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Assessment of Groundwater Resource Potential and Long-Term Sustainability in Abavo Agricultural Farmland through Geophysical Techniques

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Abstract: ***This research aimed to assess the groundwater capacity and long-term viability within the Abavo agricultural region using geophysical techniques, notably Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR). Addressing the pressing need for accurate methodologies in evaluating groundwater in agricultural contexts, the study merged quantitative geophysical data with qualitative feedback from stakeholders. Results highlighted significant variations in underground geological structures, pointing to potential aquifers crucial for irrigation, farming yield, and environmental conservation. The study underscores the importance of informed groundwater management strategies, offering insights into groundwater hydrology, agricultural sustainability, and environmental conservation. Future research avenues include a deeper exploration of groundwater dynamics, socio-economic implications, and policy considerations in similar agricultural landscapes, fostering interdisciplinary synergy for sustainable water resource management.***

Keywords: Agricultural, Assessment, Conservation, Geophysical, Groundwater, Hydrology, Irrigation, Management, Sustainability, Techniques.

1. INTRODUCTION

The agricultural acreages in Abavo significantly depend on groundwater for irrigation. Therefore, it is vital to comprehend the potential and sustainability of groundwater in order to ensure long-term agricultural productivity and environmental protection. Groundwater is crucial in the Earth's hydrological cycle, supporting ecosystems and human activities, especially agriculture (Giupponi, 2017; Okwagi et al., 2019). This study uses geophysical methods to evaluate groundwater resources' capacity and long-term viability in Abavo. This will involve analyzing the underground hydrogeological conditions, identifying potential

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groundwater storage areas, and assessing the practicality of using groundwater for agricultural activities in a sustainable manner (El-Meselhy et al., 2020; Molua & Emagbetere,2005; Abu-Bakr,2020).

The importance of this work is in its potential to make valuable contributions to both the practical and theoretical elements of groundwater management and agricultural sustainability. The results provide valuable insights for shaping policies and making decisions on managing water resources, thereby promoting more effective and environmentally friendly agricultural methods. In theory, the research enhances our comprehension of the intricate interplay between surface and subsurface hydrological processes, adding to the broader domain of hydrogeology and environmental science.

The literature needs comprehensive hydrogeological assessments utilizing sophisticated geophysical techniques in specific agricultural districts such as Abavo (Kayode et al., 2021; Amos-Uhegbu, 2012). Current research frequently emphasizes broader regional evaluations or relies on restricted data sources, missing the specificity and comprehensiveness needed for well-informed decision-making at the local level. This research addresses the knowledge gap by comprehensively analyzing a specific location. This study's findings can serve as a blueprint for other agricultural regions encountering issues linked to groundwater.

To summarize, studying groundwater potential and sustainability in the Abavo agricultural area using geophysical techniques has important implications for sustainable agriculture, environmental preservation, and scientific progress (Aykut, 2021; Molua et al., 2023a). This research enhances the current knowledge by filling in the gaps in the available literature and offering practical insights. As a result, it contributes to a comprehensive understanding of groundwater systems and their significance in sustaining agricultural productivity and resilience.

Prior groundwater evaluation and control research has predominantly concentrated on hydrological modeling, remote sensing methodologies, and geophysical approaches. These approaches have played a significant role in advancing techniques and systems for evaluating and controlling groundwater resources. Nevertheless, their suitability for particular agricultural regions such as Abavo is restricted, emphasizing the necessity for site-specific research that considers the studied area's distinct hydrogeological and socio-economic characteristics. This study aims to address this deficiency by utilizing sophisticated geophysical methods to evaluate the capacity of groundwater and provide guidance for sustainable management strategies specifically designed for the distinct attributes of the study region. This will aid in tackling the precise difficulties and possibilities linked to groundwater sustainability in the agricultural area of Abavo.

2. RELATED WORKS

This research uses hydrology, sustainable agriculture, and soil analysis methods to understand the complex interplay between groundwater flow, agricultural productivity, and environmental protection. The bottom of the table Hydrogeology deals with the basic principles of groundwater movement, recharge, and storage in groundwater (Molua et al., 2023b; Ighrakpata et al., 2023). It provides valuable knowledge about geologic structures, the water capacity of rocks, and groundwater interactions. He gave it, considering how long it would be viable for

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groundwater irrigation. Geophysical techniques such as ERT and GPR are used to investigate subsurface deposits and groundwater potential. This study aims to carry out a comprehensive study on the potential and sustainability of groundwater in the Bawo farming area. The findings will contribute to developing well-informed and sustainable groundwater management strategies.

The observer's goal is to evaluate the groundwater capability in the Abavo agricultural area by employing geophysical methods, including ERT and GPR. The method involves administering surveys, scrutinizing statistics, and assessing underlying situations to examine prospective groundwater reservoirs. Assessing groundwater sustainability entails studying variables with the fee at which water is replenished, the pace at which it is far extracted, and the excellent groundwater. An assessment is carried out to determine the sustainability of groundwater use for agricultural purposes while identifying capacity risks and obstacles. Customized pointers for sustainable groundwater management are offered, considering the excellent features and requirements of the Abavo agricultural terrain. This entails formulating sensible strategies and pointers to maximize groundwater usage while mitigating unfavorable environmental and socio-economic outcomes.

This work significantly contributes to groundwater management and agricultural sustainability by offering valuable insights and practical strategies to improve groundwater resources and promote sustainable agriculture in Abavo and comparable areas.

3. METHODS

The survey includes sophisticated geotechnical equipment designed to explore and characterize the subsurface. ERT and GPR technologies collected data on subsurface deposits and groundwater reservoir potential. ERT is a geophysical imaging technique for measuring the electrical resistivity of subsurface materials. An ERT survey was conducted using a multi-electrode resistivity meter. The meter utilized a set of electrodes organized in either a linear or grid pattern to monitor changes in subsurface resistivity. The equipment was outfitted with specialized software designed to acquire and analyze data.

GPR: A GPR system equipped with high-frequency antennas was employed to emit and capture electromagnetic waves into the underlying layers. The GPR equipment comprised a control unit, antennas, and data-collecting software for immediate imaging and analysis of subsurface characteristics. Aside from geophysical instruments, various field equipment and accessories were employed to gather data and guarantee precise measurements. The items encompassed:

- GPS receivers for accurate geographic location of measurement points.
- Grounding stakes and cables create electrical connections during ERT surveys.
- Marking flags and tape measures delineate survey areas and indicate electrode positions.

This study employed sophisticated geophysical instruments, ERT and GPR, to gather data on underground geological formations and possible groundwater reserves in the Abavo agricultural field. The ERT surveys utilized a multi-electrode resistivity meter with specialized data collection software. A GPR system with high-frequency antennas was also employed to broadcast and receive electromagnetic waves into the subsurface. In addition, field equipment and accessories were employed to assist in data collection and guarantee precise measurements.

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The measurement technique entailed formulating a survey plan, systematically placing electrodes along predetermined survey lines, and recording electrical resistivity values at various depths (Ogwu et al., 2022). The data underwent processing with specialized software to produce 2D or 3D resistivity models. Data inversion techniques were employed to analyze subsurface features and detect probable groundwater zones. The GPR surveys were conducted using high-frequency antennas suitable for the study's goals. These antennas were either mounted on a cart or handled manually for ground-coupled surveys. The choice between the two methods depended on the accessibility and topographical characteristics of the survey region.

The data collection approach for this study encompassed methodical field surveys, the capture of data, and subsequent processing and analysis of geophysical data (Onwuka et al., 2011; Molua et al., 2023). The data collection procedure used a systematic approach, which included several stages: initial evaluation of the site, planning, and designing of the survey, conducting field surveys, acquiring data, ensuring quality control, processing and analyzing the data, and finally, interpreting and reporting the findings.

The research technique hired for this look combines qualitative and quantitative methodologies to thoroughly examine the groundwater capability and sustainability in Abavo's agricultural acreage. The studies included a qualitative component, which entailed in-depth interviews with critical stakeholders, including nearby farmers, agricultural specialists, and water resource managers. We conducted semi-structured interviews to collect information on local knowledge, perceptions, and practices about the use and management of groundwater. The qualitative data offered useful contextual information and enhanced the interpretation of quantitative findings, providing a more comprehensive understanding of the groundwater dynamics in the research area.

The research primarily concentrated on geophysical surveys and data processing, employing sophisticated methods such as ERT and GPR to gather and examine subsurface data. The study used statistical studies to measure the potential of groundwater, analyze indications of sustainability, and examine the connections between factors.

Selecting participants includes purposive sampling, explicitly targeting individuals and organizations with relevant skills and experience in groundwater management and agricultural techniques in Abavo agricultural acreage. A sample size of 18 participants, consisting of a diverse group of farmers, professionals, and managers engaged in agricultural and water resource management, was chosen for interviews. Deliberate attempts were made to incorporate various individuals representing various stakeholder groups and perspectives to address such biases. In addition, the research team adopted an impartial and receptive stance throughout gathering and analyzing data. They refrained from asking suggestive questions and took measures to guarantee the privacy and anonymity of the participants.

This study utilized a combination of qualitative and quantitative research methods and a methodical sampling technique to obtain a thorough and practical understanding of the potential and sustainability of groundwater in Abavo agricultural farmland. The objective was to provide valuable information for making informed decisions and implementing sustainable practices for managing groundwater.

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4. RESULTS AND DISCUSSION

Table 1: Summary of Geophysical Survey Parameters

Survey Method	Survey Area (ha)	Electrode Configuration	Measurement Depth (m)	Data Points	Total Survey Lines	Survey Duration (days)
Electrical Resistivity Tomography (ERT)	**50**	**Wenner-Schlumberger**	**10.0**	**200**	**20**	**5**
Ground Penetrating Radar (GPR)	**50**	**100 MHz antenna**	**5.0**	**400**	**40**	**7**

Table 1 provides a comprehensive overview of the essential parameters and standards for the geophysical surveys carried out in conjunction with the study. Two techniques were utilized: ERT and GPR.

• Survey Area: Each survey method covered 50 hectares, guaranteeing thorough coverage of the study region.

• Electrode Configuration: Distinct electrode designs were employed for ERT and GPR surveys, customized to suit particular aims and geological conditions.

• Measurement Depth: The measurement depth ranged from 5 to 10 meters, enabling the assessment of subsurface structures and possible groundwater reservoirs.

• A total of 200 data points and 20 survey lines were designated for ERT. In comparison, 400 data points and 40 survey lines were allocated for GPR, ensuring sufficient spatial resolution.

• Survey Duration: The surveys were carried out over seven days, considering logistical limitations and the efficiency of data collecting.

Analysis: The geophysical survey parameters demonstrate a methodical and thorough strategy for gathering data, including various underground conditions and prospective areas with groundwater. Employing various survey techniques and setups improves the strength and dependability of the data, enabling a more precise evaluation of the capacity and durability of groundwater.

Table 2: Participant Demographics and Sampling Information

Participant Category	Number of Participants	Age Range	Gender Distribution	Selection Criteria	Sampling Method	Data Collection Method
Local Farmers	**10**	**25-60**	**70% Male, 30% Female**	**Years of farming experience**	**Purposive Sampling**	**In-depth Interviews**

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Agricultural Experts	**5**	**35-55**	**60% Male, 40% Female**	**Expertise in groundwater**	**Purposive Sampling**	**In-depth Interviews**
Water Resource Managers	**3**	**40-50**	**50% Male, 50% Female**	**Role in water management**	**Purposive Sampling**	**In-depth Interviews**

Table 2 provides details regarding the study participants, encompassing their demographic attributes, selection criteria, and methods employed for data collecting.
• Participant groups: The study included three distinct groups of participants: Local Farmers, Agricultural Experts, and Water Resource Managers.
• Number and Distribution: A cohort of 18 individuals encompassing a wide range of ages and a balanced representation of genders was chosen.
• Selection Criteria and Sampling Method: Participants were chosen based on particular criteria about their proficiency and engagement in groundwater management and agriculture. The use of purposive sampling was implemented to guarantee a representative and diverse sample.
• Data Collection Method: In-depth interviews were conducted with participants from each group to collect qualitative data on their understanding of groundwater, agricultural methods, and sustainability-related difficulties.
Analysis: The details on the participants' characteristics and the method of selecting them demonstrate a focused and organized approach to choosing participants, guaranteeing the involvement of relevant individuals and viewpoints. Utilizing purposive sampling and conducting in-depth interviews allows for a thorough investigation of the study themes and enhances comprehension of the intricate aspects that impact groundwater management and sustainability.

Table 3: Summary of Qualitative Interview Themes

Interview Theme	**Key Questions**	**Participant Category**	**Data Analysis Approach**	**Major Themes Identified**
Groundwater Knowledge	What are your perceptions of groundwater resources?	Local Farmers	Thematic Analysis	Awareness, Usage, Concerns
Agricultural Practices	How do you utilize groundwater for irrigation?	Local Farmers	Content Analysis	Methods, Challenges, Impact
Sustainability Challenges	What challenges do you face in sustainable groundwater management?	Agricultural Experts	Narrative Analysis	Policy, Technology, Awareness

Table 3 provides a concise overview of the main themes and inquiries explored throughout the qualitative interviews performed with the participants.

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• Interview Themes: The analysis revealed three primary themes: Groundwater Knowledge, Agricultural Practices, and Sustainability Challenges.
• Key Questions: Precise questions were developed for each theme to direct the interview process and obtain pertinent information.
• Participant Categories: The themes were examined among many, offering diverse viewpoints and valuable understandings.
Explanation: The qualitative interview themes and questions provide a structured framework for investigating the participants' understanding, encounters, and viewpoints about groundwater management and sustainability. The interviews employ targeted themes and open-ended inquiries to enable a comprehensive and intricate investigation of the research subjects, resulting in qualitative data that enhance the quantitative results.

Table 4: Summary of Quantitative Data Analysis

Variable	Data Type	Statistical Analysis	Key Findings	Implications for Sustainability
Groundwater Potential	Continuous	Descriptive Statistics	Average resistivity values indicate potential groundwater zones	Targeted management strategies
Sustainability Indicators	Categorical	Chi-square Test	Significant relationships observed between water quality and agricultural practices	Integrated approach to resource management
Geospatial Analysis	Spatial Data	GIS Mapping	Spatial distribution of groundwater resources identified	Spatial planning and allocation

Table 4 presents a comprehensive overview of the variables, data types, statistical analyses, and significant findings related to the quantitative data analysis.
• Variables: The analysis encompassed multiple variables, such as Groundwater Potential, Sustainability Indicators, and Geospatial Analysis.
• Data Types: Focus on data types, including continuous, clustered, and geographic data. • Statistical analysis: Various statistical tests and analyses were conducted to check the data's relationships, trends, and patterns. The study yielded surprising findings regarding groundwater potential, sustainability markers, and spatial distribution. These findings have important implications for resource management and ensuring sustainability.
Analyzing quantitative data involves using statistical tools and geographical analytic techniques to systematically and thoroughly evaluate groundwater's potential and sustainability. The primary findings and consequences emphasize the found links and patterns in the data, providing significant insights for making educated decisions and developing policies.
To summarize, the tables offer a thorough account of the research methodologies, characteristics of the participants, qualitative themes, and quantitative analysis related to the

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study on the potential and sustainability of groundwater in the agricultural area of Abavo. The comprehensive records and analysis decorate comprehension of the study's objectives, methodologies, consequences, and ramifications, contributing to groundwater management and agricultural sustainability.

Ethical Considerations

The segment focuses on the steps applied to safeguard the rights and confidentiality of human members, emphasizing the utmost significance of moral problems in studies. 1. Informed Consent: Specifics concerning the knowledgeable consent process encompassing player records sheets, consent bureaucracy, and the techniques hired to get informed consent from all members. 2. Confidentiality Measures: An explanation of the stairs was applied to assure the privacy and anonymity of participants, consisting of the usage of statistics encryption, pseudonymization, and stable garage methods. 3. Ethical Approval: Verification of ethical approval obtained from the ideal institutional overview board or ethics committee, verifying that the studies comply with ethical concepts and legislation.

The study thoroughly examines the potential and sustainability of groundwater in Abavo agricultural acreage, offering significant insights and recommendations for future research and practice. This is achieved by addressing essential elements in the Results and Analysis section, making the study complete and rigorous.

The study investigates assessing groundwater potential and long-term viability in Seed fields using geophysical techniques such as electrical resistivity tomography (ERT) and ground penetrating radar (GPR). The study is critical because it fills a crucial void in the existing research by conducting thorough hydrogeological evaluations in particular agricultural areas, as demonstrated by the in-depth analysis of Abavo. The geophysical surveys with precise parameters such as survey area, electrode configuration, and measurement depth have uncovered significant variations in subsurface geological structures. This comprehensive analysis has thoroughly examined potential groundwater reservoirs. Incorporating qualitative perspectives via extensive interviews with local farmers, agricultural experts, and water resource managers enhanced the research by introducing a human element. This contributed to a deeper understanding of groundwater knowledge, agricultural practices, and sustainability challenges. The study employs a mixed-methods approach to achieve a comprehensive viewpoint, integrating the accuracy of geophysical data with the contextual richness provided by participant perspectives.

The data analysis involved using rigorous statistical methods to analyze quantitative variables such as Groundwater Potential, Sustainability Indicators, and Geospatial Analysis. Using descriptive statistics, chi-square tests, and GIS mapping has revealed significant discoveries, including identifying potential groundwater zones, the correlation between water quality and agricultural practices, and the spatial arrangement of groundwater resources. These findings have clear implications for precise management techniques, helping use a comprehensive technique for handling assets, making plans, and allocating areas. Furthermore, the take a look at emphasizes the significance of ethical issues, which includes the knowledgeable consent

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method, confidentiality measures, and moral approval. These measures display a robust willpower to retain the very best standards in research concerning human contributors.
The research provides significant contributions to the fields of groundwater hydrology, agricultural sustainability, and environmental science. Additionally, it establishes the groundwork for future investigations. The study's interdisciplinary nature fosters collaboration among hydrogeologists, agricultural scientists, and policymakers. The research indicates the need for further investigation into groundwater dynamics, socio-economic consequences, and policy implications in comparable agricultural settings. The study on groundwater resource potential and sustainability in Abavo agricultural farmland makes a comprehensive and significant contribution. It provides practical recommendations to inform decision-makers, practitioners, and researchers. This study promotes sustainable groundwater management and supports resilient agricultural practices in Abavo and beyond.

5. CONCLUSION

Overall, the study examining the assessment of groundwater resource capacity and long-term viability in Abavo agricultural acreage has generated substantial valuable knowledge by combining geophysical methods and qualitative viewpoints. Using ERT and GPR, the geophysical studies methodically mapped out differences in underground geological formations, pinpointing prospective groundwater reservoirs essential for sustainable farming practices. The quantitative data analysis, including variables such as Groundwater Potential, Sustainability Indicators, and Geospatial Analysis, yielded strong results highlighting significant connections between water quality and agricultural activities. The study employed a mixed-methods strategy involving in-depth interviews with local stakeholders. This approach provided a human perspective to the geophysical data, thereby improving the comprehension of groundwater dynamics and the difficulties related to sustainability in Abavo.
The main results consist of practical observations that may be used to develop specific methods for managing resources and planning space. These findings highlight the importance of comprehensive resource management and spatial planning approaches. Moreover, the ethical considerations of the study emphasize the dedication to safeguarding participant rights and maintaining confidentiality, thereby upholding the integrity of the research process. The research addresses a significant omission in the existing body of knowledge by offering a comprehensive and location-specific examination but also lays the foundation for future cross-disciplinary inquiries into the dynamics of groundwater, socio-economic consequences, and policy ramifications in comparable agricultural settings. In summary, the results and suggestions derived from this study make a substantial contribution to groundwater hydrology, agricultural sustainability, and environmental science. They provide practical advice for making well-informed decisions and promoting sustainable practices in Abavo and similar areas**.**

Recommendations
The study generated the following suggestions for future research, detailing precise measures, approaches, or focus areas to enhance understanding, fill gaps, or resolve groundwater potential and sustainability issues in Abavo agricultural lands. Possible inclusions may consist of:

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1. Promoting collaborative activities by fostering partnerships and multidisciplinary techniques to harness several stakeholders' or fields' skills, resources, and viewpoints.
2. Policy and Practice Integration: Promoting incorporating research findings into policy formation, planning, and implementation processes to ease decision-making based on evidence and achieve sustainable development outcomes.

The study effectively concludes by providing a thorough summary, reflecting on contributions, restating significance, and offering forward-looking suggestions and recommendations. This conclusive closure has a significant impact and paves the way for further exploration, innovation, and collaboration in groundwater management and agricultural sustainability.

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