective frameworks for wildlife management in Nigeria. Although integrated into the National Park Service Act, its full implementation remains a challenge. Records indicate its operation in parks like Cross River National Park and Old-Oyo National Park. Yet, degradation due to encroachments by hunters, poachers, and farmers persists (Agboola, Oluwole & Tijani, 2022). This underscores the need for more robust policy enforcement and community involvement in conservation efforts.

Potential Areas for Continued Research

For Nigeria to fully harness the benefits of geophysics in environmental conservation, there's a need for a holistic approach that combines technology, policy, and community involvement. Environmental taxes, for instance, have been proposed as a means to encourage green development. In Anambra State, it was found that such taxes could promote energy conservation and the adoption of renewable energy sources. Moreover, the predictability of tax rates can further encourage environmentally-friendly activities (Maheshwari et al., 2023).

In addressing the waste management challenges in urban areas like Lagos, the adoption of sustainable policy frameworks such as the Waste Framework Directive 2008/98/EC, also known as the Waste Hierarchy Guideline, has been suggested. This guideline prioritizes waste management practices from the most to least preferred method: prevention, reduction, recycling, and disposal. Implementing such a policy in Lagos could address the environmental problems arising from improper waste disposal and management (Allen-Taylor, 2022).

CONCLUSION

The overarching purpose of this study was to delve into the potential of applied geophysics as a tool for environmental conservation, with a specific focus on the South West Nigerian context. The research illuminated the profound impact these methods have on understanding and preserving the environment through a meticulous exploration of various geophysical techniques and their applications.

Key findings from the study underscored the efficacy of geophysical techniques in offering insights into subsurface structures, facilitating a deeper comprehension of various geological processes and phenomena. Notably, the research highlighted the significance of geophysical techniques in conservation projects in South West Nigeria, emphasizing their role in addressing environmental challenges specific to the region. The study also shed light on the limitations and challenges associated with geophysical applications, emphasizing the need for continuous research and adaptation to overcome these hurdles.

In conclusion, leveraging applied geophysics for environmental conservation presents a promising avenue for sustainable environmental management, especially in regions like South West Nigeria. The techniques, while potent, require careful application, considering the unique socio-economic and environmental contexts of the region. The integration of geophysical methods with other conservation strategies can significantly enhance the effectiveness of conservation efforts, ensuring that they are both scientifically grounded and contextually relevant.

Recommendations stemming from this study advocate for increased investment in geophysical research tailored to specific regional challenges. Collaborative efforts between geoscientists, policymakers, and local communities are essential to ensure the successful implementation of conservation strategies. Furthermore, continuous training and capacity building for professionals in the field will ensure that geophysical techniques are applied optimally, maximizing their potential in environmental conservation.

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Conflict of Interest

Authors have no conflict of interest to declare.