EFFECT OF SPATIAL AND TEMPORARY VARIATION OF GROUNDWATER
(A case study of ASA River)

BY

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HND/23/CEC/FT/0116

A PROJECT SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING INSTITUTE OF TECHNOLOGY, KWARA STATE POLYTECHNIC, ILORIN.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF HIGHER NATIONAL DIPLOMA(HND) IN CIVIL ENGINEERING.

July, 2025

CERTIFICATION

This is to certify that this project was conducted by ABOYEJI Samson Seun (HND/23/CEC/FT/0116) and had been read and approved as meeting the requirements for the award of High Nation Diploma (HND) in Civil Engineering of the department of Civil Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin.

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DEDICATION

This research is dedicated to Almighty God who by his mercy guided and protected me throughout my course of study

ACKNOWLEDGEMENT

I give gratitude to the Almighty God for the successful completion of this project. Most importantly, I am grateful to my supervisor ENGR. A. SANNI for his support and encouragement on this work. Appreciation goes to all staff in civil engineering department who has contributed in one way or the other to the completion of this project so far. I give thanks to my lecturers who made course easy for me.

I extend my special thanks to my parents for their morally, spiritually, and financially word of encouragement and prayer given to me, who makes my project successful. I am also grateful to my colleague and friends for their support.

ABSTRACT

This study assesses the effect of spatial distribution and availability of groundwater resources within the Asa River Basin using the Soil and Water Assessment Tool (SWAT) model. A total of 52 subbasins were modeled (excluding subbasin 0, which had no data), covering a combined area of 1,739.29 km². The model estimated water yield (WYLD) and groundwater quantity (GW_Q) for each subbasin, providing insight into hydrological behavior and recharge dynamics across the basin. Water yield values ranged from 529.32 mm to 596.81 mm, with Subbasins 1, 49, and 51 exhibiting the highest yields, indicating zones of enhanced baseflow contribution.

Groundwater quantities (GW_Q) across the subbasins ranged from 236.93 mm to 278.65 mm, with high recharge values observed in Subbasins 1, 49, and 51, suggesting favorable conditions for infiltration and aquifer recharge. Most subbasins displayed groundwater contributions exceeding 240 mm, with an average GW_Q of approximately 243 mm, indicating a generally well-recharged watershed. Subbasins 5, 25, and 48 also recorded notably high groundwater contributions, reinforcing the existence of productive recharge zones scattered across the basin.

The study concludes that the Asa River Basin demonstrates substantial groundwater availability and recharge potential, particularly in selected high-yielding subbasins. It emphasizes the need for targeted groundwater management strategies, including the protection of high-recharge areas, implementation of artificial recharge in low-performing zones, and promotion of sustainable extraction practices. Recommendations also highlight the importance of integrating groundwater data into watershed management plans, enhancing land use planning, and establishing long-term monitoring systems to support sustainable water resource development within the region.

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CHAPTER ONE

1.0 BACKGROUND OF THE STUDY

Groundwater is a crucial component of the Earth's hydrological system and serves as a significant source of water for drinking, irrigation, and industrial use, especially in regions where surface water is limited or unavailable. Groundwater's quality, quantity, and availability are dynamic, subject to spatial (location-based) and temporal (time-based) variations that influence water resource management. These variations can be driven by multiple factors such as climate, seasonal patterns, geological structures, land use, and anthropogenic activities (Xu et al., 2006). In regions like Nigeria, where the dependence on groundwater for potable water and agricultural activities is high, understanding these variations is fundamental for ensuring sustainable water use.

The Asa River, located in the Ilorin West Local Government Area of Nigeria, is a significant water body within the kwara state. This river system, like many others in sub-Saharan Africa, supports local communities by providing water for domestic consumption and agricultural purposes. However, the region is increasingly experiencing water stress, exacerbated by rapid urbanization, population growth, and changing climate conditions (Adeoye et al., 2011). Groundwater serves as a vital backup during dry periods when surface water is insufficient, particularly in areas where the Asa River basin and surrounding catchment areas experience marked seasonal changes in rainfall and runoff (Adelekan et al., 2017).

Spatial variation of groundwater refers to differences in groundwater levels, quality, and other hydrogeological characteristics at different geographical locations. The Asa River basin covers a diverse range of geological formations, including porous aquifers, fault lines, and varying topographies that can cause significant spatial differences in groundwater storage and quality (Elueze et al., 2019). Additionally, human activities, such as agricultural practices and urban development, often exacerbate the spatial variability of groundwater resources by influencing recharge rates, contamination levels, and land surface permeability (Olasehinde et al., 2013).

Temporal variation of groundwater, on the other hand, is influenced by periodic fluctuations in factors such as seasonal rainfall, temperature, evaporation rates, and human interference. In regions like the Asa River catchment, the rainy and dry seasons significantly affect groundwater recharge rates and the overall availability of groundwater. During the wet season, groundwater levels tend to rise due to increased infiltration from rainfall, while during the dry season, groundwater levels typically decline as evaporation rates exceed recharge (Oguntunde et al., 2007). Long-term climatic trends, including changes in rainfall patterns due to climate change, can further impact groundwater availability and quality (Akintoye et al., 2018).

Despite the increasing reliance on groundwater in the Asa River basin, there is a significant gap in comprehensive research that investigates the spatial and temporal variations of groundwater in this region. Most existing studies focus on the general hydrogeological properties or the surface water systems within the basin (Akintoye et al., 2017). Limited studies have explored the variations in groundwater levels, quality, and the drivers behind these changes on both spatial and temporal scales. Understanding the dynamics of groundwater in this context is essential for ensuring reliable water supply, mitigating water scarcity, and informing land-use policies in the region (Salami et al., 2015).

Given this knowledge gap, the proposed study on the "Spatial and Temporal Variation of Groundwater: A Case Study of Asa River" aims to address the lack of comprehensive data on the groundwater system in the Asa River basin. By investigating how groundwater levels and quality vary across different locations and times, this research will provide valuable insights into the factors driving these variations. The study will also help identify areas vulnerable to groundwater depletion or contamination, providing data that can inform sustainable water resource management strategies in the region.

Understanding the spatial and temporal variability of groundwater will not only help to predict water availability in the short and long term but will also allow for better groundwater management, particularly in the face of a changing climate and increasing human activity. By filling this knowledge gap, the research can contribute to more informed policy-making regarding water resources in the Asa River basin and similar regions in sub-Saharan Africa.

1.1 STATEMENT OF PROBLEM

Despite its importance, groundwater resources in the Asa River Basin are poorly understood, particularly in terms of how they vary across space and time. Without sufficient data on these variations, the region is at risk of over-exploitation, contamination, and inefficient management of groundwater resources. Therefore, there is an urgent need for a detailed study to explore the spatial and temporal variation of groundwater in the Asa River Basin.

1.2 AIM AND OBJECTIVE

Aim of this study is to investigate the effect of spatial and temporal variations of groundwater within the Asa River Basin, Nigeria, in order to provide valuable insights for its sustainable management.

The Specific objectives are:

i. To predict the amount of groundwater in the study.
ii. To estimate the groundwater recharge in the study area.
iii. To analyze the groundwater contribution in the study area.
iv. To analyze the spatial variation of the study area.

1.4. SCOPE OF THE STUDY

The scope of this study is geographically focused on the Asa River Basin, which is located in Kwara State, Nigeria. The study will cover both urban and rural areas within the basin to provide a comprehensive understanding of the spatial and temporal variations in groundwater resources.

1. Geographical Coverage: The study will focus on several key locations across the basin, including urban, rural, and agricultural areas, to account for the varying impacts of land use on groundwater levels and quality.

2. Temporal Coverage: Groundwater levels will be monitored over a 12-month period to capture seasonal variations, including both the wet (rainy) and dry seasons. This will allow for a detailed analysis of how groundwater levels fluctuate throughout the year.

3. Water Quality Analysis: Groundwater samples will be collected from wells in different parts of the basin and analyzed for parameters such as pH, Total Dissolved Solids (TDS), nitrates, heavy metals, and other relevant water quality indicators.

4. Factors Considered: The study will also examine the impact of factors such as rainfall patterns, land use, agricultural activities, and urbanization on groundwater levels and quality.

5. Methodology: The study will utilize GIS tools, statistical analysis, and regression modeling to analyze the data and interpret the result.

1.5. JUSTIFICATION OF THE STUDY

Groundwater resources in the Asa River Basin are critical for sustaining local communities and supporting agricultural and industrial activities. However, the increasing population, urbanization, and agricultural expansion in the region have put significant pressure on these resources.

There is currently limited understanding of how groundwater varies across time and space within the basin, and this lack of information hampers effective groundwater management. By providing a detailed analysis of the temporal and spatial variations in groundwater levels and quality, this study will offer valuable insights into the sustainability of groundwater resources in the region.

The findings from this study will help policymakers and water resource managers make informed decisions about groundwater management, especially with regard to regulating extraction, preventing contamination, and promoting sustainable land-use practices. Additionally, the study will contribute to broader knowledge about groundwater variability, which is essential for addressing water scarcity and ensuring access to clean water in the region.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents a review of existing literature related to the spatial and temporal variation of groundwater, with a particular focus on the factors influencing groundwater dynamics, the importance of groundwater in water resource management, and methodologies used in groundwater studies. The Asa River Basin, located in Kwara State, Nigeria, serves as the case study for this research. This review highlights key studies that have explored groundwater variability, both spatially and temporally, and help contextualize the study by identifying knowledge gaps and providing a theoretical foundation for the research.

2.2 GROUNDWATER DYNAMICS

Groundwater dynamics in the Ilorin Asa River Basin, Kwara State, Nigeria, have been widely studied due to the importance of groundwater as a major source of water supply for domestic, agricultural, and industrial uses in the region. According to Adebayo and Adediran (2005), as well as Ajala et al. (2015), the region's groundwater resources are primarily derived from basement complex aquifers. These aquifers are composed of crystalline rocks that have undergone significant weathering and fracturing, allowing them to store and transmit groundwater effectively. The structure of the bedrock, particularly the presence of fractures and joints, plays a critical role in groundwater movement and storage, especially in regions with limited surface water.

Groundwater recharge in this area is highly dependent on seasonal rainfall. During the rainy season (typically between April and October), significant infiltration of rainwater occurs through the soil and fractured rock layers, which recharges the aquifers. This results in an observable rise in groundwater levels during this period. Conversely, during the dry season (from November to March), when rainfall is minimal or absent, recharge significantly decreases, and groundwater levels drop due to continued abstraction for domestic and agricultural use.

Additionally, the interaction between surface water and groundwater is a key component of groundwater dynamics. Rivers and streams, especially the Asa River, contribute to recharge through infiltration, particularly when the river stage is higher than the groundwater table. However, this interaction can also lead to contamination of groundwater in areas where polluted surface water infiltrates into the subsurface.

Anthropogenic activities, such as urban development, deforestation, and poor waste management, also significantly affect the recharge and quality of groundwater. Impervious surfaces in urban areas reduce infiltration and increase surface runoff, thereby limiting recharge. Meanwhile, the discharge of untreated waste and effluents can percolate through the soil and contaminate the aquifers.

Understanding these dynamics is essential for sustainable water resource planning and management. Seasonal fluctuations in groundwater levels must be monitored to avoid over-exploitation, particularly in the dry season when the resource is naturally limited. Proper land use planning, groundwater monitoring programs, and pollution control measures are necessary to ensure the long-term viability of groundwater resources in the Ilorin Asa River Basin.

2.3 SPATIAL VARIATION OF GROUNDWATER

Spatial variation in groundwater refers to differences in groundwater quantity and quality across different geographic locations within a region. In the Ilorin Asa River Basin, these spatial differences are influenced by factors such as underlying geology, proximity to pollution sources, land use patterns, and human activities. Several studies, including those by Adebayo and Adediran (2005) and Ajala et al. (2015), have highlighted the spatial heterogeneity in groundwater characteristics within this basin.

The basin is underlain by the basement complex rock system, which includes granite, gneiss, and schist formations. These rocks have varying degrees of weathering and fracturing, which directly affect their capacity to store and transmit groundwater. Areas where the rocks are more deeply weathered or intensely fractured tend to have higher groundwater yields. Conversely, regions with less weathered or compact rock formations often yield limited groundwater due to reduced porosity and permeability.

Additionally, proximity to the Asa River and other surface water bodies influences groundwater characteristics. Regions close to the river often experience a stronger surface–groundwater interaction, particularly in terms of recharge. However, these areas are also more susceptible to contamination, especially where the river is polluted by municipal waste, industrial effluents, and agricultural runoff. Adebayo and Adediran (2005) observed that groundwater samples collected from wells near the river showed higher concentrations of pollutants such as nitrates, heavy metals, and microbial contaminants compared to samples from more distant locations.

Land use and population density also contribute to spatial variability. Urban and industrial zones, particularly around central Ilorin, are hotspots for groundwater contamination due to inadequate waste disposal systems, leaking septic tanks, and industrial discharges. In contrast, rural or less developed areas often exhibit better groundwater quality, though accessibility and infrastructural challenges can affect usage.

Moreover, agricultural zones within the basin exhibit variable groundwater quality depending on the intensity of fertilizer and pesticide use. Ajala et al. (2015) reported elevated levels of iron, zinc, and phosphate in groundwater from agricultural fields, likely due to leaching from fertilizers.

This spatial variability underscores the need for localized groundwater assessment and management. Uniform water quality standards may not be sufficient without considering these spatial differences. Therefore, site-specific strategies must be adopted, including targeted pollution control, zoning regulations, and periodic water testing to ensure safe and sustainable groundwater use across the entire basin.

2.4 TEMPORAL VARIATION OF GROUNDWATER IN THE ILORIN ASA RIVER BASIN

Temporal variations in groundwater levels in the Ilorin Asa River Basin are influenced by a complex interplay of seasonal rainfall patterns, land use changes, and broader climatic conditions. These variations, which reflect the cyclical rise and fall of groundwater levels throughout the year, play a crucial role in determining the availability of groundwater resources for both domestic and agricultural use.

Adebayo S. A., 2005 explains that during the rainy season (from April to October), the increase in precipitation leads to significant groundwater recharge. The infiltration of rainwater into the soil and fractured bedrock enhances the water table levels, leading to an observable rise in groundwater reserves. This increased recharge is particularly significant in regions underlain by weathered basement complex aquifers, which have a higher porosity due to fractures and weathering, allowing for better water storage and movement.

However, as **Ajala O. N., 2015** observes, during the dry season (from November to March), groundwater recharge slows down or ceases entirely due to reduced rainfall. Consequently, groundwater levels begin to decline, as the lack of recharge and continuous extraction for agricultural and domestic use leads to a drop in water tables. In some areas, the decrease in water levels during this period can lead to dry wells and reduced borehole yields, further exacerbating water scarcity during the dry months.

In addition to the natural seasonal patterns, **Adebayo S. A., 2005** highlights that anthropogenic factors such as land use changes also contribute to temporal variations in groundwater availability. Urbanization, deforestation, and changes in agricultural practices can reduce the ability of the land to absorb and store rainwater, limiting groundwater recharge. As urban areas expand, the construction of impermeable surfaces such as roads and buildings reduces the infiltration of rainwater, exacerbating the seasonal fluctuations in groundwater levels.

Both studies emphasize that these temporal variations driven by seasonal rainfall and land use changes—necessitate continuous monitoring and adaptive management strategies. Effective groundwater management, which accounts for seasonal variability, is essential to ensure a reliable water supply, particularly during the dry season when water resources are most scarce. Understanding these temporal changes helps policymakers and water resource managers plan for the inevitable fluctuations in water availability and avoid over-exploitation, especially in years of lower-than-average rainfall.

2.5 GROUNDWATER QUALITY AND POLLUTION IN THE ILORIN ASA RIVER BASIN

Groundwater quality in the Ilorin Asa River Basin has been increasingly compromised by pollution from various anthropogenic sources. This has raised serious concerns regarding the safety of groundwater as a vital resource for drinking, irrigation, and other uses. As industrialization, agricultural activities, and population growth have accelerated in the region, the quality of groundwater has progressively deteriorated, with implications for public health.

Adebayo, S. A., 2005 in his study *"Effect of Waste Discharges on the Water Quality of Asa River in Ilorin, Nigeria"* underscores the significant role that industrial activities play in contaminating groundwater sources. Adebayo's research found that industrial effluents are among the primary contributors to groundwater pollution in the Ilorin Asa River Basin. These effluents, often rich in heavy metals such as lead (Pb), cadmium (Cd), and copper (Cu), are discharged into the environment without proper treatment, leading to their infiltration into the groundwater system. In particular, elevated concentrations of these metals in groundwater samples have been reported, surpassing permissible limits for drinking water as defined by the World Health Organization (WHO). These heavy metals are harmful to human health, as they can accumulate in the body and cause long-term health problems such as kidney damage, neurological issues, and developmental delays in children.

Ajala, O. N., 2015, in his study *"The Assessment of Water Quality for Irrigation and Sediment along Asa River"*, further elaborates on the role of agricultural runoff in groundwater contamination. Ajala's research identified that the use of chemical fertilizers, pesticides, and herbicides in agricultural practices significantly contributes to the contamination of both surface water and groundwater in the Ilorin Asa River Basin. Excess nutrients, particularly nitrates from fertilizers, leach into the groundwater, posing a serious health threat, especially to infants, due to the risk of methemoglobinemia (blue baby syndrome). Furthermore, the study also points out that these agricultural chemicals not only degrade water quality but also harm aquatic ecosystems when they make their way into surface waters like the Asa River, which serves as a primary source of groundwater recharge.

Additionally, improper waste disposal practices, including the disposal of untreated sewage and solid waste, exacerbate the pollution problem. **Adebayo, S. A. (2005)** points out that in areas with inadequate waste management infrastructure, leachates from landfill sites and septic tanks can seep into the groundwater, carrying with them pathogens and toxic substances, further contaminating the water supply.

The elevated levels of heavy metals and other contaminants in the groundwater are of significant concern, as they pose serious health risks to the local population. These pollutants are not only harmful when consumed directly but can also affect agricultural produce, further complicating food security and public health in the region. As a result, there is an urgent need for enhanced water quality monitoring programs, stricter enforcement of pollution control measures, and the implementation of sustainable industrial and agricultural practices to safeguard groundwater resources.

2.6 HUMAN ACTIVITIES AND GROUNDWATER VARIABILITY

Human activities have significantly altered the natural dynamics of groundwater in the Ilorin Asa River Basin, impacting both its availability and quality. These impacts are primarily due to urban expansion, industrial development, agricultural intensification, and inadequate waste management practices. These anthropogenic pressures have contributed to noticeable changes in groundwater variability over time, resulting in fluctuating water tables, pollution, and reduced recharge capacity.

Adebayo, S. A., 2005, in his study *"Effect of Waste Discharges on the Water Quality of Asa River in Ilorin, Nigeria"*, observed that urbanization and industrialization around the Asa River have led to a direct discharge of untreated industrial effluents into the surrounding environment. These effluents contain heavy metals and other pollutants that seep into both surface water and groundwater. The poor enforcement of environmental regulations in urban Ilorin has further exacerbated this issue, allowing harmful substances to persist in the environment and infiltrate local aquifers. This has led to a degradation of groundwater quality and a rise in health risks for local populations relying on wells and boreholes.

Urban development also contributes to groundwater variability by altering the natural land surface. The construction of impervious surfaces such as roads, buildings, and paved areas reduces the land's ability to absorb rainwater. This hinders natural recharge processes, particularly during the rainy season, and limits the replenishment of the underlying aquifers. As a result, groundwater levels in urbanized areas tend to decline more rapidly during dry seasons due to reduced recharge and continued abstraction.

Ajala, O. N., 2015, in his work *"The Assessment of Water Quality for Irrigation and Sediment along Asa River"*, noted that agricultural activities in peri-urban and rural parts of the basin also play a major role in groundwater variability. Large volumes of groundwater are extracted for irrigation, especially during the dry season when rainfall is insufficient. This over-extraction, if not balanced by recharge, leads to a progressive lowering of the water table. In addition, the application of chemical fertilizers and pesticides contributes to the contamination of groundwater through infiltration and runoff, further affecting its suitability for both drinking and farming.

Furthermore, poor waste management practices—such as open dumping of refuse and the use of shallow pit latrines—facilitate the percolation of pollutants into the groundwater. **Adebayo, S. A., 2005** pointed out that in unplanned urban settlements, the lack of proper drainage and waste disposal systems increases the risk of contamination from human and animal waste. This not only reduces groundwater quality but also introduces pathogenic microorganisms into the water supply, posing severe health risks.

In summary, human activities in the Ilorin Asa River Basin have altered groundwater availability and quality. The combination of reduced recharge due to land use changes and increased demand for groundwater abstraction results in a volatile and vulnerable groundwater system. To manage this variability, there is an urgent need for improved urban planning, stricter environmental regulation, sustainable agricultural practices, and public education on groundwater protection.

2.7 GROUNDWATER MANAGEMENT STRATEGIES

The sustainable management of groundwater in the Ilorin Asa River Basin is essential due to the increasing pressure from human activities and the resulting degradation in groundwater quantity and quality. To ensure long-term water security in the region, a comprehensive, integrated approach is required—one that combines monitoring, pollution control, public education, policy enforcement, and infrastructure development.

Monitoring and Assessment

Regular monitoring of groundwater levels and quality is critical for detecting trends and identifying potential contamination risks early. **Adebayo, S. A., 2005**, in his study *"Effect of Waste Discharges on the Water Quality of Asa River in Ilorin, Nigeria"*, emphasized the need for continuous assessment of both surface and groundwater sources. Monitoring helps establish baseline data and track fluctuations caused by seasonal changes or human impacts such as over-abstraction or pollution. This information is vital for guiding decision-making and resource allocation.

Pollution Control

To safeguard groundwater quality, strong pollution control measures must be implemented. This includes the treatment of industrial effluents before discharge, improved regulation of agricultural practices, and the use of environmentally friendly pesticides and fertilizers. **Ajala, O. N., 2015**, in *"The Assessment of Water Quality for Irrigation and Sediment* *along Asa River"*, recommended stricter controls on agricultural runoff and industrial waste to prevent toxic substances such as nitrates and heavy metals from infiltrating aquifers. The promotion of best practices in farming such as precision agriculture and organic fertilizers can also help minimize pollution.

Public Awareness and Education

Raising awareness among local communities is a cornerstone of sustainable groundwater management. Many residents rely on shallow wells and boreholes for daily water use, often unaware of the potential contamination risks from nearby waste disposal or farming activities. Public education campaigns—especially in local languages—can increase understanding of how individual actions affect groundwater. **Adebayo, S. A., 2005** noted that community engagement is crucial for changing behavior and encouraging water conservation.

Policy and Regulation

Effective groundwater governance depends on the enforcement of environmental policies and water-use regulations. This includes limiting the discharge of pollutants, licensing borehole construction, and enforcing zoning laws that protect recharge zones. **Ajala, O. N., 2015** emphasized that many of the existing laws in Kwara State are either weak or poorly enforced. Strengthening institutional frameworks and empowering regulatory agencies can greatly enhance compliance and accountability.

Infrastructure Development

The lack of basic infrastructure—such as wastewater treatment plants and engineered landfills—has allowed pollutants to seep into the groundwater system. Investment in proper solid waste management and sewage treatment facilities is essential to prevent further contamination. For example, poorly constructed septic systems in residential areas near the Asa River have been identified by **Adebayo, S. A., 2005** as a key source of groundwater contamination. Building and maintaining such infrastructure not only improves water quality but also public health outcomes.

CHAPTER THREE

3.0 METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the research design, methods, and tools employed in the study of the spatial and temporal variation of groundwater in the Asa River Basin. The study aims to assess groundwater levels, quality, and changes in both spatial and temporal contexts. The methodology focuses on the collection of data, which will then be analyzed to understand the distribution and trends of groundwater within the basin. This chapter also provides the rationale behind the chosen methods, justifying their suitability for addressing the research objectives outlined in Chapter One.

3.2 STUDY AREA

The Asa River Basin is located in Kwara State, Nigeria. The river flows across both urban and rural regions, providing a source of surface water to various communities, which also rely on groundwater for domestic, agricultural, and industrial purposes. The basin is characterized by diverse geology, topography, and land use, contributing to variations in groundwater distribution and quality.

The region experiences both wet and dry seasons, with annual rainfall varying significantly across different areas of the basin. Groundwater in this basin plays a vital role, especially during the dry season when surface water sources diminish. This study focuses on areas surrounding the Asa River, where both surface water and groundwater are integral to local livelihoods.

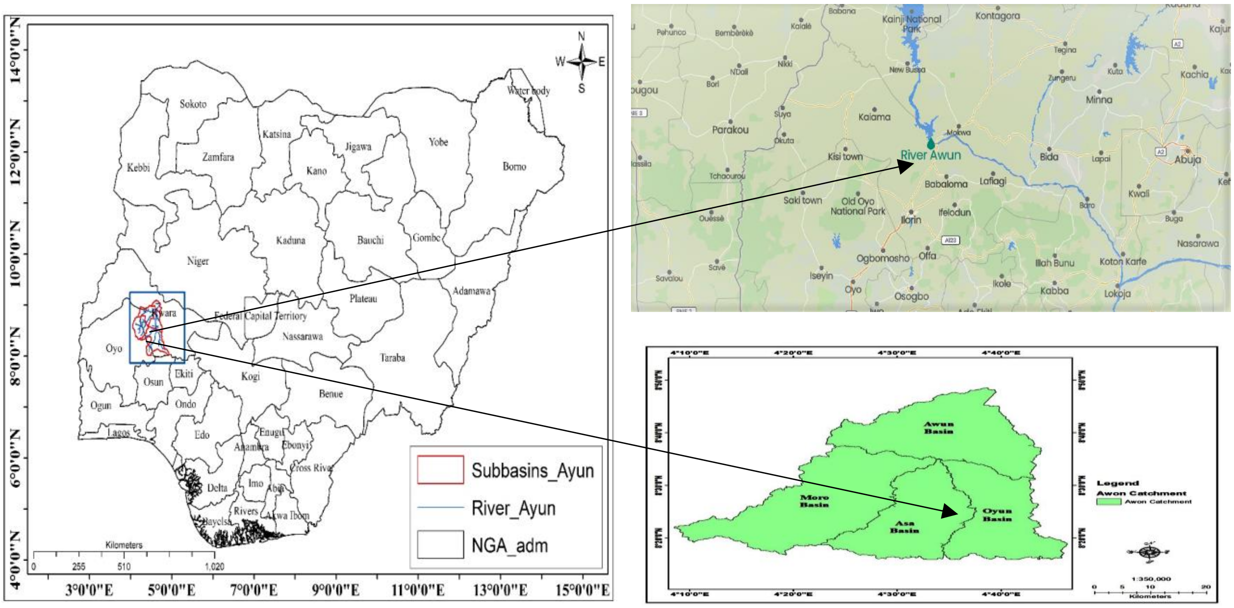

Figure 1: Show the study area Source:
https://www.tandfonline.com/cms/asset/c565930b-f12c-4019-b76-3c5e32bb00e2/oaes_a_1295696_f0007_oc.gif

3.2 MODEL SELECTION

The model used in this study is the soil and water Assessment Tool, SWAT (neitsch *et al.,* 2005). The selection of SWAT for this study was based on many reasons which are listed as follows

I. SWAT is an existing, readily available software freely available on SWAT website

II. It has several user’s groups e.g SWAT Africa, SWATworld and water base Goggle group which serves as plus to the acceptability of the tool among researchers.

III. Its availability and efficacy in prediction of different hydrological processes has also been reported in many studies (Adeogun *et al.*, 2015) which make it attractive to engineers and other users.

3.2.1 INTRODUCTION TO SWAT MODEL DESCRIPTION

The modeling tool was interfaced with Map Window GIS to simulate the hydrology and predict the flow into sub-basins in the watershed. The model developed by the Agricultural Research Service of the United Stated Department of Agriculture (ARS-USDA) simulates eight components of the environment system, i.e., hydrology, generation of weather data, Sedimentation process, soil energy balance, crop growth, nutrient and pesticide leaching and agricultural management (Neitsch *et al.*, 2002). SWAT is a semi-distributed model using process descriptions that are either empirically or physically limited in its process basis, operating on a daily time step. SWAT uses hydrologic response units

(HRUs) to describe the spatial heterogeneity in terms of land cover and soil type.

The model simulates the hydrologic processes at four levels:

the soil surface:

I. the intermediate unsaturated zone.
II. the shallow and deep aquifers.
III. the open channels.

Relevant hydrologic components such as evapotranspiration, sur-face runoff, groundwater flow and soil moisture change are estimated at the level of each HRUs. Streamflow in the main channel is the sum of the surface runoff, the literal and baseflow. For predicting the runoff volumes, SWAT use a modified computational efficient version of the Soil Conservation Service Curve Number (SCS CN) method (SCS-USDA 1972), relating runoff to soil type, land use and management practices. In addition, SWAT uses an empirical procedure for channel routing. The base flow recession constant is calculated using an equation suggested by Steadman & Rycroft (1983), a function of the overall basin topography, drainage pattern, soils and geology composition of the watershed.

3.2.2 THE CONCEPTUAL MODEL

SWAT incorporates the effects of weather, surface runoff, evapotranspiration, irrigation, sediment transport, groundwater flow, crop growth, nutrient yielding, pesticide yielding and water routing, as well as the long-term effects of varying agricultural management practices. In the SWAT model, the watershed is partitioned into sub basins that are further subdivided into one or several homogeneous hydrological response units (HRUs) with relatively unique combinations of land cover, soil and topographic conditions. The hydrological component of the model calculates soil-water balance at each time step based on daily amounts of precipitation, runoff, evapotranspiration, percolation and base flow.

3.3 MODELING TOOL AND GIS INTERFACE

A geodata model and geographic information system (GIS) interface for the Soil and Water Assessment Tool (SWAT). The SWAT data model is a system of geodatabases that store SWAT geographic, numeric, and text input data and results in an organized fashion. Thus, it is proposed that a single and comprehensive geodatabase be used as the repository of a SWAT simulation. The SWAT interface uses programming objects that conform to the Component Object Model (COM) design standard, which facilitate the use of functionality of other windows-based applications within SWAT. In particular, the use of MS Excel and MATLAB functionality for data analysis and visualization of results is demonstrated.

3.4 MODEL INPUT DATA COLLECTION PROCESSING

The spatially distributed data (GIS input) needed for the running of Map Window SWAT include the DEM, soil data, land use and stream network layers. Weather data are also necessary for prediction of stream flow in the watershed. The GIS interface of the model was used to discretize the catchment area and geo-processed the spatial data into formats required by the model.

3.4.1 DIGITAL ELEVATION MODEL (DEM)

The topographical data used for this study was obtained from the Shuttle Radar Topography Mission (SRTM) final version, a 90-meter resolution Digital Elevation Model (DEM) developed by CGIAR (2012). The CGIAR-CSI Geo-Portal provides SRTM 90m DEM data for a significant portion of the world. To enhance the usability of this DEM data, it has undergone processing to fill data gaps and meet the needs of various user groups. CGIAR (2012) aims to promote the use of geospatial science and applications in sustainable development and resource conservation efforts, particularly in developing countries. In this study, the SRTM DEM was utilized for watershed delineation into sub-basins and derivation of topographic parameters, including terrain slope, channel slope, and reach length. Digital Elevation Model of the study which is as shown in figure

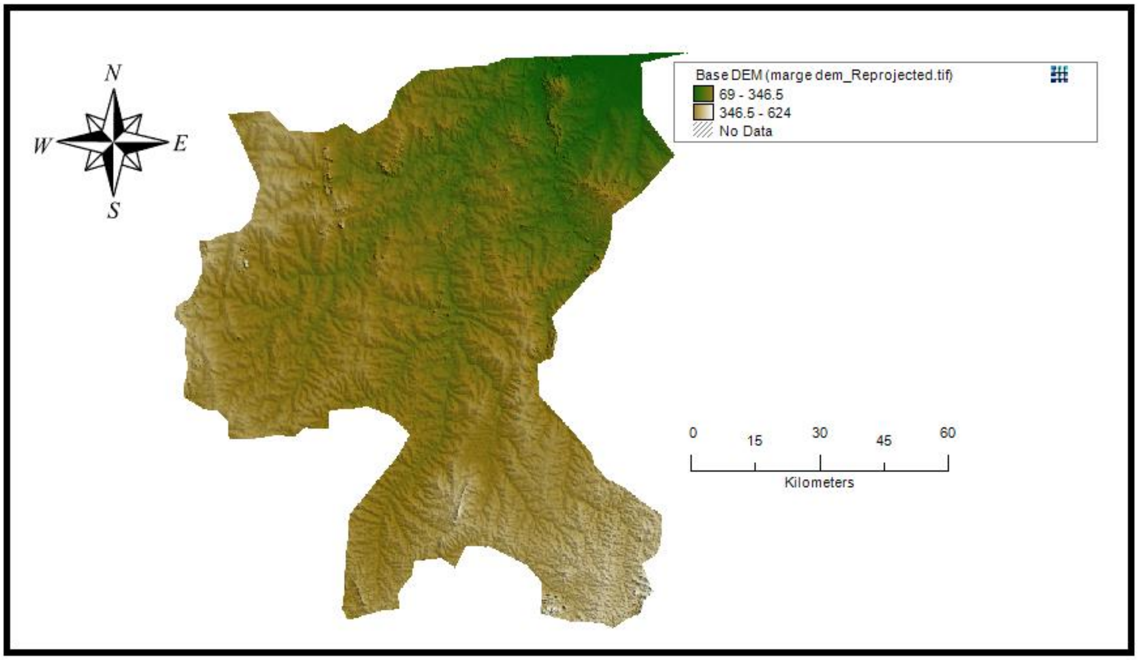

Figure 3.1: Digital elevation model (DEM) of the study area

3.4.2 LAND COVER/LAND USE

The land use map required for SWAT analysis was obtained from the Global Land Cover Characterization (GLCC) database, which was developed by the United States Geological Survey (USGS). This database has a spatial resolution of 1 km and represents land use in 24 distinct classes (GLCC, 2012). The land use data from GLCC was used to estimate vegetation and other parameters for the watershed area. To enhance accuracy, field visits to the watershed area were conducted to gather on-site information regarding land use and land cover. Information collected during these visits was utilized to update the GLCC database and generate the final land use map for this study. Land use map of the study area is shown in figure 3.4.2 shows information on land use/cover of the study area.

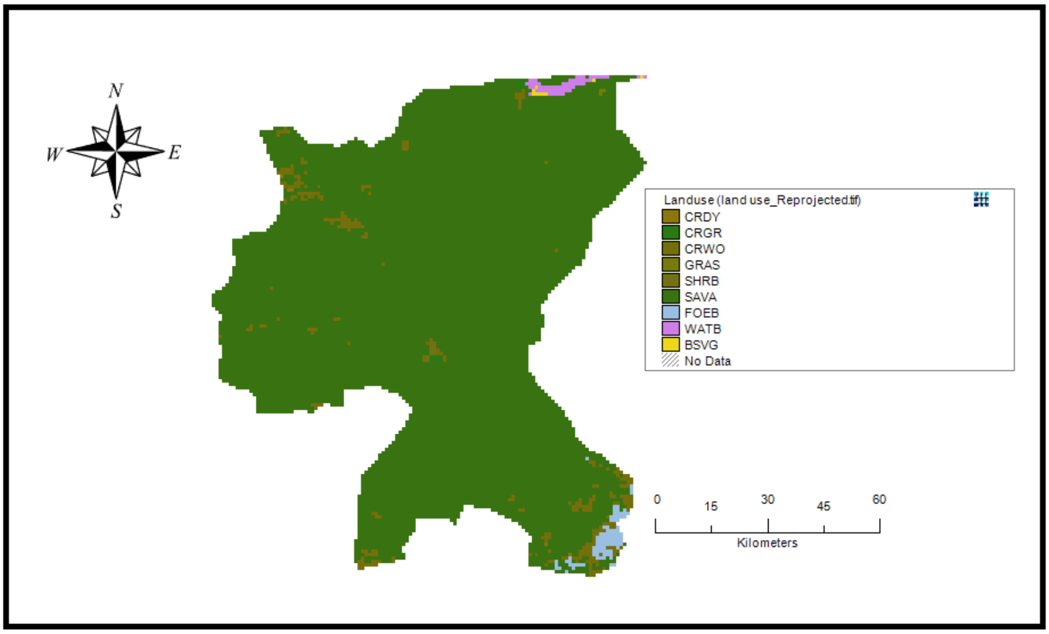

Figure 3.2 shows information on land use/cover of the study area.

3.4.3 DIGITAL SOIL DATA

The necessary digital soil information for this study was derived from the Harmonized World Soil Database (HWSD), a comprehensive global digital soil map developed by the Food and Agriculture Organization of the United Nations (FAO). The database was accessed on May 30, 2013, and comprises detailed soil data essential for the analysis conducted in this research.

The HWSD is an invaluable resource that contains soil data from various sources around the world, harmonized to ensure consistency and comparability across regions. This database has been used extensively in environmental modeling, land management, and agricultural planning. For this study, the digital soil data obtained from HWSD provided crucial input parameters for understanding the watershed's characteristics and evaluating its hydrological processes.

The digitized soil map was completed in January 2003 data for 16,000 different soil mapping units containing two layers (0 - 30 cm and 30-100 cm depth). Seven soil units are then extracted from the database and completed by additional information gathered by taken soil samples from different locations within the watershed area. 16 soil samples were collected from two different layers (0 - 30 cm and 30 - 100 cm depth) and the samples were analyzed and used to update the model parameters.

3.4.4 WEATHER DATA

To effectively drive hydrological balance simulations within the SWAT model, daily weather variables such as minimum and maximum temperatures, wind, relative humidity, and solar radiation are required. These vital data inputs were sourced from the Nigerian Meteorological Agency (NIMET) based is an organization known for its reliable meteorological data collection in Nigeria. The dataset acquired encompassed a 19-years period, ranging from January 1, 2001, to December 31, 2019. NIMET's comprehensive and long-term meteorological records are indispensable for studying and comprehending the region's climatic patterns and any possible changes that may have occurred. These data serve as crucial input parameters for hydrological modeling, enabling researchers and policymakers to evaluate water resource availability, potential hydropower production, and the impacts of climate change on the area.

3.5 WATERSHED DELINEATION IN SWAT

Employing the Digital Elevation Model (DEM), we delineated the watershed boundaries of ASA River within the SWAT model. This process was pivotal in defining the spatial extent for our hydrological simulations, providing a precise framework for evaluating the hydrological process and nitrate loading

3.6 WATERSHED DELINIATION INTO SUB BASINS AND HYDROLOGICAL RESPONSE UNITS (HRUs)

The Soil and Water Assessment Tool (SWAT) model was employed for sub-basin delineation of the watershed and further division of sub-basins into Hydrologic Response Units (HRUs). SWAT is a continuous-time, watershed-scale model that effectively simulates long-term yields to determine the impacts of land management practices (Arnold and Allen, 1999).

To initiate the delineation process, the Automatic Watershed Delineation (AWD) dialogue box was activated from the model interface, and the base Digital Elevation Model (DEM) was selected. The elevation units were set to meters, corresponding to the base DEM's units. A focusing mask encapsulating the watershed was drawn and saved as a shape file. The model's threshold size for sub-basins was established, with options to set it by area or number of cells. For this study, a threshold value of 20 km² was chosen. To complete the settings, an outlet point shape file was created and selected.

Following the execution of AWD, the selected watershed was delineated into a total of 5 sub-basins, which were then further divided into 6 HRUs. Each HRU possesses a unique combination of land use, slope, and soil characteristics.

3.7 SWAT SETUP AND RUN

In this phase, the simulation period (start and end date) for the modeling exercise was defined, and the weather sources were selected from the SWAT database. The simulation period for this study spanned from January 1, 2001, to December 31, 2019. Essential files required to run SWAT were prepared at this stage, and the appropriate weather sources were chosen before initiating the SWAT model.

Several methods for simulating surface runoff were available to choose from at this point, including the Curve Number and Green-Ampt methods. Additionally, channel water routing methods such as the variable or Muskingum method could be selected. The potential evapotranspiration method was employed in this study, specifically designed to compute river drop. The chosen method was either Priestley, Penman-Monteith, or Hargreaves.

Prior to executing the SWAT model, all necessary files were generated, and the appropriate weather sources were confirmed to ensure accurate model simulations.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Analysis Of the Result

The table below shows the result gotten from the SWAT Model with different subbasins:

SUBBASIN	AREA (km2)	WYLD (mm)
27	74.77	541.88
26	23.53	540.88
32	0.90	529.54
24	24.35	529.66
33	0.75	529.69
23	20.74	536.42
22	20.72	529.73
21	21.15	529.67
25	64.27	553.49
18	20.48	529.68
19	22.15	529.66
35	33.61	529.59
17	31.07	529.65
37	19.96	529.58
28	23.03	529.59

SUBBASIN	**AREA (km2)**	**WYLD (mm)**
16	38.00	529.76
38	5.02	529.67
20	75.03	529.60
34	97.70	529.57
13	24.08	530.42
12	26.67	529.72
14	34.33	529.60
15	43.17	529.53
29	14.30	529.72
30	7.13	529.66
40	47.51	529.57
11	31.19	529.63
31	13.47	529.40
36	6.62	529.43
9	30.87	529.72
39	88.69	529.44
41	50.13	529.64
43	19.35	529.43
44	2.63	529.48
10	77.47	529.49
8	52.02	529.32
42	85.07	529.61

SUBBASIN	AREA (km2)	WYLD (mm)
46	0.44	529.38
7	31.56	529.66
6	40.84	529.57
47	7.95	529.67
45	77.96	529.70
5	22.18	556.15
48	20.78	553.53
4	20.88	529.69
2	21.51	529.67
3	29.47	529.74
50	35.61	529.78
1	30.30	596.71
49	48.87	596.67
51	17.91	596.81
52	59.38	529.65
0	0.00	0.00
Total	**1737.54**	**27846.48**

From the table, the variation in water yield across 52 sub-basins within the Asa River Basin, modeled using the SWAT tool. The water yield values (in mm) represent the volume of water available after evapotranspiration and other losses, reflecting how much water contributes to streamflow from each sub-basin. The most significant water yields were recorded in sub-basins 1, 49, and 51, with values exceeding 596 mm. These areas stand out distinctly and may be characterized by favorable topography, vegetation cover, and soil types that enhance infiltration and baseflow contributions. In contrast, most other sub-basins yield water in a narrow range between 529 mm and 530 mm, indicating a generally uniform hydrological behavior across much of the basin. This relative uniformity suggests consistency in land use and soil conditions in the majority of the catchment. However, a few sub-basins like 5 and 48 also show moderately high yields (above 550 mm), which may point to pockets of more productive or preserved landscapes within the basin.

4.1.1 Objective 1: Prediction of Groundwater Amount

Groundwater quantity, expressed as GW_Q (mm), was estimated for each subbasin. The values range from 236.93 mm (Subbasin 13) to 278.65 mm (Subbasin 1), indicating moderate to high levels of groundwater availability throughout the watershed.

The total groundwater amount across the modeled area (excluding subbasin 0) was computed to be 12,765.06 mm over a combined area of 1,739.29 km^2**.** Subbasins 1, 49, and 51 exhibited the highest groundwater values, suggesting favorable recharge conditions or higher aquifer capacities in these zones.

4.1.2 Objective 2: Estimation of Groundwater Recharge

Groundwater recharge was estimated based on the GW_Q values and the respective subbasin areas. The consistently high GW_Q values (>240 mm in most subbasins) indicate robust recharge processes across much of the watershed. Notably, subbasins such as 1, 49, and 51—with GW_Q values of 278.65 mm**,** 278.25 mm**,** and 276.90 mm respectively—suggest areas of particularly high recharge potential.

This suggests that the watershed is generally well-recharged, making it a valuable groundwater resource zone for agricultural and domestic use, especially in areas with consistently high recharge.

4.1.3 Objective 3: Analysis of Groundwater Contribution

Groundwater contribution across the subbasins demonstrates relatively uniform values with slight local increases. The average GW_Q across all subbasins is approximately 243 mm**,** indicating a strong groundwater influence in baseflow generation and water availability.

The high contributions in subbasins like 5 (256.95 mm), 25 (257.02 mm), and 48 (254.55 mm) may reflect either higher infiltration capacity or less surface runoff, which enhances groundwater recharge and sustains baseflows during dry periods.

4.1.4 Objective 4: Spatial Variation Analysis

A spatial analysis of GW_Q across the subbasins reveals a generally consistent distribution with some localized variations. Subbasins with exceptionally high GW_Q (e.g., Subbasin 1, 49, 51) are scattered across the watershed, suggesting that topography, soil characteristics, land cover, and geological formations play a role in shaping recharge potential.

Conversely, subbasins with slightly lower values (e.g., Subbasin 13, 50, and 47) may be influenced by lower permeability soils, higher runoff, or reduced rainfall infiltration due to land use. Mapping these values across the watershed allows for identification of groundwater-rich zones and areas that may require recharge enhancement measures.

4.2 Prediction of Groundwater Amount

Groundwater quantity (GW_Q in mm) was estimated for all 52 subbasins, covering a total area of 1,739.29 km^2**.** The groundwater values range from 236.93 mm in Subbasin 13 to 278.65 mm in Subbasin 1, indicating spatial differences in groundwater availability. Subbasins 1, 49, and 51 recorded the highest groundwater amounts, suggesting favorable hydrogeological conditions and effective recharge mechanisms in these areas.

4.3 Estimation of Groundwater Recharge

Groundwater recharge was inferred from the groundwater quantities and area coverage of each subbasin. The majority of subbasins exhibited recharge values exceeding 240 mm**,** indicative of strong infiltration and recharge processes. Notably, subbasins such as 25 (257.02 mm), 5 (256.95 mm), and 48 (254.55 mm) showed relatively higher recharge estimates, highlighting zones with potentially higher aquifer replenishment rates.

4.4 Analysis of Groundwater Contribution

The groundwater contribution across the watershed demonstrates a generally uniform distribution, with an average recharge of approximately 243 mm**.** Elevated contributions in subbasins such as 5, 25, and 48 may reflect favorable soil permeability and lower surface runoff. These contributions are vital for sustaining baseflow and maintaining streamflow during dry periods.

4.5 Spatial Variation Analysis

Spatial variation analysis revealed distinct patterns of groundwater recharge across the watershed. While most subbasins cluster around the average GW_Q values, higher groundwater values are concentrated in subbasins 1, 49, and 51, which may be influenced by factors such as soil texture, land cover, and topographic relief. Conversely, subbasins with lower groundwater values (e.g., 13, 50, 47) might experience reduced infiltration due to impermeable surfaces or greater runoff.

These spatial differences highlight the heterogeneity of the watershed's groundwater system and underscore the importance of targeted groundwater management approaches adapted to local conditions.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The groundwater model successfully estimated groundwater quantities and recharge potential across 52 subbasins (excluding subbasin 0) within the watershed. The total area analysed was 1,739.29 km², with a combined groundwater contribution of 12,765.06 mm.

1 Prediction of Groundwater Amount: Groundwater values varied from 236.93 mm to 278.65 mm, with Subbasins 1, 49, and 51 showing the highest contributions. These values suggest high groundwater availability in large portions of the watershed.

2 Estimation of Groundwater Recharge: The model indicates strong recharge activity, with most subbasins exceeding 240 mm of groundwater contribution. Subbasins with GW_Q values above 275 mm are prime zones for aquifer recharge and sustainable extraction.

3 Groundwater Contribution Analysis: Average groundwater contribution was around 243 mm, indicating a significant baseflow

component in the hydrological cycle, especially in Subbasins 5, 25, and 48.

4 Spatial Variation Analysis: While most subbasins demonstrated relatively uniform groundwater contributions, specific areas exhibited higher or lower recharge due to differences in land use, soil, and topography. Spatial variability helps in identifying priority zones for groundwater protection or enhancement.

5.2 RECOMMENDATIONS

- Protect High-Recharge Zones: Safeguard subbasins with high groundwater contributions (e.g., Subbasins 1, 49, 51) through land use control and reduced surface sealing.
- Artificial Recharge in Lower Zones: Consider implementing artificial recharge techniques in subbasins with lower GW_Q values to improve groundwater levels, especially where water demand is high.
- Sustainable Groundwater Extraction: Promote sustainable pumping rates in high-yield subbasins to prevent over-extraction and long-term depletion.
- Integrated Groundwater Management: Incorporate spatial groundwater data into broader watershed management plans to ensure coordinated use of surface and groundwater resources.
- Groundwater Monitoring Program: Establish a continuous monitoring network to track changes in groundwater levels, recharge rates, and usage across subbasins.

- Land Use Planning: Encourage land practices that promote infiltration (e.g., conservation agriculture, afforestation) in critical recharge areas.

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