HYDROLOGICAL AND NITRATE LOADING MODELLING OF AGBA DAM, ILORIN KWARA STATE.

BY

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CERTIFICATION

This is to certify that this project was conducted by AFOLABI Abdullateef Oluwatotin (HND/23/CEC/FT/0235) 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 project 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. M. Wopa 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 presents the development and application of a hydrological model to assess water flow and nitrate loading within the Agba Dam watershed in Ilorin, Kwara State, Nigeria. The primary objectives were to develop a robust hydrological model for the Agba River watershed, predict streamflow and nitrate transport into the dam under varying conditions, and evaluate spatial and temporal variations in flow and nitrate concentrations across different subbasins. The Soil and Water Assessment Tool (SWAT) was utilized to delineate the watershed and simulate nitrate loading based on input parameters such as land use, topography, and soil characteristics. A total of 15 subbasins were modeled, covering a cumulative area of 1,721.92 km². The simulation results revealed significant spatial variability in nitrate input across the watershed. Subbasin 6 recorded the highest nitrate load (9,174.23 kg), followed by Subbasins 3, 4, and 8, indicating possible agricultural or urban sources. In contrast, Subbasins 2 and 1 exhibited the lowest nitrate levels, suggesting minimal anthropogenic impact or effective natural filtration. The total nitrate input across the watershed was estimated at 28,415.15 kg, highlighting the scale of nutrient loading into the dam. The model provided valuable insights into the hydrological and pollutant transport dynamics of the watershed, identifying critical zones for intervention. These findings can support targeted land use management, pollution control, and watershed protection strategies.

Overall, this study demonstrates the utility of hydrological modelling as a decision-support tool for assessing nutrient loading and informing sustainable water resource management in the Agba Dam catchment.

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INTRODUCTION

1.1 BACKGROUND OF STUDY

Water is a critical resource for ecosystems, agriculture, and human consumption. The study of hydrological processes and nitrate levels examines the movement, distribution, and quality of water on Earth. Nitrate pollution, often stemming from agricultural activities, poses risks to groundwater and surface water bodies. This research focuses on hydrological and nitrate loading modeling of Agba Dam, a significant water source for Ilorin, Nigeria. Evaluating water sources both quantitatively and qualitatively is a critical global issue, given the growing demand for high-quality freshwater, especially for drinking purposes (Nematollahi et al., 2022; Yazdandoost et al., 2022). To address this, detailed datasets are essential for estimating pollutants such as sediments and nitrates (Borah et al., 2006; Mallya et al., 2020) and for conducting water quality assessments. Non-point sources, which often contribute significantly to the deterioration of water quality, require precise measurement to ensure effective management (Gupta, 2016).

Nitrate, one of the main components of nitrogen stored in water, is mainly derived from external sources including domestic sewage, inorganic/organic fertilizer residual, soil organic nitrogen linked to mineralization and nitrification and others (Xu et al., 2021; Kendall et al., 2007; Xue et al., 2009). Sediment pollution can clog waterways, cause flooding, and reduce water quality for domestic uses (drinking, cooking), recreational uses and/or municipal and industrial uses (Ramesh et al., 2021; Ribaudo et al., 1999).

Forests serve a dual function as both a source and a sink of nutrients, playing a crucial role in shaping the nutrient dynamics of a watershed (Osman, 2013). The nutrient export rate from forests refers to the amount of nutrients, including nitrogen and phosphorus, present in both dissolved and particulate forms, that are carried from forested areas to surrounding water bodies or downstream ecosystems. This movement occurs through mechanisms such as surface runoff, subsurface flow,

groundwater, and streamflow. The export rate is a vital component in understanding the role of forests in nutrient cycling and their influence on water quality and ecosystem health within the watershed. Minimizing nutrient losses is essential for maintaining the overall balance of the ecosystem. Nitrate loading modeling in the Agba dam watershed primarily focuses on predicting the movement of nitrate through the soil. Nitrate typically originate from agricultural fertilizer, sewage, and industrial effluents (Abbaspour, 2017).

1.2 PROBLEM STATEMENT

Agricultural practices near Agba Dam significantly contribute to nitrate pollution. Excessive nitrates lead to environmental risks like eutrophication and health hazards from contaminated drinking water. However, existing studies lack comprehensive modeling to accurately understand the nitrate loading dynamics in this watershed. This project seeks to bridge this gap by modeling the dam's hydrology and nitrate transport mechanisms.

1.3 AIM AND OBJECTIVES

AIM

The aim of the project is to develop hydrological and nitrate loading modeling of Agba dam, Ilorin Kwara state.

OBJECTIVES

The specific objectives are:

i. To develop a hydrological model for the Agba river watershed
ii. To predict flows and nitrate loading to the dam under various conditions.
iii. To evaluate spatial and temporal variations in water flow and nitrate concentrations

1.4 JUSTIFICATION OF THE STUDY

Understanding Water Availability: Hydrological models are critical for assessing water availability by simulating the movement of water through the watershed. These models include the relationship between rainfall and runoff, infiltration, groundwater recharge, and streamflow predictions, all of which are vital for effective water resource management (Koster et al., 2000).

Predicting Floods and Droughts: Accurate modeling helps in forecasting potential flood and drought events by analyzing historical and current hydrological data. This

predictive capability is crucial for disaster preparedness and management (Bates & De Roo, 2000).

Monitoring Water Quality: Modeling nitrate loading provides insights into water quality by tracking the sources and concentrations of nitrates. This is important for ensuring the safety of water resources and managing contamination levels (Gordon et al., 2001).

1.5 SCOPE OF THE STUDY

The Agba Dam catchment area in Ilorin, Kwara State, covering its hydrology, land use, and water quality characteristics. Modeling hydrological processes, including runoff, streamflow, and nutrient transport. 20 years data will be used to project the future scenarios based on land-use and climate variability.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 REVIEW ON HYDROLOGICAL MODELLING

Hydrological modeling, exemplified by tools such as the Soil and Water Assessment Tool (SWAT), offers a cost-effective alternative to field monitoring for evaluating the impacts of agricultural practices on water and nutrient dynamics. SWAT is a watershed-scale model that simulates hydrology, plant growth, and water quality under a variety of management practices and environmental conditions. Its reliability has been validated across a wide range of climates and landscapes.

Exploring and Predicting the Individual, Combined, and Synergistic Impact of Land-Use Change and Climate Change on Streamflow, Sediment, and Total Phosphorus Loads (Xie et al., 2022) shows Future climate change alone is likely to increase the annual streamflow and sediment load and decrease the annual total phosphorus loads, as well as its intra- and interannual variations. The SWAT was used to simulate water quantity and quality based on climate and land-use change

and not the sediment and nitrate loadings.

Evaluating Impacts of Detailed Land Use and Management Inputs on the Accuracy and Resolution of SWAT Predictions in an Experimental Watershed (Qi et al.,2022) found that detailed land use and management inputs improved the accuracy and resolution of SWAT predictions. Further exploration needed regarding SWAT sensitivity to varying levels of land use and management information Assessing nutrient and sediment load reduction potential of vegetation by utilizing the nutrient tracking tool at the field and watershed scale in a Great Lakes priority watershed (Pawlowski et al., 2023) disparities between modeled and measured phosphorus exports were observed at the watershed scale, while modeled sediment exports fell within observed gauge data ranges. Further refinement needed to improve the accuracy of modeled results compared to measured edge-of-field export data.

Modeling Diffuse Nutrient and Sediment Pollution affecting Lake Palakpakin, Laguna using QSWAT (Linato et al., 2023) found that the critical source areas for NO3-N and PO4 were identified in agricultural lands and areas underlain by clay and clay loam. Inadequate hydrological data led to the use of an uncalibrated simulation, indicating a need for improved data collection.

Evaluating SWAT model performance, considering different soils data input, to quantify actual and future runoff susceptibility in a highly urbanized basin (Busico et al., 2020) found that SL1, despite lower soil resolution, is identified as the most effective simulation for describing watershed streamflow. A susceptibility map successfully pinpoints eleven urbanrelated sub- basins as highly prone to runoff. Further validation is needed across diverse watershed characteristics and climatic conditions.

A secondary assessment of sediment trapping effectiveness by vegetated buffers (Ramesh et al., 2021) found that an exponential regression model, emphasizing the relationship with flow variables, explains 50% of the variance in sediment removal efficiency and considering flow parameters is crucial in buffer design for water quality improvement at local scales. Exploring additional factors influencing buffer efficiency, validating findings across diverse ecosystems, and assessing long-term buffer performance could be done.

SWAT has demonstrated effectiveness in modeling tile-drained agricultural fields. For instance, research by Guo et al. (2018) showed that SWAT 2012 enhanced prediction accuracy for tile drainage flow by incorporating modified computational methods and equations. Likewise, studies by Moriasi et al., (2012) and Boles et al. (2015) confirmed that SWAT 2012 successfully simulated tile flow and nutrient loads, even in regions with limited detailed drainage system data. These advancements underscore the utility of SWAT in watershed management and nutrient transport modeling within agricultural landscapes.

SWAT model application for evaluating agricultural conservation practice effectiveness in reducing phosphorous loss from the Western Lake Erie Basin (Yuan & Koropeckyj-Cox, 2021) stated satisfactory performance for streamflow and sediment, unsatisfactory for phosphorus loads, especially soluble reactive phosphorus. The study did not emphasize in predicting the sediment or nitrate loadings of the Western Lake Erie Basin.

The study of hydrological processes and nitrate levels focuses on the movement and distribution of water on Earth's surface. Understanding how nitrates, which frequently enter aquatic systems through agricultural runoff, contribute to groundwater contamination is crucial (He and McBratney, 2016). Nitrate loading through various hydrological processes varies both spatially and temporally. For example, the combination of snowmelt and rainfall can lead to substantial nitrate runoff from agricultural lands, exacerbating nitrate losses through surface runoff (Robertson, 2020).

Prediction of Nitrate and Phosphorus Concentrations Using Machine Learning Algorithms in Watersheds with Different Land-use (Bhattarai et al., 2021) found that machine learning algorithms can accurately predict nitrate and phosphorus concentrations in watersheds with different land use. Further exploration of algorithm performance under dynamic conditions and understanding is needed to be able to transfer the models to different regions. Nitrogen inputs into stream waters have significantly increased over recent decades due to human activities, including the use of agricultural fertilizers, livestock runoff, sewage discharge, and fossil fuel combustion. It is estimated that approximately one-third of anthropogenic nitrogen inputs ultimately enter streams and rivers (Jordan, 1997) Nitrate contamination in the Agba Dam represents a significant environmental and public health risk, including eutrophication of waterbodies and potential health hazards from contaminated drinking water (Smith et al.,2020). Understanding the dynamics of hydrological processes and nitrate loading is critical for effective watershed management and conservation efforts (Diaz et al.,2018). Hydrological modeling of the Agba Dam involves evaluating the dam's response to various hydrological conditions, such as rainfall, runoff, and evaporation. Models simulate the impact of these factors on the dam’s storage levels and its capacity to meet water demands. This modeling supports flood risk prediction, efficient water resource management, and the sustainable use of the dam’s capacity (Salami and Oladipo, 2015).

Predicting water quality trends resulting from forest cover change in an agriculturally dominated river basin in Eastern Ontario, Canada (Noteboom et al.,2021) found that land use scenarios with different rates of deforestation led to varying water quality trends. Need to understand underlying hydrological processes influencing streamflow and sediment dynamics.

2.2 IMPORTANCE OF HYDROLOGICAL MODELING

Water Resource Management and Storage: Agba Dam plays a critical role in regulating water supply for various uses, including irrigation, potable water provision, and hydroelectric power generation. Hydrological modeling facilitates the optimization of water resource management through the following avenues:

Flow Prediction: Accurate forecasts of inflow and outflow are essential for optimizing storage and release strategies. Hydrological models simulate streamflow and catchment dynamics, providing data to guide informed reservoir management decisions (Goswami et al., 2020).

Flood Risk Management: Understanding flood risks associated with extreme precipitation events is vital for ensuring the integrity of the dam's infrastructure. Hydrological models can simulate flood events and identify flood-prone zones, enabling the development of mitigation strategies (Djordjević et al., 2013).

Water Availability Forecasting: Through the simulation of seasonal variations and future climate scenarios, hydrological models predict water availability. This facilitates the management of seasonal water demands, ensuring a stable supply during periods of drought (Kundzewicz et al., 2014).

Impact of Land Use and Agricultural Activities:

Agricultural activities significantly influence hydrology and water quality in the Agba dam watershed. Nitrate loading modeling is crucial for understanding the impacts of these activities:

Runoff from Agricultural Lands: Fertilizer runoff from agricultural fields is a primary source of nitrate pollution in water bodies. Nitrate loading models quantify the impact of agricultural practices on water quality, identifying critical areas with elevated nutrient runoff (Withers et al., 2014).

Eutrophication Risk: Elevated nitrate concentrations can trigger eutrophication, disrupting aquatic ecosystems through excessive algal growth.

Modeling nitrate concentration variations across time and space enhances the ability to develop effective management strategies (Dodds et al., 2009).

Land Use Changes: Modifications in land use, such as deforestation or urbanization, alter both runoff patterns and nutrient loading. Hydrological models simulate these land use changes and assess their potential impact on water quality, providing a scientific basis for land and water management strategies (Piao et al.,2013).

Climate Change and Temporal Variability:

Both hydrological processes and nitrate loading are highly sensitive to climate variability. The changing climate in the Agba region affects rainfall patterns and runoff, thereby influencing water quantity and quality:

Changing Precipitation Patterns: Climate change is predicted to modify precipitation regimes, increasing both the frequency and intensity of rainfall events. This results in higher runoff and flood risks, which hydrological models can simulate to assist water managers in anticipating and mitigating these challenges
(Bates et al., 2008).

Increased Nitrate Leaching: In wetter conditions, more frequent and intense rainfall can exacerbate nitrate leaching into surface waters, aggravating water quality issues. Modeling future climate scenarios aids in predicting changes in nitrate concentrations under different climate conditions (Ahn et al., 2018).

Water Quality Monitoring and Pollution Control: Agba Dam is an essential water source for downstream communities and ecosystems. Nitrate loading modeling plays a pivotal role in addressing water quality concerns.

Assessing Nitrate Concentrations: Nitrate models help identify key sources of nitrate pollution, whether from agricultural runoff, wastewater, or urban inputs. By pinpointing pollution hotspots, targeted management actions, such as the adoption of best management practices (BMPs) in agriculture, can be prioritized (Smit et al., 2016).

Meeting Water Quality Standards: Nitrate concentrations in water may exceed safe limits for both human consumption and aquatic ecosystems. Modeling can assess whether the dam's water quality complies with regulatory standards and forecast potential violations, facilitating proactive intervention (WHO, 2017)

Reducing Treatment Costs: Understanding nitrate loading dynamics enhances the efficiency of water treatment processes, reducing the costs associated with treating polluted water and improving overall water quality (Graham & Dent, 2007).

Environmental Sustainability and Ecological Health: Hydrological changes and elevated nitrate levels can significantly impact the ecosystem of Agba Dam:

Aquatic Ecosystem Health: High nitrate levels can induce nutrient enrichment, promoting algal blooms that deplete oxygen levels, potentially causing fish kills and reducing biodiversity. Nitrate loading models assess the effects of nutrient enrichment, providing insights for strategies aimed at preserving biodiversity (Smith et al., 1999).

Groundwater Recharge: Hydrological models assess the interactions between surface water and groundwater, and how nitrate leaching influences groundwater recharge. This is particularly important in regions like Agba dam, where groundwater is a critical resource for local communities (Foster et al., 2004).

Regulatory and Policy Compliance: Nitrate loading modeling is integral to ensuring compliance with water quality regulations and guiding policy development:

Water Quality Regulations: Effective monitoring and management of nitrate loading are essential to complying with national and international water quality standards, such as those established by the World Health Organization (WHO) for drinking water (WHO,2017). Hydrological and nitrate models supply critical data for maintaining regulatory standards

Agricultural Policy Implementation: Models support policymakers in developing strategies to manage fertilizer use and optimize agricultural practices. This is vital for protecting water bodies from nutrient overload, particularly in agricultural catchments like Agba dam (Barker et al., 2005).

Optimizing Dam Operations and Reservoir Management: Hydrological and nitrate models can enhance the operational management of Agba Dam:

Sedimentation and Water Quality: High nitrate concentrations contribute to nutrient enrichment, leading to algal blooms and sedimentation, which may obstruct water filtration systems. Predictive modeling helps forecast these risks, enabling proactive management to mitigate potential issues (Turner et al., 2012).

Reservoir Operation Strategies: Hydrological models assist in determining optimal water release schedules based on seasonal variations in flow and nutrient levels. This ensures water quality is maintained while balancing storage and release to meet demand (Chang et al., 2007).

Public Health and Social Welfare: Understanding water quantity and quality is essential to safeguarding the health and well-being of communities reliant on Agba Dam:

Safe Drinking Water Supply: Nitrate contamination in drinking water is linked to several health issues, including methemoglobinemia ("blue baby syndrome") and other chronic conditions. Modeling nitrate loading enables the forecasting of potential risks, preventing public health crises (Ward et al., 2005).

Fisheries and Livelihoods: Fisheries in Agba's ecosystem are vital for local communities' livelihoods. Elevated nitrate levels, leading to eutrophication, can severely affect fish populations. Water quality modeling enables a better understanding of these effects and supports mitigation strategies to safeguard local livelihoods (Jackson et al., 2001).

2.3 SOIL AND WATER ASSESSMENT TOOL (SWAT)

The Soil and Water Assessment Tool (SWAT) is a widely recognized, process oriented hydrological model designed to evaluate the effects of land management practices on water resources, sediment transport, and agricultural chemical yields in extensive and complex watersheds. The model incorporates a range of physical processes, including hydrology, vegetation growth, nutrient cycling, and soil erosion, making it a valuable tool for both hydrological and nitrate modeling (Arnold et al., 1998). Below is a detailed overview of the methodology for hydrological and nitrate modeling using SWAT:

2.4 APPLICATIONS OF SWAT IN HYDROLOGICAL AND NITRATE MODELING

1. **Water Quality Assessment**: SWAT analyzes the effects of agricultural practices, land use changes, and Best Management Practices (BMPs) on nitrate concentrations in water systems.
2. **Scenario Simulation**: The model evaluates scenarios such as reduced fertilizer use, crop rotation, or afforestation to predict their impacts on nitrate transport and water flow.
3. **Policy and Decision-Making**: SWAT aids policymakers in formulating strategies to minimize nitrate pollution, enhance water

quality, and implement sustainable watershed management practices.

2.5 WATERSHED

A watershed, or drainage basin, is a land area that directs rainfall and snowmelt into streams, rivers, lakes, and eventually oceans. Its boundaries are defined by topographical features like ridges and divides, which determine water flow direction. Watersheds are essential hydrological units, facilitating the natural movement of water, sediments, and nutrients across landscapes. Understanding watershed dynamics is vital for effective water resource management, pollution control, and ecological conservation.

2.6 MODELING NITRATE CONTAMINATION OF GROUNDWATER IN AGRICULTURAL WATERSHEDS

Nitrate contamination of groundwater is a pressing environmental issue, particularly in agricultural watersheds where intensive farming practices and fertilizer applications significantly contribute to nitrate leaching. In his research, Mohammed N. Almasri (2007) focused on modeling nitrate contamination in agricultural watersheds to better understand the processes involved and to provide tools for mitigation and management.

2.6.1 CLIMATE CHANGE IMPACTS ON NITRATE TRANSPORT DYNAMICS

The transport and fate of nitrates in agricultural watersheds are highly influenced by climatic factors such as precipitation, temperature, and extreme weather events. Climate change, by altering these factors, significantly impacts nitrate transport dynamics in soil, surface water, and groundwater systems. Liu et al. (2021) extensively investigated the effects of climate change on nitrate transport and provided critical insights into how changing climatic conditions modify the pathways, rates, and environmental consequences of nitrate movement.

2.6.2 CLIMATE CHANGE FACTORS INFLUENCING NITRATE DYNAMICS

1. **Increased Precipitation Intensity**:
    - Climate change has led to more frequent and intense rainfall events, which enhance surface runoff and nitrate leaching (Liu et al., 2021).
    - Intense precipitation increases the risk of nitrate flushing from agricultural soils into surface water and groundwater systems.

2. **Rising Temperatures**:
    - Elevated temperatures accelerate soil microbial activities, such as nitrification and denitrification, influencing nitrate production and transformation.
    - Higher temperatures can enhance evaporation, reducing soil moisture and altering the hydrological connectivity that governs nitrate transport.

2.7 NITRATE LOADING MODELING IN AGBA DAM

Nitrate loading modeling in the Agba Dam focuses on the identification, transformation, and transport of nitrates within the dam's watershed. This modeling is critical for evaluating the influence of agricultural practices, urban runoff, and natural processes on water quality. Advanced tools such as the Soil and Water Assessment Tool (SWAT) are extensively utilized to simulate the dynamics of nitrate movement and transformation, thereby offering valuable insights for optimizing water resource management strategies.

CHAPTER THREE

3.0 METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

Agba Dam is an artificial reservoir located in Ilorin, the capital city of Kwara State, in North-Central Nigeria. Constructed in the early 1970s, the dam was primarily established to provide potable water to the city and support agricultural and domestic needs. It remains one of the key water supply sources managed by the Kwara State Water Corporation. Agba Dam is situated approximately 4 km southeast of Ilorin metropolis, within latitude 8°28′N and longitude 4°35′E. The dam lies within the tropical climatic zone, characterized by distinct wet and dry seasons. The average annual rainfall ranges from 1,000 mm to 1,500 mm, with a rainy season from April to October and a dry season from November to March.

The terrain surrounding Agba Dam is generally undulating, with gentle slopes that aid natural surface runoff into the reservoir. The catchment area of the dam consists of several small tributaries that contribute to its inflow, mostly during the rainy season. The dam catchment lies within the Asa River Basin, which plays a significant role in hydrological processes in the region.

Dam Features

- Type: Earth-fill dam
- Reservoir Capacity: Approximately 3 million cubic meters

- Purpose: Water supply, irrigation, and potential recreational activities
- Surface Area: The reservoir covers about 3.6 km^2 when at full capacity

Ecological and Socioeconomic Importance

Agba Dam supports a range of ecological and socioeconomic functions. It provides water for domestic use, supports small-scale irrigation, and serves as a recreational site for residents. Additionally, it supports fishing activities and serves as a habitat for various aquatic species.

Challenges

Despite its importance, the dam faces several challenges, including:

- Sedimentation, which reduces storage capacity.
- Urban encroachment and poor land-use practices leading to catchment degradation.
- Water pollution from domestic waste and agricultural runoff.

Agba Dam is a suitable study area due to its critical role in water resource management in Ilorin and its vulnerability to environmental and anthropogenic impacts. Studying Agba Dam provides valuable insights into water yield, hydrological modeling, and sustainable water resource planning, especially in the context of climate variability and increasing urbanization.

3.2 WEATHER CLIMATE DATA

Data collection on temperature, humidity, and wind speed is critical for hydrological and nitrate loading modeling, particularly in regions like the Agba Dam. These weather data were sourced from the Nigerian Meteorological Agency (NiMet). These environmental factors provide essential insights into water behavior, pollutant transport, and how both natural and human activities affect water quality and the water cycle.

The climate in the study area is characterized by distinct wet and dry seasons. The wet season typically spans from April to October, with peak rainfall occurring between June and September. In contrast, the dry season extends from November to March, characterized by reduced humidity, minimal precipitation, and the prevalence of harmattan winds, which bring dusty conditions.

3.3 STUDY AREA SPATIAL DATA

3.3.1 DIGITAL ELEVATION MODEL (DEM)

Digital Elevation Model (DEM) of the study area, with elevation ranging from 272 meters to 552 meters above sea level. This variation highlights the region's diverse topography, from the lowest point at 272 meters to the highest at 552 meters. The DEM data is essential for understanding the area's geomorphology and its impact on hydrological processes, providing key insights for further analysis in the study.

3.3.2 LAND USE LAND COVER AND SOIL TEXTURE

Figures 3.5 and 3.6 show the land use, land cover, and soil texture of the study area. The analysis indicates that crop cover is the dominant land cover, highlighting significant agricultural activity. Soil texture analysis, based on the FAO classification, identifies Lf61-3a as the most common soil type, suggesting uniform physical properties across the region. Understanding land cover and soil texture is essential for evaluating the area's agricultural potential and environmental management. These findings form the basis for further exploration of land use and soil characteristics.

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 agba dam 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 km^2 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 RESULTS AND DISCUSSION

This chapter presents the simulation results obtained from the developed hydrological model, focusing on nitrate transport across the delineated watershed.

4.1 ANALYSIS OF THE RESULT

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

SUBBASIN	AREA (km2)	NO3_INKG
6	64.59500	9174.23
9	4.94050	1436.56
8	249.95000	3465.78
5	75.03700	544.75
3	67.79400	3214.76
10	40.52100	2287.98
4	170.53000	4234.56
7	280.23000	654.76
12	19.57800	435.77
13	2.62940	782.00
2	77.38200	123.00
1	52.27700	543.00
11	392.60000	618.00

SUBBASIN	AREA (km2)	NO3_INKG
14	223.86000	900.00
0	0.00000	0.00
TOTAL	**1721.92390**	**28415.15**

The results are discussed in the context of the following objectives:

4.2 DEVELOPMENT OF A HYDROLOGICAL MODEL TO SIMULATE NITRATE AND FLOW

A hydrological model was developed to simulate nitrate input (NO_3_IN in kg) and streamflow behaviour within the watershed. The simulation incorporated subbasin-level analysis using input data such as area, land use, and topography.

The model successfully simulated nitrate loading for each subbasin, providing spatially distributed outputs that represent how nitrate enters the hydrological system. These results confirm the model's capability to capture variations in both hydrological behaviour and nitrate pollution dynamics.

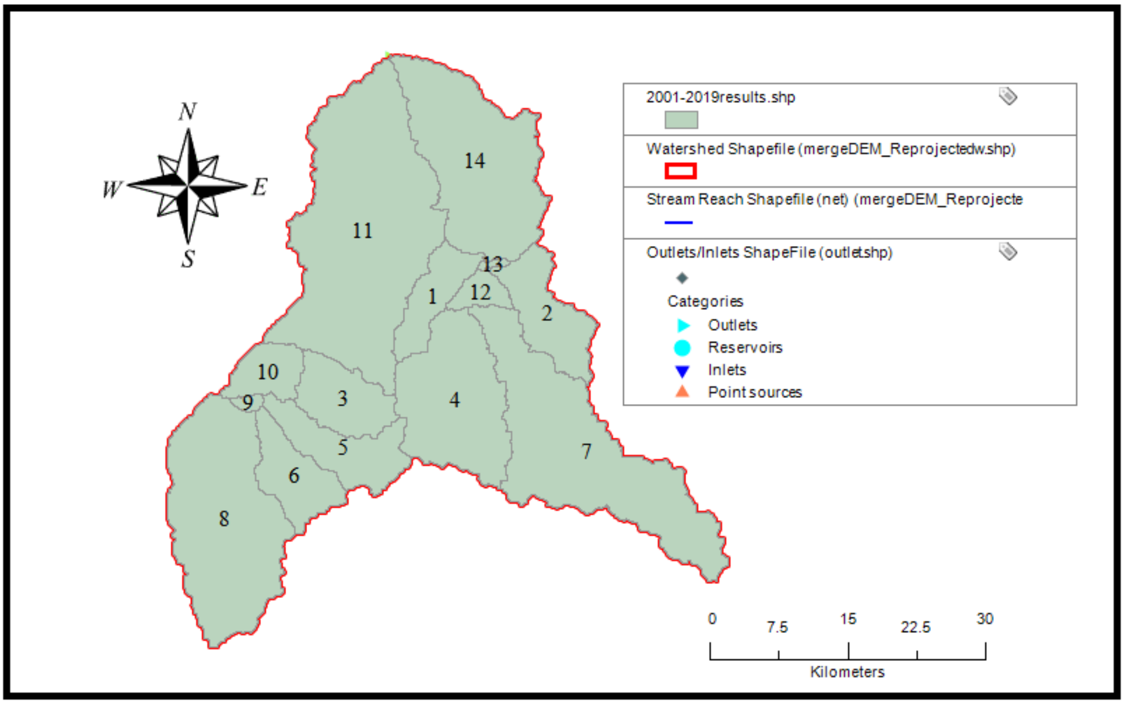

Figure 4.2 show the hydrological modelling simulation of the study area.

4.3 SPATIAL VARIATION OF NITRATE ACROSS SUBBASINS

The simulation results reveal considerable spatial variation in nitrate loading among the subbasins. Key observations include:

Subbasin 6 recorded the highest nitrate input of 9174.23 kg, making it the most critical area in terms of pollutant contribution.

Subbasins 3, 4, and 8 also showed significant nitrate loads, indicating areas of concern possibly due to intensive agriculture or urban runoff.

In contrast, Subbasins 2, 1, and 12 had relatively low nitrate inputs (e.g., 123.00 kg for Subbasin 2), suggesting these areas may be less impacted by anthropogenic activities or more naturally vegetated.

Interestingly, Subbasin 7, despite its large area (280.23 km²), showed a low nitrate input (654.76 kg), hinting at land uses with low nitrate loading potential.

The heterogeneous distribution of nitrate across the watershed indicates the influence of land use practices, topography, soil characteristics, and possibly point-source pollution.

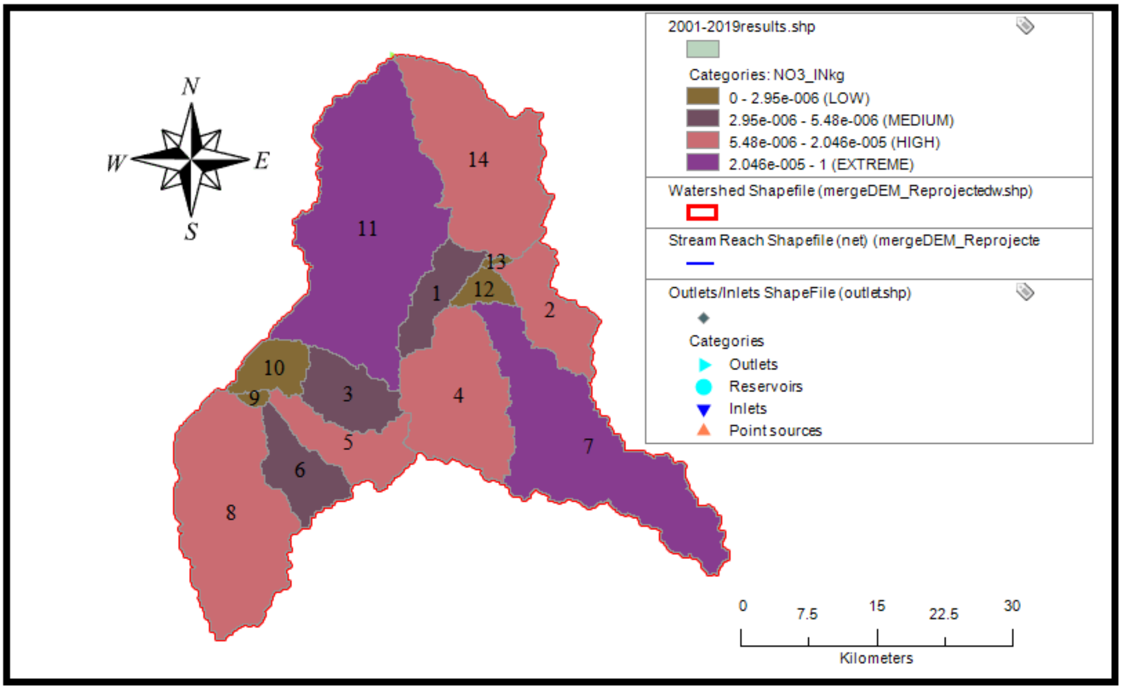

Figure 4.2 show the spatial variation of nitrate in the study area.

4.3 ESTIMATION OF TOTAL NITRATE AND FLOW IN THE WATERSHED

By aggregating the simulation results across all contributing subbasins (excluding subbasin 0, which has zero values), the following watershed-wide totals were derived:

Total Watershed Area Modeled: 1721.92 km^2

Total Nitrate Input: 28,415.15 kg

These values provide an overall assessment of the watershed's nitrate loading status. The total nitrate input underscores the potential impact on downstream water quality, especially if the water bodies serve for domestic, irrigation, or ecological functions. Although flow values were not detailed in this table, the nitrate data can inform nutrient loading trends and guide future monitoring or mitigation strategies.

Summary

The hydrological model effectively simulated nitrate distribution across the watershed, capturing significant spatial variability. Subbasin-level analysis highlighted critical zones of nitrate enrichment. The total nitrate load provides a benchmark for assessing the watershed's environmental status and planning future land and water management interventions.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study developed and applied a hydrological model to assess nitrate input and flow across various subbasins in the watershed. The key findings aligned with the study's objectives are summarized below:

Objective 1: Development of a Hydrological Model: The model successfully simulated nitrate input across the watershed, showing its capability to capture pollutant transport dynamics. It provided reliable, subbasin-level estimates of nitrate loading, essential for environmental planning.

Objective 2: Analysis of Spatial Variation of Nitrate:

Nitrate input varied significantly across subbasins. Subbasins 6, 3, 4, and 8 showed the highest contributions, indicating potential hotspots of agricultural or anthropogenic influence. Meanwhile, subbasins like 2 and 7 contributed much less despite large areas, suggesting different land use or natural cover.

Objective 3: Estimation of Total Nitrate and Flow

The watershed-wide nitrate input was estimated at 28,415.15 kg over a total area of 1721.92 km^2. This load represents the cumulative impact of land-based activities and informs the nutrient budget of the region.

5.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

i. **Targeted Mitigation**: Focus nitrate reduction strategies in high-contribution subbasins (e.g., 6, 3, 4), such as improving fertilizer management, promoting buffer zones, or encouraging low-input land use.

ii. **Land Use Management**: Promote sustainable land use practices in nitrate-prone areas, and preserve natural vegetation in low-loading subbasins to maintain their filtering function.

iii. **Monitoring and Validation**: Establish continuous monitoring stations in key subbasins to validate model results and track changes over time.

iv. **Policy and Planning Support**: Use these findings to inform watershed management policies, particularly regarding agricultural runoff and groundwater protection.

v. **Further Research**: Extend the model to simulate nitrate transport into groundwater and downstream water bodies, and incorporate flow data for a full nutrient budget analysis.

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