IJAAR PUBLISHING®

Scholarly Journal of Science and Technology Research & Development | ISSN: 2955-0807
Vol. 3, Issue 7 (July, 2024) | www.ijaar.org/sjstrd

A REVIEW OF THE IMPACT OF LAND USE MODIFICATION AND CLIMATE CHANGE ON GROUNDWATER-SURFACE WATER DYNAMICS IN NORTHWESTERN NIGERIA

Odoh, B. I.[1], Ahaneku, C. V.[2*], Enwereuzo, C. D.[1], Ezeonye, C. A.[2], Arukwe-Moses, C. P.[2]

[1]Department of Applied Geophysics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
[2]Department of Geological Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

Corresponding author email: cv.ahaneku@unizik.edu.ng

ABSTRACT

Land use modifications and climate change broadly impact groundwater-surface water dynamics in Northwestern Nigeria. This paper discusses how land use and climate change changes affect groundwater and surface water in Northwestern Nigeria. Land use modifications in Northwestern Nigeria, driven by agricultural expansion, urbanisation, and traditional practices, have significantly disrupted groundwater-surface water dynamics, resulting in various alterations of hydrological processes, leading to frequent water shortages, increasing surface runoff, and reducing water infiltration. Climate change worsens these issues by altering rainfall patterns, droughts, and rising temperatures. However, through a detailed desk study, literature review, and data analysis, the paper underscores the importance of continuous monitoring and research in understanding and addressing these issues. Integrating local knowledge is also highlighted as crucial to developing sustainable water management practices. The review further emphasises the need for effective strategies to deal with the combined effects of land use changes and climate change. Implementing sustainable land and climate-resilient water management practices incorporating local knowledge and technological innovations is crucial for ensuring long-term water security and resilience in Northwestern Nigeria.

Keywords: Land Use, Groundwater, Surface water, Climate Change, Northwest, Nigeria.

Odoh, B. I., Ahaneku, C. V., Enwereuzo, C. D., Ezeonye, C. A., & Arukwe-Moses, C. P. (2024). A Review of the Impact of Land Use Modification and Climate Change on Groundwater-Surface Water Dynamics in Northwestern Nigeria. *Scholarly Journal of Science and Technology Research & Development. 3*(7), 46-58. DOI: 10.5281/zenodo.14062199

1. INTRODUCTION

In Northwestern Nigeria, land use modification is a significant driver of water stress, surface water contamination, and groundwater depletion (Efe-Jeffery et al., 2024). Land use modifications involve the transformation of the natural landscape or using land, especially for economic activities (Bimal et al., 2017). Land use and climate change play a critical role in groundwater-surface water interactions (Warku & Abera., 2023), and these interactions take place through the replenishing of surface water by groundwater seepage, the loss of surface water to groundwater, or the combination of both (Haris et al., 2019). Therefore, any effect on groundwater or surface water quality or quantity typically affects each other (Winter et al., 1998).

Climate change is worsening the water resource condition in Northwestern Nigeria, where surface and groundwater sources are depleting at unprecedented rates (Salihu & Aishetu., 2022). The impacts of climate change in the Northwestern region of Nigeria are leading to changes in rainfall patterns, increased frequency of droughts, and shrinking water bodies (Owonikoko & Momodu, 2020).

The Northwestern region of Nigeria, a part of the six geopolitical zones of the country, includes states such as Kano, Kaduna, Katsina, Sokoto, Zamfara, Kebbi, and Jigawa (Quadri & Opeyemi, 2021). These states have a rich history of being important agricultural centres, contributing significantly to Nigeria's food production and economy (Amos et al., 2022). The climate is predominantly semi-arid, with distinct wet and dry seasons (Ekpoh & Imo. 2011). The region covers 212,350 km² (National Bureau of Statistics, 2017) and is located between latitudes 08º59'58.5"N to 13º52'39.5"N and 03º28'25.6"E to 10º36'10.2"E (Figure 1). Rainfall in the region is typically concentrated between May and September, with an annual precipitation of 500 mm (Olaniran, O., 2007). According to the National Bureau of Statistics, the region represents 23.338% of Nigeria's total land area (National Bureau of Statistics, 2017).Aside from the agricultural strength of the North-west Nigeria region, the region is also known for having the highest fertility rates in the developing world (Bertoni et al., 2016). According to the Nigeria Demographic and Health Survey (NDHS) conducted in 2018, the report indicated that the total fertility rate in the northwestern part of Nigeria was 6.6 live births per woman, with an average of 8.3 births for women aged 40 to 49 years in their reproductive lifetimes (NPC and IPF, 2018). The region's population has been proliferating, and this has caused an increased demand for land and water resources (Adegboyega Adeniran et al., 2021). Population growth in Nigeria is also as urban as it is local. Nigeria will have a population of about 229 million in 2024, and demographic projections indicate that the population might experience a constant increase in the following decades, with a population growth of over 377 million people by 2050 (Doris, 2023). DeFries et al. (2010) opine that just as population growth affects rural demand for agriculture and water, the steady growth of the urban population will directly fuel the economic drive to increase agricultural productivity, thereby leading to significant land-use modifications. Understanding the climate status and land use information in northwestern Nigeria is paramount for human and natural resource development (E.M. Okon et al., 2021). However, this region presents a concrete example of a data-poor region (Sedano et al., 2020). Land use changeprocesses combined with the growing impacts of climate change not only compromise household livelihood strategies but also significantly increase the stress on the groundwater-surface water dynamics in the region (Sedano et al., 2020).



Figure 1**:** Map of Nigeria Showing the Northwest Region (Danibrahim et al., 2022).

2. METHODOLOGY

Selection Criteria and Search Strategy

The methodology employed for this review involved a desk study and a literature review approach. We conducted a comprehensive search across prominent academic databases such as PubMed, Google Scholar, ScienceDirect, and Web of Science, utilizing a combination of keywords including "land use change," Northwestern Nigeria," "groundwater dynamics," "surface water dynamics," "climate change impacts," and "sustainable land management." The inclusion criteria prioritized studies addressing the challenges of Northwestern Nigeria's hydrology and land use modification. The screening and selection process encompassed evaluating titles, abstracts, and full-text content, followed by data extraction and synthesis to organize findings into thematic categories based on predefined research objectives: 1. To analyze historical land use patterns and recent modifications in Northwestern Nigeria. 2. To assess the impacts of climate change on the region's water resources. 3. To explore the interactions between groundwater and surface water under changing environmental conditions, and 4. To identify the implications of these changes for sustainable water management and agricultural practices. The exclusion criteria were as follows: (1) studies that did not relate to the impact of land use or climate change on groundwater-surface water interactions, (2) studies published in languages other than English.

Data Sources and Methods of Analysis

Data was extracted from the selected studies using a standardised approach. The data extracted included study location, land use types or change scenarios, hydrologic response variables measured, and methods used to measure hydrologic response.

Limitations and Potential Biases

We are aware of certain limitations and potential biases in our review process:

Our search method might not have identified all relevant studies, and our criteria for including or excluding studies could have unintentionally excluded some pertinent ones.

1. Differences in how studies were designed and measured may affect how comparable their results are.

2. The findings may not be broadly applicable due to the specific periods covered by the studies we reviewed.

3. Biases related to which studies get published and which languages might have influenced our selection.

To address these issues, we implemented a thorough search strategy and clearly defined criteria for study inclusion. Each study included in our review was carefully assessed for quality and relevance. We also acknowledge potential biases in our interpretation of the results, demonstrating our commitment to transparent and unbiased reporting.

3. FINDINGS AND DISCUSSIONS

HISTORICAL LAND USE PATTERNS IN NORTHWESTERN NIGERIA

Traditional agricultural practices in Northwestern Nigeria have given way to more intensive farming methods and have resulted in substantial deforestation rates to make way for agricultural expansion (Sedano et al., 2020). Peter Kojo Boateng (2017) observed that traditional agricultural practices, pastoralism, and small-scale subsistence farming characterized land use patterns in Northwestern Nigeria during the pre-colonial period. The Indigenous communities, including the Hausa and Fulani, practiced shifting cultivation and rotational grazing (Mbih, Richard et al., 2018). Shifting cultivation, also known as slash-and-burn agriculture, involves clearing a piece of land, using it for farming for a few years, and then moving to a new area to allow the old one to regenerate (Stefan et al., 2013). This method was sustainable due to the low population density and the long fallow periods, which allowed the soil to recover its fertility (Mortimore, 1993). The advent of British colonial rule in the early 20th century introduced significant changes to land use patterns (Stephen Olasunkanmi, 2021). According to Watts (1983), the colonial administration initiated cash crop farming to integrate the region into the global economy. Crops such as groundnuts (peanuts) and cotton became dominant, replacing some of the traditional food crops. The emphasis on cash crops expanded agricultural land and intensified farming practices (Watts, 1983). The colonial government also implemented land tenure reforms aimed at maximising agricultural production. However, this disrupted traditional land management systems and often led to the marginalisation of pastoralists and small-scale farmers (Scoones, I., 2020). The introduction of railways equally facilitated the transport of agricultural produce to coastal ports for export, further encouraging the cultivation of cash crops (Lugard, 1922).

The post-colonial period marked Nigeria's independence in 1960 and the continued focus on agricultural modernization in the country (Falola et al., 2024). The government implemented policies to promote large-scale farming and mechanisation to achieve food security and economic growth. However, these policies were biased and often favoured large-scale farmers, displacing smallholders and pastoralists. This policy bias further transformed agricultural practices (Emami et al., 2018).

Northwestern Nigeria has experienced rapid population growth and urbanisation in recent decades, further altering land use patterns. The expansion of urban areas has encroached on agricultural land and natural habitats (Aliyu et al.; L., 2017). Additionally, the demand for food and economic pressures have led to the intensification of agriculture, with increased use of irrigation and mechanised farming techniques. These changes have resulted in significant deforestation, soil degradation, and changes in hydrological systems (Sedano et al., 2020).

The study by Sedano et al. (2020), using remote sensing technology, provided detailed insights into the current state of land use in northwestern Nigeria. Their Landsat-based mapping framework revealed that agriculture remains the dominant land use, with arable land covering 52.5% of the area. This data peaks the national average and indicates the extensive agricultural activities in the region. Sedano et al. (2020) further highlighted the prevalence of irrigated agriculture, which is critical for crop production in northwestern Nigeria's arid and semi-arid conditions.

Northwestern Nigeria has evolved to more intensive agricultural systems, and the current landscape indicates extensive agricultural activities and significant environmental changes due to population pressure and urbanisation. Notably, these changes significantly impact water resources in the region (Sedano et al., 2020).

DRIVERS OF LANDUSE CHANGE

Agricultural expansion driven by the need to feed a growing population, as seen in Northwestern Nigeria, can lead to deforestation and the conversion of wetlands (Mfon, Philip et al., 2014). Ogundele et al. (2016) explored the effects of agricultural expansion on groundwater and surface water and inferred that increased agricultural land use reduces the natural infiltration of rainwater into the soil, lowering groundwater recharge rates and increasing surface runoff, and causing soil erosion and sedimentation in water bodies.

Rapid urbanisation drives land use and results in the proliferation of impervious surfaces such as roads, buildings, and pavements (Z. Wang et al., 2020). Studies by M.M. de Sousa et al. (2022) indicated that these surfaces prevent water from infiltrating the ground, reducing groundwater recharge and increasing surface runoff. Sohn et al. (2022) also suggest that urban runoff often carries pollutants, degrading surface water quality and potentially contaminating groundwater. According to observations by R.D. Stewart et al. (2019), urbanisation can influence the impairment of water resources across various levels through increased runoff, water quality issues, flooding risks, hyper-salinization, and loss of aquifer recharge.

The shifting cultivation, also known as the slash-and-burn agriculture pattern, practiced in northwestern Nigeria contributes to the intensification of desertification in the region (Audu & Adie, 2018). Removing forests for agriculture or urban development diminishes the land's capacity to retain and infiltrate water. Trees and vegetation play a crucial role in the water cycle by intercepting rainfall, promoting infiltration, and reducing runoff (Aizebeokhai, 2012).

EFFECTS OF LAND USE CHANGE ON GROUNDWATER-SURFACE WATER DYNAMICS IN NORTHWESTERN NIGERIA

T.A. Woldesenbet et al. (2020) explored the effects of deforestation, urbanisation, and agricultural expansion on groundwater-surface water dynamics and that removing vegetation cover prevents water infiltration into the soil. Without vegetation, rainwater is more likely to

flow over the surface rather than seep into the ground, reducing groundwater recharge and increasing the likelihood of floods (Babaremu et al., 2024). Studies conducted by (Cooley et al., 2021 Huo et al., 2021 and Su et al., 2021) indicate that streamflow patterns of water bodies are also affected by land use (Jorge et al. et al., 2019). For instance, deforestation can lead to higher peak flows during the rainy season and reduced base flows during dry seasons (Hesslerova et al., 2010). These changes are caused by forests acting as natural sponges, absorbing and slowly releasing water. Deforestation affects the capacity of the land to hold, and the gradual release of water diminishes, leading to more erratic streamflow patterns (Da'u et al., 2021). The extensive groundwater use for irrigation in the Northwestern region has led to a decline in groundwater levels. Sedano, Molini, and Azad's (2020) study indicates that nearly 20% of the region's land is under irrigation, significantly stressing groundwater resources. Over-extraction of groundwater lowers the water table, making it more difficult and expensive to access groundwater, and can lead to the depletion of aquifers (Gordon et al., 2010).

According to a review by Mishra et al., 2014, land use changes, particularly the intensification of agriculture, can lead to groundwater contamination. Using fertilizers and pesticides in agriculture can lead to the leaching of nitrates, phosphates, and other chemicals into the groundwater. This contamination risks human health and affects the quality of water available for domestic and agricultural use (Babaremu et al., 2024). Due to deforestation and agricultural expansion, increased surface runoff increases erosion and sedimentation rates in rivers and streams. Sediments can carry nutrients, pesticides, and other pollutants from agricultural fields into surface water bodies, degrading water quality (Gordon et al., 2010). Changes in precipitation patterns and increased temperatures due to climate change can worsen the effects of land use on water resources. For example, reduced rainfall and higher evaporation rates can further stress groundwater and surface water systems already impacted by land use changes (IPCC, 2014). Land use changes can also contribute to climate change, creating feedback mechanisms affecting water dynamics. For example, deforestation leads to the release of carbon stored in trees, contributing to greenhouse gas emissions and global warming, influencing water availability and distribution (Bonan, 2008).

CLIMATE CHANGE AND GROUNDWATER-SURFACE WATER DYNAMICS

Studies from (Amjath-Babu et al., 2016; Adeniran et al., 2021) suggest that the increasing demands for groundwater in Northwestern Nigeria, propelled by population growth, urban expansion, agricultural intensification, and industrialisation, frequently outgrow the natural replenishment processes—Nigeria's Northern region experience a decline in water availability and grazing fields (Gürsoy, 2024). The IPCC study using climate models reports projected changes in the amount and distribution of rainfall, leading to more erratic and unpredictable weather patterns (IPCC, 2014). These changes cause decreased rainfall and increased rainfall intensity. Ernest Benjamin Ikechukwu Ugwu (2023) stated that evidence suggests a long-term decline in rainfall in the Sahel and Sudan regions of Northwestern Nigeria. Reduced rainfall decreases surface water availability and limits the recharge of groundwater aquifers, resulting in water scarcity, particularly during the dry season, and affecting agricultural activities and water supply for domestic use (Hong Wang et al., 2015).

In the case of increased rainfall intensity, when rainfall does occur, it is often more intense, leading to higher surface runoff and less infiltration into the soil (Wilk Sampaio et al., 2021). Intense rainfall can also cause flash floods, quickly carrying water away before it can percolate into the ground, thus reducing groundwater recharge (Nnaji et al., Nnennaya., 2014). Rising temperatures due to climate change increase the rate of evapotranspiration, the process

by which water is transferred from the land to the atmosphere through evaporation and plant transpiration (Abtew et al., Assefa, 2013). Higher temperatures can significantly affect both surface and groundwater resources through increased evaporation rates from surface water bodies, reducing the volume of surface water available for various uses (Chen et al., Qi., 2004), and by depletion of soil moisture, which is crucial for recharging groundwater (Kumar, C.P., 2003).

The combined effects of altered precipitation and increased evapotranspiration contribute to the declining groundwater levels in Northwestern Nigeria Ashaolu (Eniola & Iroye, Kayode., 2018). Omole, David (2013) studied groundwater levels in Northwestern Nigeria and observed that groundwater levels declined in many parts of the region, partly due to reduced recharge rates and increased abstraction for agricultural and domestic use. Wilby, Robert (2009) stated that climate change affects not only groundwater but also the availability and dynamics of surface water. Alterations in flow regimes due to changes in rainfall patterns and increased evaporation rates can disrupt the balance of hydrologic systems and affect the livelihoods of communities dependent on riverine resources (Ayoade, 1975).

Climate change and land use have a combined effect. Climate change can exacerbate the hydrological impacts of land use modifications. The interaction of these two factors can increase runoff and decrease groundwater recharge in the Northwestern Nigeria region (M.L. Tan, 2021).

Comprehensive and up-to-date data on land use, groundwater levels, and surface water quality in Northwestern Nigeria must be improved. Continuous monitoring and interdisciplinary studies are required. Regardless, there has been significant progress in related studies. Land use modifications in Northwestern Nigeria, driven by agricultural expansion, urbanisation, and traditional practices, have significantly disrupted groundwater-surface water dynamics. However, the long-term impacts of current land use practices and climate change on water resources remain unclear, highlighting the need for longitudinal research.

Climate change has worsened the issues in the region. Unprecedented precipitation patterns, increasing drought frequency, and rising temperatures sporadically intensify water scarcity and stress in the region. Land use modification and climate change have a combined effect. For all impacts of land-use modification on groundwater and/or surface water, climate change ripples the speed of these impacts and hinders the region from adjustment and development.

Despite the current progress and the importance of the situation, effective mitigation and adaptation strategies to address these combined impacts are under-researched. However, there is a significant potential for positive change. By increasing the engagement of local communities and incorporating Indigenous knowledge in water management practices, we can make significant strides in addressing these issues. This potential for positive change should inspire hope and motivation in our collective efforts.

4. CONCLUSION

The interplay between land use modifications and climate change in Northwestern Nigeria has profoundly disrupted groundwater-surface water dynamics and worsened water scarcity and quality issues. Available research shows that how land is used and reused in the region has contributed to the hydrological system's stress. Whatever the effects, climate change worsens the condition and impact range and makes adaptation and mitigation efforts futile or burdensome. Addressing these challenges requires comprehensive data collection and

interdisciplinary research. It also involves the development of climate resilient-sustainable land and water management practices that incorporate local community involvement and technological innovations in the region.

REFERENCES.

Abtew, Wossenu & Melesse, Assefa. (2013). Climate change and evapotranspiration. 10.1007/978-94-007-4737-1_13.

Adegboyega Adeniran, Katherine A. Daniell, and Jamie Pittock. (2021). Water Infrastructure Development in Nigeria: Trend, Size, and Purpose. Water, 13(17), 2416; https://doi.org/10.3390/w13172416

Aizebeokhai, Ahzegbobor. (2012). Potential impacts of climate change and variability on groundwater resources in Nigeria. African Journal of Environmental Science and Technology. 5. 10.5897/AJESTX11.001.

Aliyu, A. A., & Amadu, L. (2017). Urbanization, cities, and health: The challenges to Nigeria - A review. Annals of African medicine, 16(4), 149–158. https://doi.org/10.4103/aam.aam_1_17

Amos Abimbola Oladunni, Usman Abubakar Haruna, Alaka Hassan Olayemi, Adewusi Bukola Adedoyin, Abia Chinedu Ndubisi, Amene Terhemen, Sow Alhaji Umar, Don Eliseo Lucero-Prisno. (2022). Chapter Six - Agriculture and food security in Northern Nigeria, Part I: The implications of climate change, Editor(s): Marc J. Cohen, Advances in Food Security and Sustainability, Elsevier, Volume 7, Pages 137-148, ISSN 2452-2635, ISBN 9780323989862, https://doi.org/10.1016/bs.af2s.2022.07.005.

Ashaolu, Eniola & Iroye, Kayode. (2018). Rainfall and potential evapotranspiration patterns and their effects on climatic water balance in the Western Lithoral Hydrological Zone of Nigeria. Ruhuna Journal of Science. 9. 92-116. 10.4038/rjs.v9i2.45.

Audu, Ignatius & Linus, Adie. (2018). Desertification in Northern Nigeria: Causes and Consequences.

Ayoade, J. O. (1975). Water Resources and their Development in Nigeria. Hydrological Sciences Journal, 20(4), 581-591.

Babaremu, Kunle & Taiwo, Olalekan & Ajayi, Dickson. (2024). Impacts of Land Use and Land Cover Changes on Hydrological Response: A Review of Current Understanding and Implications for Watershed and Water Resources Management. 19. 256-267. 10.5281/zenodo.10049652#89.

Bertoni, E., F. Clementi, V. Molini, F. Schettino, and H. Teraoka. (2016). "Poverty Work Program: Poverty Reduction in Nigeria in the Last Decade." Working Paper, World Bank, Washington, DC. http://documents.worldbank.org/curated/en/103491483646246005/Poverty-workprogram-poverty-reduction-in-Nigeria-in-the-last-decade

Bimal Kanti Paul, Harun Rashid (2017). Chapter Six - Land Use Change and Coastal Management, Editor(s): Bimal Kanti Paul, Harun Rashid, Climatic Hazards in

Coastal Bangladesh, Butterworth-Heinemann, Pages 183-207, ISBN 9780128052761, https://doi.org/10.1016/B978-0-12-805276-1.00006-5.

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. Science, 320(5882), 1444-1449.

Chen, X. & Hu, Qi. (2004). Groundwater influences on soil moisture and surface evaporation. Journal of Hydrology. 297. 285-300. 10.1016/j.jhydrol.2004.04.019.

Cooley, S. W., Ryan, J. C., and Smith, L. C. (2021). Human alteration of global surface water storage variability. Nature 591 (7848), 78–81. doi:10.1038/s41586-021-03262-3

Danibrahim, Nuhu & Abdul Kohar, Umar Haiyat & Indiran, Logaiswari. (2022). Influence of Entrepreneurial Competencies on the Performance of SMEs in Northwest Nigeria. International Journal of Academic Research in Business and Social Sciences. 12. 10.6007/IJARBSS/v12-i5/13074.

Da'u Abba Umar, Mohammad Firuz Ramli, Abubakar Ibrahim Tukur, Nor Rohaizah Jamil, Muhammad Amar Zaudi (2021). Detection and prediction of land use change impact on the streamflow regime in Sahelian river basin, northwestern Nigeria. H2Open Journal 1; 4 (1): 92–113. doi: https://doi.org/10.2166/h2oj.2021.065

E.M. Okon, B.M. Falana, S.O. Solaja, S.O. Yakubu, O.O. Alabi, B.T. Okikiola, T.E. Awe, B.T. Adesina, B.E. Tokula, A.K. Kipchumba, A.B. Edeme. (2021). Systematic review of climate change impact research in Nigeria: implication for sustainable development, Heliyon, Volume 7, Issue 9, e07941, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2021.e07941.

Efe Jeffery Isukuru, James Odafe Opha, Obaro Wilson Isaiah, Blessing Orovwighose, Stephen Sunday Emmanuel (2024). NIGERIA'S WATER CRISIS: ABUNDANT WATER, POLLUTED REALITY, Cleaner Water, 100026, ISSN 2950-2632, https://doi.org/10.1016/j.clwat.2024.100026.

Ekpoh, Imo. (2011). Extreme Climatic Variability in North-western Nigeria: An Analysis of Rainfall Trends and Patterns. Journal of Geography and Geology. 3. 10.5539/jgg.v3n1p51.

Emami, M., Almassi, M., Bakhoda, H. et al., (2018). Agricultural mechanization, a key to food security in developing countries: strategy formulating for Iran. Agriculture & Food Security 7, 24. https://doi.org/10.1186/s40066-018-0176-2

Ernest Benjamin Ikechukwu Ugwu, Desmond Okechukwu Ugbor, Jonas Udoka Agbo, Abigail Alfa, (2024).Analyzing rainfall trend and drought occurrences in Sudan Savanna of Nigeria, Scientific African, Volume 20, e01670, ISSN 2468-2276, https://doi.org/10.1016/j.sciaf.2023.e01670.

Falola, T. O., Udo, Reuben Kenrick , Ajayi, . J.F. Ade and Kirk-Greene, . Anthony Hamilton Millard (2024). Nigeria. Encyclopedia Britannica. https://www.britannica.com/place/Nigeria

Gordon, L. J., Finlayson, C. M., & Falkenmark, M. (2010). Managing water in agriculture for food production and other ecosystem services, Agricultural Water Management,

Volume 97, Issue 4, Pages 512-519, ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2009.03.017.

Gürsoy (2024). Farmers-Herders Conflict in Nigeria.

Haris Hasan Khan, Arina Khan (2019). Chapter 14 - Groundwater and Surface Water Interaction, Editor(s): Senapathi Venkatramanan, Mohan Viswanathan Prasanna, Sang Yong Chung, GIS and Geostatistical Techniques for Groundwater Science, Elsevier, Pages 197-207, ISBN 9780128154137, https://doi.org/10.1016/B978-0-12-815413-7.00014-6.

Hesslerova, Petra & Pokorný (2010). Forest clearing, water loss, and land surface heating as development costs. Int. J. of Water. 5. 401 - 418. 10.1504/IJW.2010.038732.

Hong Wang, Jian En Gao, Meng-jie Zhang, Xing-hua Li, Shao-long Zhang, Li-zhi Jia (2015). Effects of rainfall intensity on groundwater recharge based on simulated rainfall experiments and a groundwater flow model, CATENA, Volume 127, Pages 80-91, ISSN0341-8162, https://doi.org/10.1016/j.catena.2014.12.014.

Huo, J., Liu, C., Yu, X., Jia, G., and Chen, L. (2021). Effects of watershed char and climate variables on annual runoff in different climatic zones in China. Sci. Total Environ. 754, 142157. doi:10.1016/j.scitotenv.2020.142157

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

IPCC. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge University Press

Jorge L. Peña-Arancibia, L. Adrian Bruijnzeel, Mark Mulligan, Albert I.J.M. van Dijk (2019). Forests as ‘sponges’ and ‘pumps’: Assessing the impact of deforestation on dry-season flows across the tropics Journal of Hydrology, Volume 574, 2019, Pages 946-963, ISSN 0022-1694, https://doi.org/10.1016/j.jhydrol.2019.04.064.

Kumar, C. P. (2003). Estimation of Ground Water Recharge Using Soil Moisture Balance Approach. Journal of Soil and Water Conservation, Soil Conservation Society of India. Volume 2. pp. 53-58.

Lugard, F. D. (1922). The Dual Mandate in British Tropical Africa, Edinburgh: Blackwood.

M.L. Tan, J. Liang, N. Samat, N.W. Chan, J.M. Haywood, K. Hodges, Hydrological extremes and responses to climate change in the kelantan river basin, Malaysia, based on the CMIP6 highresmip experiments, Water (Switzerland). 13 (2021). https://doi.org/10.3390/w13111472

M.M. de Sousa, O.M. Rezende, A.C.P. Jacob, L.B. de França Ribeiro, P.M.C. de Magalhães, G. Maquera, M.G. Miguez, Flood Risk Assessment Index for Urban Mobility with the Aid of Quasi-2d Flood Model Applied to an Industrial Park in São Paulo, Brazil, Infrastructures. 7 (2022) 1–25. https://doi.org/10.3390/infrastructures7110158.

Mbih, Richard & Driever, Steven &Ndzeidze, Stephen & Mbuh, Mbongowo & Bongadzem, Carine & Mairomi, Wirngo. (2018). Fulani pastoralists' transformation process: a sustainable development approach in the Western Highlands of Cameroon. Environment Development and Sustainability. 20. 10.1007/s10668-017-9910-3.

Mfon, Philip & AKINTOYE, OLUYEMI &Mfon, Glory & Olorundami, Tokunbo & Ukata, Sammy & Adesolaakintoye, Taiwo. (2014). Challenges of Deforestation in Nigeria and the Millennium Development Goals. International Journal of Environment and Bioenergy, 2014, 9(2): 76-94. 9. 76-94.

Mishra, Nitin & Khare, Deepak & Gupta, K & Shukla, Rituraj. (2014). Impact of Land Use Change on Groundwater - A Review. Advances in Water Resource and Protection. 2. 28-41.

Mortimore, M. (1993). The intensification of peri-urban agriculture: The Kano close-settled zone, 1964-1986. Environment and Urbanization, 5(1), 243-252.

National Bureau of Statistics (2017). 2016 Annual abstract of statistics. Vol. 1. National Bureau of Statistics National Bureau.

National Population Commission (NPC) [Nigeria] and ICF. Nigeria Demographic and Health Survey (2018). Maryland: Abujpreturna, Nigeria and Rockville; 2019.

Nnaji, Chidozie& Mama, Nnennaya. (2014). Preliminary Assessment of Rainwater Harvesting Potential in Nigeria: Focus on Flood Mitigation and Domestic Water Supply. Water Resources Management. 10.1007/s11269-014-0579-1.

Ogundele, Adeolu& Tunde, Ogundele & Oladipo, Micheal & Adebisi, Olusegun & Mathew,. (2016). Deforestation in Nigeria: The Needs for Urgent Mitigating Measures

Olaniran, O.. (2007). Rainfall anomaly patterns in dry and wet years over Nigeria. International Journal of Climatology. 11. 177 - 204. 10.1002/joc.3370110206.

Omole, David. (2013). Sustainable Groundwater Exploitation in Nigeria. Journal of Water Resources and Ocean Science. 2. 9. 10.11648/j.wros.20130202.11.

Peter Kojo Boateng (2017). Agricultural Land Use Changes and Narratives about Land Degradation in the Savannahs of Northeast Ghana during the Pre-Colonial and Colonial Periods. Journals Social Sciences Volume 6 Issue 1 10.3390/socsci6010035

Quadri, Opeyemi (2021). "6 Geopolitical Zones In Nigeria And The States Under Them". infomediang.com. Retrieved 2022-11-04.

R.D. Stewart, A.S. Bhaskar, A.J. Parolari, D.L. Herrmann, J. Jian, L.A. Schifman, W.D. Shuster, (2019). An analytical approach to ascertain saturation-excess versus infiltration-excess overland flow in urban and reference landscapes, Hydrol. Process.33.3349–3363. https://doi.org/10.1002/hyp.13562.

S.B. Owonikoko, J.A. Momodu (2020). Environmental degradation, livelihood, and the stability of Chad Basin Region Small Wars. Insur., 31 (2020), pp. 1295-1322

Salihu, Abdullahi & Abdulkadir, Aishetu. (2022). Modeling Climate Change Impact on Water Resources of Northern Nigeria.

Scoones, I. (2020). Pastoralists and peasants: perspectives on agrarian change. The Journal of Peasant Studies, 48(1), 1–47. https://doi.org/10.1080/03066150.2020.1802249

Sedano, Fernando & Molini, Vasco & Azad, M. (2020). The State of Land Use in Northern Nigeria Landsat-Based Mapping Framework The State of Land Use in Northern Nigeria: A Landsat-Based Mapping Framework.

Sohn, Wonmin & Kim, Jun-Hyun & Li, Ming-Han & Brown, Robert & Jaber, Fouad. (2020). How does increasing impervious surfaces affect urban flooding in response to climate variability?. Ecological Indicators. 118. 106774. 10.1016/j.ecolind.2020.106774

Stefan Hauser, Lindsey Norgrove. (2013). Slash-and-Burn Agriculture, Effects of, Editor(s): Simon A Levin, Encyclopedia of Biodiversity (Second Edition), Academic Press, Pages 551-562, ISBN 9780123847201, https://doi.org/10.1016/B978-0-12-384719-5.00125-8.

Stephen Olasunkanmi, Abatan & Lawal, Musibau & Omolara, Bankole & Racheal, Babarinde. (2021). HISTORY OF NIGERIA LAND USE ACT (AN OVERVIEW). International Journal of Engineering Applied Sciences and Technology. 6. 10.33564/IJEAST.2021.v06i05.031.

Su, X., Li, X., Niu, Z., Wang, N. a., and Liang, X. (2021). A new complexity-based three-stage method to comprehensively quantify positive/negative contribution rates of climate change and human activities to changes in runoff in the upper Yellow River. J. Clean. Prod. 287, 125017. doi:10.1016/j.jclepro.2020.125017

T.A. Woldesenbet, N.A. Elagib, L. Ribbe, J. Heinrich. (2017) . Hydrological responses to land use/cover changes in the source region of the Upper Blue Nile Basin, Ethiopia, Sci. Total Environ. 575,724–741. https://doi.org/10.1016/j.scitotenv.2016.09.124.

Warku, Fikadu & Abdissa, Abera. (2023). Impact of land-use dynamics and climate change scenarios on Groundwater recharge in the case of Anger watershed, Ethiopia. Heliyon. 9. e18467. 10.1016/j.heliyon.2023.e18467.

Watts, Michael (1983). Silent Violence: Food, Famine and Peasantry in Northern Nigeria. Berkeley CA: University of California Press, American Journal of Agricultural Economics, Agricultural and Applied Economics Association, vol. 66(4), pages 536-537.

Wilby, Robert & Battarbee, Richard &Kernan, Martin & Wade, Andrew. (2009). A Review of the Potential Impacts of Climate Change on Surface Water Quality. Hydrological Sciences Journal/Journal des Sciences Hydrologiques. 54. 10.1623/hysj.54.1.101.

Wilk Sampaio de Almeida, Steffen Seitz, Luiz Fernando Coutinho de Oliveira, Daniel Fonseca de Carvalho (2021). Duration and intensity of rainfall events with the same erosivity change sediment yield and runoff rates, International Soil and Water Conservation Research, Volume 9, Issue 1, Pages 69-75, ISSN 2095-6339, https://doi.org/10.1016/j.iswcr.2020.10.004.

Winter, T. & Harvey, Judson & Franke, O. & Alley, William. (1998). Ground water and surface water a single resource: U. U.S. Geol. Surv. Circ.. 1139.

Z. Wang, S. Zhang, Y. Peng, C. Wu, Y. Lv, K. Xiao, J. Zhao, G. Qian, Impact of rapid urbanization on the threshold effect in the relationship between impervious surfaces and water quality in shanghai, China, Environ. Pollut. 267 (2020) 115569. https://doi.org/10.1016/j.envpol.2020.115569.