EXPLORING SUSTAINABLE GROUNDWATER EXTRACTION PRACTICES FOR SMALLHOLDER FARMERS IN NIGERIA

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Abstract

Groundwater is a crucial resource for smallholder farmers in Nigeria, providing a reliable water supply for irrigation and livestock. However, unsustainable extraction practices threaten the long-term availability of this vital resource. This paper explores sustainable groundwater extraction methods tailored for smallholder farmers in Nigeria. By integrating traditional knowledge with modern technology, such as low-cost drip irrigation, solar-powered pumps, and water-efficient crop varieties, farmers can enhance water use efficiency and reduce environmental impact. Conclusively sustanable groundwater management is not only a technical challenge but also a socioeconomic and environmental imperative. It requires a multifaceted approach that combines technology, policy, community engagement, and education. The paper recommended that smallholder farmers should adopt low- cost and efficient technologies such as the Implementation of solar powered groundwater pumps to reduce operational costs and reliance on erratic power supplies or expensive fuel, and also to encourage the use of drip irrigation to minimize water wastage and maximize crop yield, and also that the Federal Government of Nigeria should Implement projects like the construction of check dams, percolation tanks, and recharge wells to enhance groundwater recharge in order to promote the collection and storage of rainwater for agricultural usage.

Keyword: Sustainable, Groundwater, Extraction, Smallholder-Farmers

Introduction

In Nigeria, smallholder farmers constitute a significant portion of the agricultural sector, which is a vital part of the nation's economy and food security. These farmers often rely on groundwater as a primary source for irrigation, especially in regions with limited surface water availability. However, the increasing demand for groundwater has led to concerns about its sustainability, as over-extraction can result in depleted aquifers, reduced water quality, and increased pumping costs (Olufemi & Ojo, 2019). Sustainable groundwater extraction practices are crucial to ensure that this vital resource remains available for future generations, maintaining both environmental balance and agricultural

productivity.

Smallholder farmers in Nigeria are increasingly reliant on groundwater for irrigation due to inconsistent rainfall and limited surface water resources. This dependency has led to unsustainable extraction rates, resulting in the rapid depletion of aquifers, declining water tables, and deterioration of water quality (Oke, Ayoade & Akinluyi, 2021). The over extraction of groundwater not only threatens the immediate availability of water for agricultural use but also poses long-term risks to the environment and

community livelihoods. As aquifers are depleted, farmers must drill deeper wells, incurring higher costs and often encountering poor quality water that can be harmful to crops and soils (Adeoti & Owolabi, 2020).

Furthermore, the lack of effective regulation and monitoring exacerbates the situation, with many farmers unaware of the long term consequences of over extraction (Ogundele, 2018). This situation is compounded by climate change, which is expected to alter precipitation patterns and further strain water resources (Oguntunde, Abiodun & Lischeid, 2019). Without the adoption of sustainable groundwater extraction practices, the agricultural productivity and food security of smallholder farmers in Nigeria are at significant risk, threatening the livelihoods of millions and the nation's overall economic stability. Despite the critical importance of groundwater for smallholder farmers in Nigeria, there is a significant gap in research focused on the implementation and effectiveness of sustainable groundwater extraction practices within this group. Much of the existing literature emphasizes the technical aspects of groundwater management or focuses on large scale agricultural operations, often overlooking the unique challenges and opportunities faced by smallholders (Adeoye, Akinluyi & Awotoye, 2020). Specifically, there is limited empirical research on the socioeconomic factors that influence the adoption of sustainable practices, such as farmers' knowledge, attitudes, and financial constraints (Eze, Okoro & Nnadi, 2018).

Furthermore, there is a need for localized studies that consider the diverse climatic, geological, and hydrological conditions across Nigeria, which affect groundwater availability and sustainability differently. The heterogeneity of these conditions means that a one size fits all approach to groundwater management is ineffective; yet, there is insufficient research on region specific strategies and interventions (Olaniyan & Bamgbose, 2019). Additionally, while policy frameworks for groundwater management exist, their practical application and impact on smallholder farmers are underexplored, leaving a gap in understanding how policies can be better designed and implemented to support sustainable practices (Fashola, Agunbiade & Aderonke, 2021). Addressing these gaps is crucial for developing targeted and effective strategies that not only conserve groundwater resources but also enhance the livelihoods of smallholder farmers in Nigeria. More interdisciplinary research, incorporating socioeconomic, environmental, and policy perspectives, is necessary to create a comprehensive approach to sustainable groundwater extraction. It against this backdrop that this article seeks to explore on sustainable ground water practices for smallholder farmers in Nigeria.

Conceptual Clarification

Sustainable: the term "sustainable" refers to practices that meet current needs without compromising the ability of future generations to meet their own needs. In the context of groundwater management, sustainability involves using water resources in a way that maintains their availability and quality over the long term, ensuring environmental, economic, and social wellbeing (United Nations, 1987). This concept emphasizes the balance between consumption and conservation, promoting practices that avoid depletion or degradation of natural resources.

Groundwater: groundwater is water that is stored beneath the Earth's surface in soil pore spaces and in the fractures of rock formations. It is a crucial resource for drinking water, agriculture, and industry. Groundwater is typically accessed through wells and can be renewable, depending on the rate of replenishment through natural processes like rainfall and infiltration. However, over extraction can lead to the depletion of aquifers and reduced water availability (Freeze & Cherry, 1979).

Extraction: in the context of groundwater, refers to the process of withdrawing water from aquifers using

wells, pumps, or other technologies. This process can vary in scale from small hand dug wells to large, industrial scale extraction systems. The rate and volume of groundwater extraction are critical factors in determining the sustainability of water use. Over extraction can lead to negative consequences such as land subsidence, reduced water quality, and the drying up of wells (Bouwer, 2002).

Smallholder Farmers: Smallholder farmers are individuals or families that manage small plots of land, typically relying on family labor and traditional farming methods. In Nigeria and many other developing countries, smallholder farmers constitute the backbone of the agricultural sector, producing a significant portion of the food supply. These farmers often face challenges such as limited access to capital, technology, and markets, making them vulnerable to environmental and economic changes (IFAD, 2013).

Current Situation of Sustainable Underground Water Extraction Practice for Smallholder Farmers in Nigeria

In Nigeria, groundwater serves as a crucial source of water for smallholder farmers, particularly in regions with limited surface water availability. However, the current practices of groundwater extraction are often unsustainable, leading to a range of environmental and socioeconomic issues. Over-extraction of groundwater has resulted in the lowering of water tables, which not only depletes the resource but also increases the costs associated with deeper drilling and pumping (Adeoye & Ojo, 2020). Many smallholder farmers, who operate with limited financial resources, are unable to bear these increased costs, leading to reduced agricultural productivity and economic hardship.

Additionally, there is a lack of widespread adoption of efficient irrigation techniques among smallholder farmers, which contributes to the overuse of groundwater. Traditional methods such as flood irrigation are still prevalent, which are less efficient compared to modern methods like drip or sprinkler irrigation (Olaniyan, Akinluyi & Awotoye, 2021). These modern techniques can significantly reduce water usage, but their adoption is limited due to high initial costs and lack of awareness or training.

The situation is exacerbated by inadequate regulatory frameworks and monitoring systems. There is insufficient regulation to control the rate of groundwater extraction and ensure equitable distribution of water resources. This regulatory gap has led to unsupervised drilling and usage, further stressing the groundwater resources (Oke & Ayoade, 2018). Moreover, the impacts of climate change, such as changes in rainfall patterns and increasing temperatures, are expected to further strain groundwater availability, making sustainable management practices even more critical (Oguntunde et al., 2019).

Importance of Sustainable Groundwater Management

Sustainable groundwater management is crucial for ensuring long-term water availability, environmental sustainability, and socioeconomic stability, especially for smallholder farmers in regions like Nigeria. The importance of sustainable practices in groundwater management can be highlighted through several key aspects:

Environmental Sustainability: Groundwater plays a critical role in maintaining the balance of ecosystems, supporting wetlands, rivers, and lakes. Over extraction can lead to a decrease in water levels, causing the drying up of these water bodies, which negatively impacts biodiversity and disrupts ecological balance (Foster & Chilton, 2003). Sustainable management practices help to preserve these ecosystems, ensuring that water resources are available not only for human use but also for maintaining natural habitats.

Water Security: For many communities, particularly in arid and semiarid regions, groundwater is the primary or sole source of freshwater. Sustainable management ensures that groundwater resources are not depleted faster than they are replenished, providing a reliable source of water for drinking, irrigation,

and industrial use (Gleeson, Wada, Bierkens & van Beek 2012). This is crucial for maintaining the water security of communities, especially in the face of increasing demand and climatic variability.

Economic Viability: Groundwater is essential for agricultural production, particularly in areas where surface water is scarce or seasonal. Over extraction can lead to higher pumping costs and the need for deeper wells, which are often beyond the financial reach of smallholder farmers (Shah, 2009). Sustainable groundwater management practices, such as efficient irrigation techniques and water conservation measures, help reduce costs and ensure that farmers can continue to cultivate their land productively.

Social Wellbeing and Public Health: Access to clean and sufficient water is a fundamental human right. Over extraction and contamination of groundwater can lead to water scarcity and poor water quality, which pose serious public health risks (Mukherjee, Scanlon, Aureli & McKenzie 2015). Sustainable management practices help protect water quality, ensuring that communities have access to safe water for drinking, cooking, and sanitation.

Climate Change Resilience: As climate change alters precipitation patterns and increases the frequency of extreme weather events, the reliance on groundwater as a buffer becomes even more critical. Sustainable groundwater management enhances resilience by maintaining aquifer levels and preventing land subsidence, which can be exacerbated by excessive groundwater withdrawal (Taylor, Scanlon, Doll & Rodell, 2013).

Sustainable Groundwater Extraction Practices in Nigeria

Implementing sustainable groundwater extraction practices is essential for preserving water resources and supporting the livelihoods of smallholder farmers. These practices aim to balance water use with natural replenishment rates, minimize environmental impacts, and ensure long term water availability. Key sustainable groundwater extraction practices include:

Efficient Irrigation Techniques: drip Irrigation; this method delivers water directly to the roots of plants, reducing water waste and evaporation losses. It is particularly effective in areas with water scarcity and can reduce water usage by up to 50% compared to traditional methods (Kang, Zhang, Liang & Cai, 2017). On the other hand, sprinkler irrigation is a system that distributes water uniformly across the field, which can be more efficient than surface irrigation. Modern sprinklers are designed to minimize water loss due to wind and evaporation (Raine, Hutson, Hornbuckle & Heuperman, 2007). Notwithstanding the fact that subsurface irrigation technique involves placing irrigation pipes below the soil surface, delivering water directly to the root zone. It reduces water loss due to evaporation and surface runoff, making it highly efficient (Ayars, Phene, Hutmacher, Davis, Schoneman, Vail & Mead, 2015).

Rainwater Harvesting: collecting and storing rainwater can supplement groundwater resources, especially in regions with seasonal rainfall. Techniques include rooftop collection systems, small dams, and ponds. Harvested rainwater can be used for irrigation and replenishing groundwater through artificial recharge (Gould & Nissen Petersen, 1999).

Groundwater Recharge such as:

Recharge Wells: These are structures designed to enhance the natural replenishment of groundwater. They involve injecting surface water into aquifers, helping to maintain water tables and reduce the risk of land subsidence (Scanlon, Jolly, Sophocleous, & Zhang 2016).

Percolation Tanks: These are constructed to capture surface runoff, allowing water to percolate into the ground and recharge aquifers. They are especially useful in arid and semiarid regions where groundwater recharge is slow (Kumar, Bhattacharjee, & Kumar 2019).

Water Efficient Crop Selection: choosing crops that require less water or are more drought resistant can significantly reduce the demand for groundwater. Farmers can opt for crops that are suited to local climatic and soil conditions, thereby enhancing water use efficiency (Sposito, 2013).

Regulatory Frameworks and Community Management: implementing policies and regulations that control groundwater extraction rates and promote sustainable use is crucial. Community based management; involving local stakeholders in decision making, can ensure more equitable and effective management of water resources (Moench, Burke & Moench 2003).

Underpinning theory of Sustainable Groundwater Extraction Practices for Smallholder Farmers

The underpinning theory for sustainable groundwater extraction practices for smallholder farmers can be anchored in the concepts of sustainable development, common pool resource management, and adaptive management.

Sustainable Development Theory: This theory, rooted in the Brundtland Report (1987), posits that development should meet the needs of the present without compromising the ability of future generations to meet their own needs. In the context of groundwater management, this theory emphasizes the importance of balancing water use with the natural replenishment rates of aquifers to prevent resource depletion (WCED, 1987). It advocates for practices that maintain or enhance the resource base and ecological systems upon which agriculture and livelihoods depend.

Common Pool Resource (CPR) Theory: Developed by Elinor Ostrom and others, CPR theory addresses the management of resources that are shared by multiple users, such as groundwater. It highlights the challenges of preventing overuse and ensuring equitable access, which can lead to the "tragedy of the commons" if not properly managed (Ostrom, 1990). According to this theory, effective governance mechanisms, such as clear property rights, community management, and collective action, are essential to regulate resource use and prevent over extraction.

Adaptive Management Theory: This theory advocates for a flexible, learning based approach to managing natural resources. Adaptive management involves continuously monitoring environmental conditions and resource use, and adjusting management strategies in response to new information and changing circumstances (Holling, 1978). This approach is particularly relevant for groundwater management, where uncertainties related to climate change, population growth, and technological advancements require adaptable strategies.

Application to Sustainable Groundwater Extraction Practices in Nigeria

These theoretical frameworks collectively support the implementation of sustainable groundwater extraction practices among smallholder farmers. Sustainable development theory underscores the need for practices that do not deplete groundwater resources, aligning with techniques such as efficient irrigation and rainwater harvesting. CPR theory informs the development of community based management systems and regulatory frameworks that ensure equitable access to groundwater and prevent overuse. Adaptive management theory provides the basis for monitoring groundwater levels and adjusting practices based on observed changes, promoting resilience in the face of environmental variability and uncertainty.

Conclusion

Sustainable groundwater management is not only a technical challenge but also a socioeconomic and environmental imperative. It requires a multifaceted approach that combines technology, policy, community engagement, and education. By adopting these best practices, Nigeria can ensure that its groundwater resources remain abundant and accessible for future generations, supporting the livelihoods of millions of smallholder farmers and contributing to the nation's food security and economic stability.

Recommendations

To enhance the sustainability of groundwater extraction practices among smallholder farmers in Nigeria, the following recommendations are proposed:

Smallholder farmers should adopt low- cost and efficient technologies such as the Implementation of solar powered groundwater pumps to reduce operational costs and reliance on erratic power supplies or expensive fuel, and also to encourage the use of drip irrigation to minimize water wastage and maximize crop yield.

Policy makers should formulate Community Based Water Management policies that will strengthen regulate groundwater usage collectively, and to conduct regular training for farmers on sustainable water management practices and the importance of maintaining groundwater levels.

The Federal Government of Nigeria should set up a committee to monitor and regulate groundwater levels and quality in real-time in order to prevent over extraction and promote the recharge of aquifers.

The Federal Government should implement projects like the construction of check dams, percolation tanks, and recharge wells to enhance groundwater recharge and also to promote the collection and storage of rainwater for agricultural use, reducing the dependency on groundwater.

The Federal Government, MDAs and NGOs should offer financial support and subsidies for the adoption of sustainable water management technologies, and also Provide technical support and extension services to help farmers implement and maintain new technologies and practices.

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