

Assessing water security in Sub-Saharan Africa in the context of climate change threats: a case study

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Abstract

Purpose – This paper aims to investigate water security in Iwo, Nigeria, located in the sub-Saharan region, within the broader context of climate change threats and contributes insights towards achieving the Sustainable Development Goal 6 (SDG 6) targets by 2030. It unravels the interplay between climate change, demographics and water dynamics, employing meticulous surveys and climatic analyses. The study identifies critical patterns and urges urgent action through evidence-based recommendations. By evaluating household water use and predictive models, the research guides stakeholders towards strategic interventions. The overarching goal is to prompt proactive measures for enhanced water justice, aligning with SDG 6, and fostering global dialogue on sustainable water management in similarly challenged regions.

Design/methodology/approach – The investigation employs a multifaceted methodology: a 12-month survey (937 households) assesses water sources and usage; climatic data (31 years) from the Nigeria Meteorological Agency identifies trends. Descriptive and inferential statistical analyses unravel patterns. Demographic assessments illuminate key factors, notably the prevalent involvement of female heads. Regression analysis also unveils predictive capabilities. This comprehensive approach, integrating surveys, climatic data analysis and statistical tools, ensures a nuanced understanding of water security dynamics in Iwo, Nigeria.

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Findings – This study on water security in Iwo, Nigeria, reveals climate change threats jeopardizing national water accessibility goals by 2030. Surveying 937 households, it finds a predominantly domestic water use pattern, with significant reliance on female heads and individuals above 18. Climatic data analysis indicates water loss during dry and previously rainy months, confirming climate change impacts. Household water use consistently exceeds supply, falling below WHO recommendations. Regression analysis identifies significant predictive models, emphasizing the need for urgent efforts to enhance water accessibility and align with SDG 6 targets.

Research limitations/implications – Limitations of this research include potential model inadequacy (indicated by low R values), suggesting the need for additional variables for better predictive accuracy. The study's focus on a specific region, Iwo, Nigeria, may limit generalizability to broader contexts. The reliance on self-reported data from households introduces the possibility of response bias, impacting the accuracy of findings. Furthermore, the study's duration (12 months) may not fully capture long-term trends, and the exclusive use of climatic data from a single national agency may overlook nuanced local variations. These limitations highlight areas for future research refinement and expansion.

Practical implications – Practical implications of this research underscore the urgency of addressing climate change-induced threats to water security, especially in regions like Iwo, Nigeria. The findings emphasize the need for targeted interventions to enhance water accessibility, considering the predominance of domestic usage. Policymakers should prioritize sustainable water management strategies, considering climatic variations, and actively involve communities in decision-making. The identification of predictive models signals the potential for effective planning and resource allocation. Overall, the study highlights the imperative for immediate, intentional efforts to ensure just and sustainable water access, aligning with SDG 6 targets, particularly in agrarian communities facing climate-related challenges.

Social implications – The research's social implications are significant, reiterating a predominantly female and adult population involved in water-related activities in Iwo, Nigeria. The findings highlight the domestic nature of water use, reflecting the area's agrarian character. The identified water accessibility challenges underscore potential socio-economic disparities. Urgent interventions are needed to ensure equitable access, aligning with Sustainable Development Goal 6. Policymakers should consider the socio-demographic dynamics uncovered, emphasizing community involvement in crafting solutions. Addressing these social aspects is crucial for fostering resilience in the face of climate change and promoting sustainable, just water practices in the region.

Originality/value – The research offers original contributions by specifically assessing water security in Iwo, Nigeria, in view of the prevailing global climate change projections. Original elements include a year-long survey of 937 households, incorporating climatic data spanning three decades. The study identifies a predominantly female and adult involvement in water-related activities, emphasizing the agrarian nature of the region. The revelation of predictive models and the examination of water use patterns contribute novel insights. These original aspects enhance our understanding of localized challenges, providing a basis for targeted interventions. Overall, the research adds unique perspectives to the discourse on water security and climate resilience in the studied region.

Keywords Nigeria, Climate change, Hazard, Water security, SDG 6, Household water use, Sub-Saharan region

Paper type Research paper

Introduction

Availability and access to clean and reliable water are fundamental human rights, essential for the sustenance of life and the well-being of communities (Salman, 2012; He *et al.*, 2014; Hall *et al.*, 2014; de Oliveira, 2017; Khalifa and Bidaisee, 2018; Ogunbode *et al.*, 2022, 2024a). In tropical environments, where the interplay of climate and geography poses unique challenges to water supply systems, understanding the dynamics of household water inventory, accessibility and predictability becomes paramount (Levy *et al.*, 2018; Godde *et al.*, 2021; Mishra *et al.*, 2021; Yang *et al.*, 2021).

Despite the efforts of various stakeholders in ensuring water security in Africa and sub-Saharan regions, water accessibility is still adjudged to be poor. The report of the World Bank (2023) showed that about 226 million people in both Eastern and southern Africa did not

have access to basic water services in urban centres, while the situation is even worse in rural areas. Similarly, sub-Saharan African countries, according to Statista (2024), showed that Gambia, Ghana and Cote d'Ivoire had 48%, 44% and 44% water access, topping the countries in that region in terms of water access, while Sao Tome and Principe, Nigeria, Lesotho, Senegal, Zimbabwe, Guinea Bissau, and Madagascar, respectively, had 36%, 29%, 28%, 27%, 27%, 24% and 22% water access. Egypt, however, was rated as the country with improved water access, with 70% of its populace enjoying good access to potable water while Somalia, Chad and Niger are the least in terms of accessibility to potable water in the continent [United Nations University Institute for Water Environmental and Health (UNUIWEH, 2022)].

The global effort to ensure water availability and accessibility is prominently addressed through Sustainable Development Goal 6 (SDG 6), which is part of the United Nations' broader agenda for sustainable development (Bebbington and Unerman, 2018; Atukunda *et al.*, 2021; Ogunbode *et al.*, 2024b). Evaristo *et al.* (2023) and Ogunbode *et al.* (2024b) stressed that SDG 6 specifically focuses on "clean water and sanitation" and outlines targets and indicators to achieve universal access to safe and affordable drinking water and adequate sanitation by 2030. SDG 6 emphasizes the importance of sustainable water management, acknowledging the interconnectedness of water availability, sanitation and hygiene. Some key components of SDG 6, according to Herrera (2019) and Atukunda *et al.* (2021), include improving water quality, increasing water-use efficiency, protecting and restoring water ecosystems and expanding access to safe sanitation facilities. The international community, governments, NGOs and other stakeholders collaborate to implement strategies and projects aligned with SDG 6. Amongst such areas of collaboration include investments in water infrastructure, the promotion of efficient water use in agriculture and industry and initiatives to enhance water quality and sanitation services in rural and urban communities (Atukunda *et al.*, 2021). To ensure the implementation of the targets in SDG 6, various machineries have been put in place to monitor the progress. Such measures involve tracking indicators such as the proportion of the population with access to safely managed drinking water and sanitation services (Ben *et al.*, 2021; Meran *et al.*, 2021), the reduction of water pollution and the implementation of integrated water resource management practices (Cosgrove and Loucks, 2015; Herrera (2019). While significant strides have been made, challenges remain, particularly in regions facing water scarcity, inadequate infrastructure and sanitation issues, especially in the underdeveloped regions of the world (Cosgrove and Loucks, 2015; Ogunbode *et al.*, 2019).

This study delves into the intricacies of assessing the availability of water resources and its accessibility through a comprehensive case study focused on Iwo, Nigeria. Nigeria, a country with a diverse climate ranging from arid to tropical, faces multifaceted challenges in providing adequate and dependable water supply, particularly in regions like Iwo situated in the tropical belt (Deitch *et al.*, 2017; Ogunbode *et al.*, 2023a, 2023b, 2024a). The tropics, characterized by high temperatures, intense rainfall, and a range of geographical features, present a complex scenario for water management (Ogunbode and Ifabiyi, 2019a, 2019b, 2019c; Salhi *et al.*, 2019). The accessibility and predictability of household water supply in such environments are influenced by a myriad of factors, including climatic variations, population density, infrastructure development and socio-economic conditions (Davison *et al.*, 2012; Hansen *et al.*, 2019; Cuevas Madrid *et al.*, 2020). Iwo, a city in southwestern Nigeria, serves as a compelling case study due to its location within the tropical climate zone and its distinctive socio-economic and geographic features. The city's water supply landscape reflects the broader challenges encountered in tropical regions, where the abundance of natural resources does not always translate into equitable and reliable access

for all residents. The need for a comprehensive examination of household water supply in Iwo stems from the recognition that water scarcity and inadequate access persist as pressing issues affecting the daily lives of its residents. Despite Nigeria's rich water resources, the distribution and availability of clean water at the household level remain uneven, posing significant health and socio-economic implications. Moreover, the unpredictable nature of climatic conditions in tropical environments introduces an additional layer of complexity to water supply systems. Understanding how households in Iwo cope with, adapt to, and manage their water resources is crucial for designing effective and sustainable interventions. The primary aim of this research is to conduct a thorough examination of the household water supply inventory, accessibility, and predictability in Iwo, Nigeria. Specific objectives are to:

- evaluate the status of household water demand and supply inventory;
- analyse the accessibility of household water supply; and
- develop predictive models for household water supply.

By achieving these objectives, the study seeks to contribute valuable insights into the challenges and opportunities associated with household water supply in a tropical setting. This research holds significance at various levels. Firstly, it contributes to the academic discourse on water resource management, particularly in tropical environments. The findings will add depth to existing knowledge, informing scholars, policymakers and practitioners working in the fields of environmental science, geography and public health. Secondly, the study addresses a critical issue with direct relevance to the well-being of the residents of Iwo. By shedding light on the nuances of household water supply, the research aims to provide evidence-based recommendations for improving access, ensuring sustainability and enhancing the resilience of communities in the face of climate-related challenges. In conclusion, the examination of household water supply inventory, accessibility and predictability in Iwo, Nigeria, transcends its local context to offer insights applicable to tropical regions globally. Specific objectives are to:

- evaluate the status of household water demand and supply inventory;
- analyse the accessibility of household water supply; and
- develop predictive models for household water supply.

This research sets the stage for a nuanced understanding of the intricate interplay between.

Theoretical framework

The theoretical framework of this study is grounded in several key concepts and theoretical perspectives that collectively provide a comprehensive lens through which to analyse the household water supply inventory, accessibility and predictability in the tropical setting of Iwo, Nigeria. The framework encompasses elements from environmental science, geography, sociology and public health to enhance a multidimensional understanding of the complex interactions at play. In the first instance, the hydrological cycle forms the foundation of understanding water availability and distribution (Meran *et al.*, 2021; Yang *et al.*, 2021). In a tropical setting like Iwo, characterized by distinct wet and dry seasons, climatic factors play a pivotal role in shaping the dynamics of water resources. The study will draw from hydrological principles to assess the impact of rainfall patterns, evaporation rates and temperature fluctuations on water availability, influencing both the natural water sources and the efficiency of water supply infrastructure, as reiterated by Yang *et al.* (2021). Apart from this geographic factor, including topography and land use, contributes significantly to water accessibility.

Understanding how geographic features influence the location and effectiveness of water sources helps in evaluating the accessibility and predictability of household water supply.

Also, the study adopts the social-ecological systems (SES) framework to explore the intricate relationship between human communities and their environment. By analysing how socio-economic factors, cultural practices and community dynamics interact with the local ecology as observed by McGinnis and Ostrom (2014), the study aims to unravel the socio-ecological complexities that influence household water management practices. This theoretical perspective helps in identifying feedback loops and potential interventions within the broader system. Given the potential impacts of climate change on water availability, the study incorporates concepts from community-based adaptation and resilience theory (Shammin *et al.*, 2022). Understanding how communities in Iwo adapt to climatic variations and develop resilience in the face of water supply challenges provides valuable insights into the sustainability of water management practices at the household level.

The theoretical framework incorporates principles of environmental justice to analyse the equitable distribution of water resources among different socio-economic groups within the community (Seigi Karasaki *et al.*, 2023). Recognizing that unequal access to clean water can exacerbate existing social disparities, the study explores the implications for public health and advocates for the promotion of environmental justice in water resource management. Institutional and policy analysis serve as a crucial aspect of the theoretical framework, emphasizing the role of governance structures and policies in shaping water supply systems as Hukka *et al.* (2010) advocated. By examining local and national policies related to water resource management, the study assesses how institutional frameworks influence accessibility and predictability and identifies potential areas for policy improvement.

By integrating these theoretical perspectives, the study aims to provide a holistic understanding of the household water supply dynamics in Iwo, Nigeria. This comprehensive approach facilitates a nuanced exploration of the interconnections between climatic factors, geographical features, socio-economic dynamics, and institutional frameworks, ultimately contributing to the development of context-specific and sustainable interventions for improving water accessibility and predictability in tropical environments.

However, the limitations of this study include potential model inadequacy due to low R values in regression analysis, suggesting the need for additional variables to improve predictive accuracy. The focus on a specific region, Iwo, Nigeria, may limit generalizability to broader contexts, and reliance on self-reported household data introduces the possibility of response bias, potentially impacting the accuracy of findings. The study's duration of 12 months may not fully capture long-term trends, and reliance on climatic data from a single national agency may overlook nuanced local variations. These limitations highlight areas for future research refinement, such as incorporating more variables for modelling accuracy, considering broader geographical contexts, validating findings through diverse data sources, and extending study durations to capture long-term trends accurately.

Method of study

Study area

The study area, Iwo (Figure 1), located at latitude 7°38'N and longitude 4°11'E, is one of the ancient towns in the southwestern zone of Nigeria, covering a land area of 245 square kilometres. It serves as the seat of the Iwo Local Government headquarters in Osun State, situated in the north-eastern part of the Ibadan metropolis, forming the interchange between Ibadan and Osogbo, the capital of Osun State. The headcount record of 2006 in Nigeria indicated that the

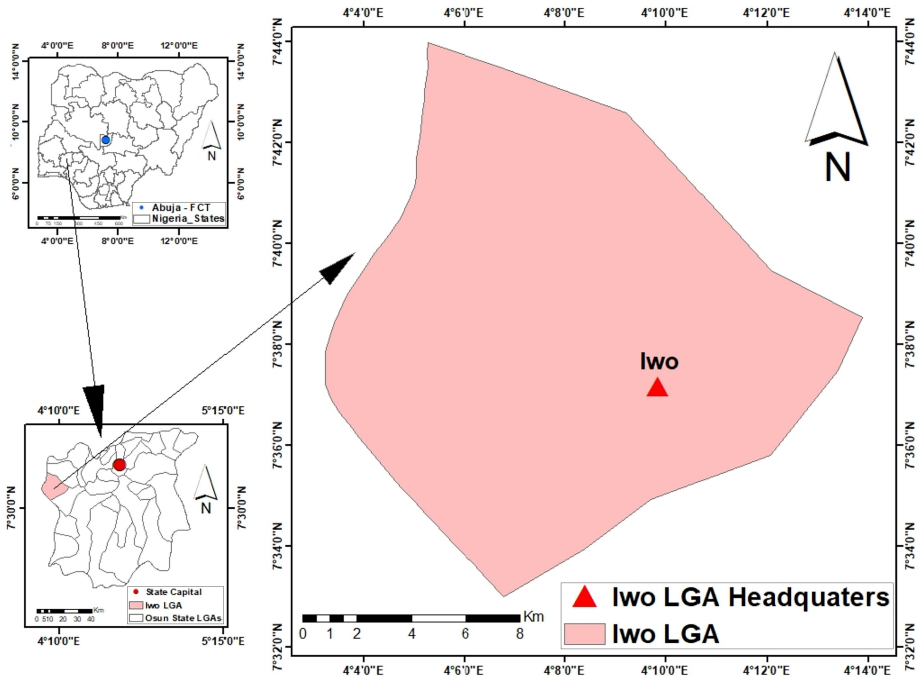


Figure 1. Map of Osun state, Nigeria, showing the location of Iwo (the study area)
Source: Created by author

town had a total of 191,348 inhabitants, primarily from the Yoruba tribe, with the majority practicing either Islam or Christianity. However, according to [City Population's 2024](#) data, the estimated population of Iwo was reported to be 240,000 as of 2022. According to [Ogunbode \(2015\)](#), Iwo enjoys a tropical climate with two distinct seasons, receiving approximately 1,000 mm of rainfall annually and maintaining an average daily temperature of 31°C. The wet season typically begins in March and concludes in October, while the dry season spans from November to the end of February each year. The characteristics of the Iwo population have been significantly influenced by the location of Bowen University, owned by the Nigerian Baptist Convention, which is still undergoing expansion. The city attracts people from various walks of life globally, including students, researchers, hoteliers, staff of different categories, businessmen and women.

Furthermore, the recent commencement of activities in the newly established Federal College of Education in the town and the continuous growth of the popularly known Odo-Ori Market, among other institutions, are all expected to impact the socio-demographic attributes of the inhabitants. Major occupations of the residents include farming, trading, and operating slaughter slabs. The town is blessed with both surface and groundwater resources. Major rivers include Aiba River, which has been dammed to provide quality water for the inhabitants and the suburbs, and Oba River. Due to the poor performance of Aiba Water Works (AWW), the exploitation of ground sources has become expedient to ensure timely and spatial access to potable water for household use ([Akinola et al., 2018](#)).

Sampling techniques

The Iwo township was segmented into four distinct sections by two primary trunk A roads that intersect it: the Gbongan-Iwo-Oyo trunk A road, which traverses the central Round-about junction, and the Ibadan-Iwo-Osogbo Road, which passes through Adeeke, the central Round-about junction and the Ori-Eru terminal junction. These four sections served as the organizational framework for conducting the questionnaire administration. These divisions were not necessarily based on the population but on land area to ease the administration of the town, which serves as the centre of administration for Iwo Local Government Area. Every household had an equal chance of being selected for the questionnaire survey. However, 15 households were randomly selected as the sample size monthly, running from February 2023 through January 2024. Thus, 80 households were surveyed across the town monthly as shown in Figure 2. The scope of the survey, covering this aforementioned number of households, was on the basis of the available funding and the allocated project timeline. Each selected house was promptly marked with a sticker in an obscured place on the house for identification to avoid being surveyed twice during the exercise. The obscured placement of the sticker on each building was to prevent its removal.

Iwo is a community known for its homogeneity, marked by similarities in ethnicity, culture, religion, socioeconomic status, and language. The inhabitants share a high degree of

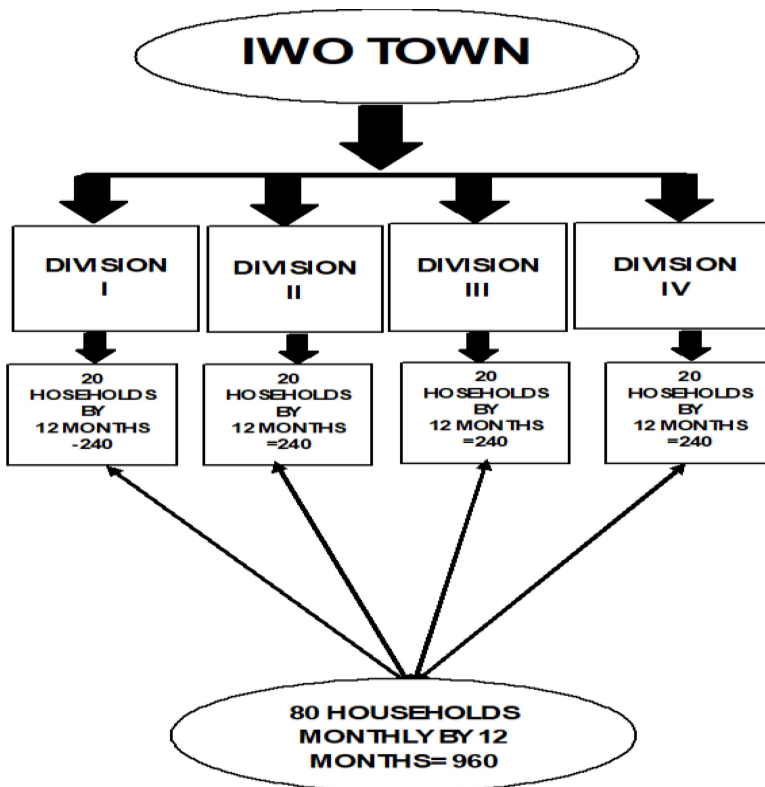


Figure 2. The flow chart showing monthly sampling design procedure

Source: Created by author

uniformity in their lifestyles, beliefs, and practices, fostering a strong sense of shared identity and social cohesion. Despite religious diversity, cultural ties remain strong among the residents. The town is predominantly Yoruba, with smaller populations of Hausa, Igbo and Fulani. Yoruba is the primary language, with English also widely spoken. Islam and Christianity are the main religions, coexisting with traditional Yoruba practices. The cultural heritage of Iwo is rich, featuring vibrant festivals such as Egungun and Oro that celebrate Yoruba traditions.

Iwo skilfully integrates its cultural heritage with modern development, creating a dynamic and diverse community. The economy is primarily based on agriculture, trade and small-scale industries, with key crops including cocoa and cassava. Education is supported by numerous schools and tertiary institutions, while healthcare services are provided by both public and private facilities. The homogeneity of the community contributes to the validity and representativeness of data and the generalizability of this research findings.

However, the female head of each household was preferred for the survey because it has been established that women in African homes are usually responsible for water provision, while men are more concerned with financial provision and other basic needs of the family. Thus, it is believed that females in the house are more likely to provide relevant information on water use in their various homes than their male counterparts. However, where the female head was not available, the male head was considered for the survey. At the end of the exercise in January 2024, 937 questionnaires were successfully completed and retrieved for further analysis.

The questionnaire contents

The questionnaire was comprehensive, consisting of four sections, namely:

- (1) Respondents' details;
- (2) Pipe-borne water inventory;
- (3) Groundwater inventory; and
- (4) Surface water inventory.

The respondents' details included questions relating to the identity of the respondent, such as age, marital status, household size, level of education, household's source of water, household's daily water use, among others. The section on pipe-borne water inventory consisted of structured questions relating to the respondent's access to that source, distance to pipe-borne water, water tariff payment, views on pipe-borne water, among others. The part of the questionnaire on groundwater resources inventory was directed towards generating information on the use, availability, and accessibility of groundwater resources in the study area, while the surface water resources section also contained structured questions on household use of stream or river water.

However, although the case study area is in the humid tropical region where rainwater ought to form a significant source of water for household use, this source was not considered in this project. The reason was that rainfall is seasonal and the events may not coincide with immediate needs in homes (Henry, 2005; Ogunbode and Ifabiyi, 2019a). This, however, is also compounded by the poverty level which hinders the acquisition or possession of enough storage facilities (DeFries *et al.*, 2022).

Data collection and handling

The administration of the questionnaire was conducted by the head of the investigation team and four other field research assistants. The questionnaire survey was done both in the early

and evening time. The time chosen was based on the potential time of availability of the respondents – most of the respondents often leave their homes in the morning for their respective farms or marketplaces and may not come back until evening time. No specific date was selected for the survey in each of the months, but most often it was done between the 10th and 25th of each month. Respondents were assisted in completing the questionnaire, but where the respondents could not read or write, the field assistant came to their aid in completing the survey. However, there were instances where the respondents were made to complete the questionnaire by themselves, which was permitted by the researcher. At that instance, the questionnaire was left with such respondents to be collected the following day. The survey was strictly monitored to avoid missing and or mutilation of the questionnaire so that appreciable returns can be achieved. The distribution of the monthly surveys and the respective returns is presented in Table 1. At the end of each monthly exercise, an office assistant was responsible for coding and entering data in the computer system already provided for the purpose. The potential bias in the collection of data could emanate from the random sampling of households used, respondent identification, especially where the female head would ask her female child to complete the questionnaire or represent her before the field assistant. Data storage included secure handling of completed questionnaires and regular backups. The head of the investigation team oversaw quality control, ensuring ethical considerations such as confidentiality and informed consent were maintained. Detailed documentation of the survey process and monthly reporting ensured comprehensive tracking and reporting of activities.

Data analysis

The data analysis was performed using Statistical Product for Service Solutions (SPSS), version 2022. Both descriptive and inferential statistics were applied to scrutinize the data. Descriptive statistics, such as tabulation, percentages and means, involved basic arithmetic operations. Regression analysis was used to examine the predictability of domestic water usage, with variables derived from various questionnaire items. These regression variables were chosen based on their potential impact on water usage, identified through preliminary correlation analyses and expert judgement to ensure accurate analysis. The weights of the variables were determined using a combination of statistical significance from the correlation

Table 1. The distribution of the monthly surveys and the respective returns

S/No.	Month/Year	No. of households	No. retrieved (%)	Cumulative retrieved
1	February, 2023	80	80 (100)	80
2	March, 2023	80	80 (100)	160
3	April, 2023	80	77 (96.25)	237
4	May, 2023	80	78 (97.5)	315
5	June, 2023	80	76 (95.0)	391
6	July, 2023	80	80 (100)	471
7	August, 2023	80	80 (100)	551
8	September, 2023	80	77 (96.25)	628
9	October, 2023	80	78 (97.5)	706
10	November, 2023	80	77 (96.25)	783
11	December, 2023	80	76 (95.0)	859
12	January, 2024	80	78 (97.25)	937 (97.60%)

Source(s): Created by author

analyses and expert assessments, assigning higher weights to variables with stronger correlations and more relevance to the study.

Additionally, water balance and loss were assessed using a 31-year dataset (1992–2022) of rainfall and temperature. This assessment employed a straightforward water balance model and the [Papadoupulou et al. \(2003\)](#) model, as utilized by Ogunbode and Ifabiyi in their 2019 studies. These analytical methods not only deepened the understanding of the data set but also provided valuable insights into the factors influencing domestic water usage over the study period.

Results and discussion

Basic attributes of the respondents

The gender distribution, as presented in [Table 2](#), revealed that females constituted a higher proportion, accounting for 85.9%, compared to their male counterparts at 12.9%. The survey prioritized female respondents due to their significant role as custodians of water-related

Table 2. Households’ sources of water distribution

S/No.	Respondents’ attribute	Frequency (%)
1	<i>Sex</i>	
	Male	121 (12.9)
	Female	805 (85.9)
	Null	11 (1.2)
2	<i>Age distribution</i>	
	<18years	19 (2.0)
	19–45	519 (55.4)
	46–65	325 (34.7)
3	<i>>65</i>	71 (7.6)
	<i>Level of education</i>	
	Primary	168 (17.4)
	Secondary	403 (43.0)
4	Tertiary	287 (30.6)
	No formal education	79 (8.4)
	<i>Household size</i>	
	<5	255 (27.2)
5	6–10	555 (59.2)
	11–15	70 (7.5)
	16–20	45 (4.8)
	>20	12 (1.3)
6	<i>Home regular water source</i>	
	Pipe-borne water	175 (18.7)
7	Groundwater	724 (77.3)
	<i>Time taken to get water</i>	
	<10 mins	494 (52.7)
	11–20 mins	237 (25.3)
8	21–30 mins	147 (15.7)
	>30 mins	59 (6.3)
9	<i>Payment of water tariff</i>	
	Yes	89 (9.5)
	No	848 (90.5)

Source(s): Created by author

information (Ogunbode *et al.*, 2022). The proportion of informed males primarily comprised those who completed the questionnaire when the female head was unavailable or adult males who participated as directed by their respective mothers, either due to illiteracy or non-availability. The investigation also discovered that 98% of respondents were 18 years and above, in accordance with the adulthood stage defined by [The Constitution of Federal Republic of Nigeria \(CFRN\) \(1999\)](#) in Section 29. This criterion aimed to ensure the survey targeted adults, with the remaining 2% suspected to be school children assisting female heads in questionnaire completion.

The study also indicated that only 8.4% of all respondents lacked formal education, with the majority having attained education at either primary (17.4%), secondary (43.0%) or tertiary (30.6%) levels. The investigation did not establish any special preference for a particular education level, as water use encompasses all. However, field assistants provided assistance where challenges in understanding or completing the questionnaire arose. Among the households surveyed, 27.2% had five or fewer members, 66.7% had between six and fifteen members and the remaining 6.1% had sixteen or more members, reflecting the typical African home structure characterized by extended families living together.

In terms of water sources, 77.3% obtained water from ground sources such as hand-dug wells or deep boreholes, while 18.7% relied on pipe-borne water. The survey revealed that 92.7% of respondents could access water within ten minutes, aligning with the United Nations recommendation of <30 min for establishing people's access to water. About 90.5% claimed not to pay any water tariff, attributing it to the fact that most respondents did not connect their homes to the pipe-borne water network. Instead, they constructed hand-dug wells or boreholes on their premises or sourced water from ground sources provided by various entities, including the government, international donors, religious organizations, philanthropists and politicians (Ogunbode *et al.*, 2023a, 2023b).

Domestic water utilization components in Iwo

Table 3 displays the diverse components of water usage at the household level within the study area. The survey results unveiled that all households utilize water for essential purposes such as drinking, laundry, cooking, dishwashing, bathing and incidental needs, as outlined in Table 3. Furthermore, the findings revealed that 54.2% of households use water for car or motorcycle washing, 12.9% for watering their lawns, 43.6% for religious practices, particularly ablution in Islamic worship, and for miracles in certain Christian denominations.

Table 3. Breakdown of household water use components in Iwo

S/No.	Water use component	Frequency	%
1	Drinking	937	100
2	Laundry	937	100
3	Cooking	937	100
4	Dish washing	937	100
5	Bathing	937	100
6	Car wash	508	54.2
7	Lawn watering	121	12.9
8	Religious use	439	43.6
9	Home gardening	356	16.6
10	Livestock	533	56.9
11	Industrial processing	42	4.5

Source(s): Created by author

Additionally, 16.6% make use of water for tending to their home gardens, while 56.% provide water for their livestock, and 4.5% claim to use water for processing activities, including the preparation of local staples such as “ogi” (pap), as well as commercially produced local drinks like “*kunnu*” and “*zobo*.”

The diverse applications of water in Iwo indicate its characteristic as a typical agrarian community, primarily reliant on agriculture and related activities for sustainable livelihoods. This observation aligns with the findings of [McClain \(2013\)](#) and [Ogunbode and Ifabiyi \(2017\)](#) in the rural communities of Oyo state, Nigeria, attributing the limited industrial use of water to the predominantly agricultural nature of such areas.

Water supply situation in the study area between 1992 and 2022

The results of the water supply in Iwo over the 31-year period are presented in [Table 4](#). The findings indicate a significant variation in monthly water supplies during this period. Water shortages are consistently experienced throughout the 12 months, with particular attention warranted for certain months. Despite the shortage in comparison to the mean monthly water demand, months such as February, March, April, August, November and December stand out for notable water runoff. In litres, the recorded runoff in these months were 4.4, 3.5, 0.5, 2.1, 5.0, 1.8 and 5.0, respectively ([Ogunbode and Ifabiyi, 2019a, 2019b, 2019c](#)). The runoff between November and February is expected due to the dry season within the study area, characterized by high evaporation, temperatures ranging from 29°C to 38°C, dry harmattan winds, hazy and dusty atmospheric conditions, and a general reduction in rainfall events. However, runoff in March, April and August draws attention. Typically, the rainy season begins in March and ends in October. Water supply challenges during these months highlight the probable impact of climate change, leading to prolonged dry seasons in the tropical environment. The runoff in August also signifies hydrological drought, which could be attributed to climate change in the region.

Understanding the results presented here is crucial, as they indicate that if current trends persist, accessing potable water for household use may become increasingly difficult. This issue has been linked to social, ecological, political, and economic factors by [Yaro et al. \(2015\)](#) and [Dinko and Bahati \(2023\)](#). To address water scarcity challenges in sub-Saharan Africa, various strategies have been proposed. These include coordinating institutional

Table 4. Household monthly water demand and supply in the study area

S/No.	Month/Year	Mean monthly water use (litres)	Monthly per capita water demand (litres)	Mean monthly water balance (litres)	Mean monthly water deficit (litres)
1	February	431.5	143.8	-4.4	427.2
2	March	362.4	120.8	-3.5	358.9
3	April	444.5	148.1	-0.5	444.0
4	May	397.3	132.4	0.6	396.7
5	June	390.0	130.0	1.3	388.7
6	July	389.7	129.9	0.9	388.8
7	August	364.0	121.3	-2.1	361.9
8	September	348.9	116.3	1.8	347.1
9	October	394.8	131.6	0.3	394.5
10	November	376.0	125.3	-5.0	371.0
11	December	412.8	137.6	-1.8	411.0
12	January	444.6	148.2	-5.0	439.6

Source(s): Created by author

responses, implementing well-planned technologies, preparing for projected climate risks, extending climate services, increasing climate change literacy and integrating indigenous knowledge (Ayanlade *et al.*, 2022; Filho *et al.*, 2022; Jones *et al.*, 2023). Additionally, Dinko and Bahati (2023) emphasize the importance of capacity building to facilitate adaptation and mitigation processes among different stakeholders. It is essential for all parties to collaborate effectively to prevent climate change-induced water insecurity and ensure reliable access to household water in the region.

The results further indicate that household water demand surpassed hydrological water supply between 1992 and 2022. Descriptive results revealed that groundwater is the primary water source for inhabitants, with surface sources being neglected (Ogunbode *et al.*, 2020; Ogunbode *et al.*, 2022). It is crucial to emphasize that the volume of harvestable rainwater largely depends on the available storage facilities. Therefore, the proportion of rainwater not available for harvest becomes part of surface runoff and percolation/infiltration processes (Rahman *et al.*, 2014; Tamagnone *et al.*, 2020). To maximize the use of rainwater for home use, especially the portion that forms surface runoff, there is a need to develop dam construction and pipe-borne water network facilities (Liaw and Chiang, 2014; Li *et al.*, 2021; Ogunbode *et al.*, 2024a, 2024b).

The water balance model's assumption that rainfall is the sole water source is limited, as it overlooks essential antecedent water sources such as surface and ground reservoirs in the region. Additionally, the assumption fails to account for the seasonality of rainfall in the tropical region, where rainwater is not consistently available (Faramarzi *et al.*, 2013; Gebrechorkos *et al.*, 2019). Climate change projections indicate future trends of rainfall variability, which are likely to impact water availability (Faramarzi *et al.*, 2013; Thomas and Nigam, 2018; Alrawi *et al.*, 2023; Dinko and Bahati, 2023). The studies by Faramarzi *et al.* and Thomas and Ngam underscore the urgent need for targeted climate adaptation strategies in Africa, especially in regions like the southern sub-Saharan area, which are increasingly vulnerable to heat stress, declining rainfall, and desertification. They stress the importance of improving climate modelling and enhancing our understanding of regional climate dynamics to develop effective responses to these challenges. As the African continent continues to experience significant climate shifts, the effects on agriculture, water resources, and human livelihoods are likely to intensify, making proactive and informed policy decisions essential. Moreover, changes in rainfall patterns, including more intense and unpredictable precipitation events, could worsen water scarcity. Prolonged dry seasons and irregular rainy periods may reduce groundwater recharge and surface water availability (Payus *et al.*, 2020; Matchawe *et al.*, 2022; Palmer *et al.*, 2023). Therefore, understanding and adapting to these projections is critical for sustainable water management.

To address these challenges, various strategies have been proposed. These include coordinating institutional responses, implementing well-planned technologies, preparing for projected climate risks, extending climate services, increasing climate change literacy and integrating indigenous knowledge (Ayanlade *et al.*, 2022; Filho *et al.*, 2022; Jones *et al.*, 2023). Additionally, Dinko and Bahati (2023) emphasize the importance of capacity building to facilitate adaptation and mitigation processes among different stakeholders. It is essential for all parties to collaborate effectively to prevent climate change-induced water insecurity and ensure reliable access to household water in the region.

Figure 3 illustrates that mean monthly water use at the household level ranges from 348.9 litres in September to 444.6 litres in January, indicating higher water usage during dry months and lower usage in the rainy season. Ibrahim A *et al.* (2021) and Akinyemi *et al.* (2022) support these findings. Similar high-water usage in homes is observed in other dry season months, including February (431.5 litres) and December (412.8 litres). The lower

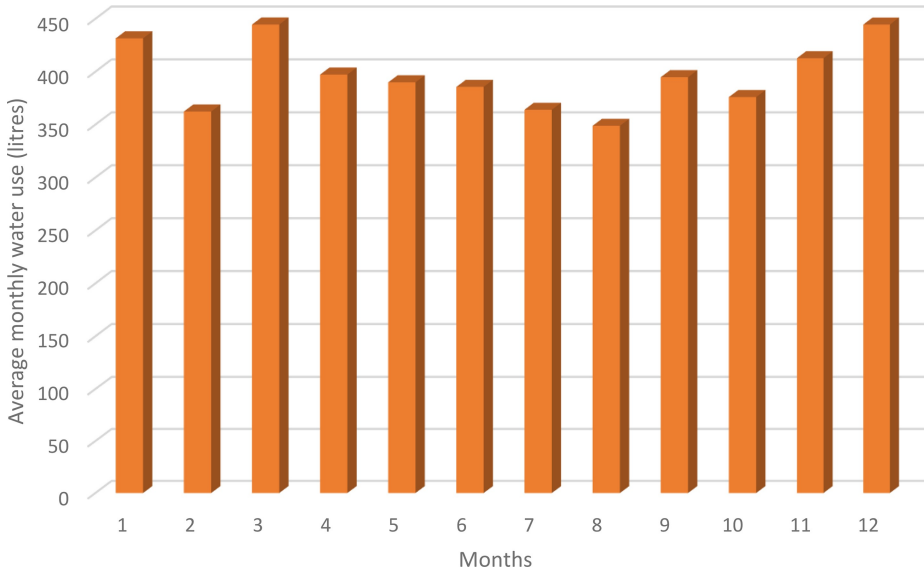


Figure 3. Households' mean monthly water use
Source: Created by author

water usage recorded in November can be attributed to its proximity to the end of the rainy season, characterized by extended wetness and clear atmospheres. The onset of the harmattan wind during the dry period often commences in December (Balarabe *et al.*, 2016; Okeahialam, 2016; Sufiyan, Abdulaziz and Naven, 2022).

Per capita water demand in Iwo

Delving deeper into the data set, it was revealed that the average household size stood at three members. Consequently, the per capita water demand monthly, outlined in Table 4, exhibited a range from 116.3 litres in September to 148.2 litres in January. This outcome falls significantly below the World Health Organisation's (WHO) (2024) recommended minimum of 20 litres per capita per day to meet basic hygiene and food safety standards. This underscores a potential challenge in ensuring access to an adequate and essential water supply to meet the fundamental needs of the community, highlighting the importance of addressing this deficit for improved public health.

The significant disparities between hydrologic water balance and household water demand underscore the need for urgent attention from all stakeholders. A crucial consideration should be the maximization of surface water usage for household needs. There exists a substantial water reserve in various rivers, such as the Oba and Osun Rivers, and others within the study area, making them potential sites for dam construction. Additionally, revisiting the dormant mini water works initiated by the Osun state government in 2006 could be an effective strategy to enhance water accessibility, benefiting both urban and rural communities. Prioritizing the development of surface water resources through a pipe-borne water network is suggested over groundwater exploitation due to its perceived environmental friendliness and safety. This strategic shift aligns with the broader goal of ensuring

sustainable and secure water access for the community while minimizing potential adverse environmental impacts.

Household water use modelling

The results of the regression analysis, as presented in Table 5, revealed the generation of six models. The first three models were deemed significant with $p < 0.005$, while the last three were not significant with $p > 0.005$. Among the 14 variables analysed, the third significant model (Model C) highlighted the influence of three variables: (1) Number of females in the household, (2) Household preferred water source and (3) Attitude towards water storage. This model yielded an R value of 42.3% and a standard error of +79.05. The characteristics of the predicting variables are detailed in Table 6.

A thorough examination of the regression results revealed that the R and R-squared values for the significant models were relatively low. The R value of 42.3% indicates a moderate correlation between the predictor variables and the dependent variable (domestic water usage). However, the R-squared value, which explains the proportion of variance in the dependent variable that can be predicted from the independent variables, suggests that the model explains only 17.9% of the variance. This low R-squared value implies that most of the variations in household water usage is not accounted for by the model. The inadequacy of the models for predicting household water usage is evident from these low R and R-squared values. Despite identifying some significant predictors, the overall explanatory power of the models remains weak. This indicates that other factors, not included in the analysis, likely play a significant role in determining household water usage. Further research is needed to identify additional variables that could improve the predictive power of the models. The inclusion of more relevant predictors and potentially non-linear relationships might enhance the accuracy and reliability of future models. Additionally, the large standard error (+79.05) in the significant model suggests considerable variability in the predictions, further emphasizing the need for a more robust analytical approach to accurately forecast household water usage.

Table 5. Summary of the models generated regression analysis

Model	R	R square	Adjusted R square	Std. Error of the estimate	R square change	Change statistics			Sig. F change
						F change	df1	df2	
1	0.351 ^a	0.123	0.122	81.63478	0.123	131.146	1	935	0.000
2	0.385 ^b	0.148	0.146	80.49567	0.025	27.650	1	934	0.000
3	0.423 ^c	0.179	0.177	79.05941	0.031	35.244	1	933	0.000
4	0.429 ^d	0.184	0.180	78.88998	0.004	5.012	1	932	0.025
5	0.435 ^e	0.189	0.185	78.66018	0.006	6.454	1	931	0.011
6	0.443 ^f	0.196	0.191	78.35795	0.007	8.196	1	930	0.004

Note(s): ^aPredictors = (Constant), Number of females; ^bPredictors = (Constant), Number of females, Reason for the preferable source of water; ^cPredictors = (Constant), Number of females, Reason for the preferable source of water, Conserving water; ^dPredictors = (Constant), Number of females, Reason for the preferable source of water, Conserving water, Time spent to get water; ^ePredictors = (Constant), Number of females, Reason for the preferable source of water, Conserving water, Time spent to get water, Preferable water source; ^fPredictors = (Constant), Number of females, Reason for the preferable source of water, Conserving water, Time spent to get water, Preferable water source, Household size

Source(s): Created by author; Regression analysis using SPSS v.22

Table 6. Significant models and their respective predictors with their properties

Model	Unstandardized coefficients		Standardized coefficients	<i>t</i>	Sig.
	B	SE	β		
<i>Model 1</i>					
(Constant)	152.174	5.360		28.389	
No. of females	14.801	1.292	0.351	11.452	0.000
<i>Model 2</i>					
(Constant)	131.894	6.543		20.157	
No. of females	14.849	1.274	0.352	11.651	
Water source preference	22.876	4.333	0.159	5.258	0.000
<i>Model 3</i>					
(Constant)	177.472	10.012			
No. of females	14.346	1.255	0.340	17.276	
Water source preference	29.333	4.392	0.204	11.435	
Attitude to water storage	26.544	4.471	0.152	6.655	0.000

Source(s): Created by author

However, the potency of the female composition in predicting water use at home echoes findings by [Graham et al. \(2016\)](#) and [Ogunbode et al. \(2023a, 2023b\)](#), highlighting the crucial role of household characteristics in domestic water use. Similarly, the household composition favouring females emerges as a significant variable in water supply planning, considering their distinct water demand rate for personal hygiene, laundry, and cleaning, which differs from their male counterparts ([Ogunbode et al., 2022](#); [Bera et al., 2022](#); [Ayanlade et al., 2023](#)). Moreover, the study underscores that household preference for a specific water source significantly determines domestic water use. Various reasons contribute to this preference, including water quality, proximity, and the ease of fetching, whether through mechanical or manual methods. This aligns with the findings of [Morakinyo et al. \(2015\)](#) and [Sridhar et al. \(2020\)](#), where the influence of household water source preference on water demand was observed.

Furthermore, respondents' attitudes towards water storage were identified as another significant predictor of water use in homes. As noted by [Fan et al. \(2013\)](#), [Sridhar et al. \(2020\)](#) and [Ogunbode et al. \(2023a, 2023b\)](#), individuals' attitudes and decisions regarding water storage play a pivotal role in determining the volume of water utilized for domestic needs. Water storage serves as a means of bringing the resource to the point of demand at a specific time, ensuring water availability for various household uses. The significance of this factor in predicting water use highlights that managing the variability of the resource in space and time is feasible when users adopt a proactive attitude towards storing it for future use ([Fan et al., 2013](#); [Ogunbode et al., 2023a, 2023b](#)).

However, it is notable from [Table 5](#) that the R values of 35.1, 38.5 and 42.3 for models 1, 2 and 3, respectively, although significant, are relatively low. This suggests that there may be other variables beyond the ones analysed that require consideration for investigation, to establish the strength and validity of the predictive models generated.

However, the uniqueness of this research in water resource management in the sub-Saharan Africa cannot be overlooked. Its holistic approach of this research to understanding water security dynamics in Iwo, Nigeria, amidst climate change threats and demographic

influences. It employs a multifaceted methodology combining a 12-month household survey, 31 years of climatic data analysis, and various statistical tools including regression analysis, highlighting Model 3 for predictive capabilities. The study reveals the significant involvement of female heads and adults in water-related activities, emphasizing the agrarian nature of the region. Original contributions include insights into localized water use patterns, socio-economic disparities and the urgency of addressing climate-induced threats for sustainable water management aligned with Sustainable Development Goal 6 targets. The findings stress the need for targeted interventions, community involvement in decision-making and equitable access to water resources, providing valuable insights for policymakers and stakeholders in enhancing water security and resilience in similar contexts.

Conclusion and recommendation

An investigation was conducted to assess the water supply security in the sub-Saharan region, using Iwo, Nigeria, as a case study, considering water supply variability caused by climate change. The study examined household water sources, availability and use throughout the 12 months among 937 households, with an overwhelming 95% involvement of female heads and 95% being above 18 years of age. Notably, 92.7% spent less than 10 min to reach and obtain water for their homes, while 90.5% did not pay water tariffs. Only 4.5% claimed to use water for processing local food items such as “ogi” and “zobo”, indicating the agrarian nature of the study area. Analysis of 31 years of climatic data, including rainfall and temperature, revealed water loss during dry season months and in March, April and August, previously considered rainy months. This suggests a prolonged dry season and hydrological droughts, confirming the prevailing climate change in the region. Furthermore, the study discovered that household water use consistently exceeded water supply over the period, ranging from 348.9 litres in June (a wet month) to 444.6 litres in January (a dry month). The per capita water demand per month, with a value of 148.6 litres (4.95 litres per day), fell below the World Health Organisation’s recommendation of 10 to 20 litres/day. Regression analysis results revealed three significant predictive models at $p < 0.005$, while the last three were not. Model 3 demonstrated a notable level of predictability for household water use with an R value of 42.3 at $p < 0.005$ and a standard error of +79.05941. However, the generally low R value suggests the need to consider additional variables beyond the 14 analysed in this study to complement the findings and further establish the validity of the generated models.

Despite these challenges, intentional efforts should be made to exploit surface water resources, which are largely available in the study area, to enhance access to this vital resource. The involvement of appropriate institutions in water distribution will contribute to water justice for all, even amid the growing threats of climate change. This aligns with the targets of Sustainable Development Goal 6, which aims to ensure universal access to water and sanitation by 2030.

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